New Points Annexure-VIII(a)
Ref. Pt.10.10 of Ch.10

HT SWITCHGEAR

A)SWITCHGEAR EQUIPMENT PREVENTIVE MAINTENANCE CHECKLIST

Sl. No.	Preventive Maintenance Check-off List	Comments
1	**Obtain permit for work – hot/cold work permit**	
2	**Get positive electrical isolation clearance**	
3	**Disconnect primary power from switchgear & ensure positive electrical isolation**	
4	**Switch off all incoming and outgoing feeders and remove all control fuses to take megger values**	
5	**Disconnect control power & switch ON as per requirement during testing.**	
6	**Remove PT secondary fuses to prevent high voltage back feed.**	
6	**Record the megger values of the switchboard / portion of switchboard to be serviced**	
7	**Check exterior of equipment for damage.**	
8	**Check equipment ground bus and its connection(s) to station ground.**	
9	**On outdoor switchgear, check integrity of seal against weather and rodents.**	
10	**Check doors for damage.**	
11	**Check door handles, locking bars, keys and interlocks for positive operation.**	
12	**Insure structure is tight.**	
13	**Check cabinet lighting**	
14	**Check heaters and heater circuits**	
15	**Check that all power and control cable entrances are sealed against rodents and fire contaminants.**	
16	**Check all wiring connections, including those on terminal blocks.**	
17	**Check draw-out racking mechanisms (also check lubrication).**	
18	**Check shutter mechanism.**	
18.1	**Check shutter condition for signs of corana and tracking**	
19	**Inspect bus and support insulators & inter panel separators for evidence of corona or insulation deterioration**	

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Sl. No.	Preventive Maintenance Check-off List	Comments
20	**Check tightness of all bus bar connections and torque as per OEM recommendations. Check contact resistance.**	
20	**Megohmmeter test switchgear lightning arresters (if present).**	
21	**Check control knobs and switches for freedom of movement and contact condition.**	
22	**Check mechanical and electrical integrity of all relays**	
23	**Perform sequencing check of protective, auxiliary, and control relays.**	
24	**Inspect switchgear instruments (meters, switches, and indicating lights).**	
25	**Inspect all instrument transformers for signs of tracking, heating & corona.**	
26	**Inspect all fuses.**	
27	**Inspect and check batteries and battery charging equipment (perform a load test).**	
28	**Clean all compartments and bus sections.**	
29	**Check to insure that all key interlocks are operational and no spare keys are used.**	
30	**Measure the insulation resistance of the switchboard after maintenance and record**	

B) CIRCUIT BREAKER PREVENTIVE MAINTENANCE CHECK-OFF LIST

Sl. No.	Description	Comments
1	**Check that breaker is open and discharged.**	
2	**Record breaker serial number and number of operations.**	
3	**Inspect for damage to breaker (exterior).**	
4	**Perform a visual inspection of the breaker and remove dust and contaminants from the interrupter housing, insulation, and mechanism. Do not use compressed air.**	
5	**Inspect the interrupters and operating mechanism carefully for loose nuts, bolts and damaged parts. All cam latch and roller surfaces should be inspected for damage or excessive wear.**	
6	**Check that the trip coil plunger and close coil plunger move freely.**	
7	**Inspect condition of primary and secondary disconnects.**	
8	**Inspect for evidence of overheating or tracking.**	
9	**Lubrication as per OEM recommendation**	

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Sl. No.	Description	Comments
9.1	On all sleeve, needle, and roller bearings.	
9.2	On each silver plated primary disconnect finger assembly, wipe & clean	
9.3	On the vacuum interrupter connector rod.	
10	Operate the breaker slowly to be sure there is no binding or friction and that the movable contact of the interrupter can move to the fully opened and fully closed position.	
11	Check physical condition and integrity of shrouds on breaker arms	
12	Check interrupter and mechanism adjustments.	
13	Check contact erosion indicator.	
15	Check all wiring for tightness of connections and possible damage to insulation.	
16	Check primary circuit integrity by means of a 2500 volt megohmmeter (breaker in the closed position phase to phase and phase to ground)	
17	Check control circuit integrity by means of a 500/1000 volt megohmmeter. (Note: Disconnect motor leads to prevent winding insulation damage.)	
18	Perform vacuum integrity test on each vacuum interrupter as per OEM recommendation for ensuring healthiness of the vacuum bottle. WARNING: X-Radiation may constitute a health hazard. Refer to instruction book for proper procedures.	
19	Operate the breaker using the test mode / cabinet and observe the following:	
19.1	Breaker charges properly.	
19.2	Breaker closes and opens correctly.	
19.3	Breaker trips freely.	
19.4	Indicators show correct position.	
20	Place breaker iof the equipment in the test position and operate it electrically.	
21	Check the operation of all electrical relays (including protective relay devices), solenoid switches, motors, control switches, and indicating devices.	
22	Check negative interlock.	
23	Check positive interlock.	
24	Check spring discharge interlock	

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New Points Annexure-VIII(b)
Ref. Pt.10.10 of Ch.10

TYPICAL MAINTENANCE CHECKLIST FOR POWER CONTROL CENTRE / MOTOR CONTROL CENTRE

STEP-1 POSITIVE ISOLATION OF RUNNING EQUIPMENT FOR MAINTENANCE				
S. No.	Work Steps	Status		Remarks
		OK	MADE OK	
1.	**Obtain permit for work – hot/cold work permit**			
2.	**Get positive electrical isolation by customer on paper / permit**			
3.	**Ensure positive electrical isolation**			
4.	**Switch off all incoming and outgoing feeders and remove all control fuses to take megger values**			
5.	**Record the megger values of the switchboard / portion of switchboard to be serviced**			
STEP-2 OPENING OF BUSBAR CHAMBERS / COVERS / DOORS FOR MAINTENANCE OF SWITCHBOARD				
1.	**Open the comp. Doors and busbar covers / shrouds / barriers by loosening screws**			
2.	**Remove all air circuit breakers by ACB racking handle and lifting trolley care fully**			
3.	**Marking the respective compartment no. on air circuit breakers by yellow sticker**			
4.	**Remove all draw out modules by module racking handle and unscrew the modules to take out from switchboard for maintenance**			
5.	**Marking the respective compartment no. on each module by yellow sticker**			
STEP-3 CHECK COMPARTMENT DOORS FOR ALIGNMENT & DOOR DRIVEN MECHANISM				
1.	**Check door sagging / alignment of door fixing screws with hinge nuts**			
2.	**Check position and tightness of hinges of doors**			

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3.	Check the gasket on door			
4.	Check the door interlock operation of the door			
5.	Check earthing links of doors for connection			
6.	Clean the doors, door operated mechanism, door interlocks and hinges door knobs etc. with cleaning agent			
CLEANING, CHECKING AND TIGHTNESS OF BUSBAR CHAMBERS				
1.	Clean the ACB compartments, busbar chambers and modules compartments for dust accumulation by vacuum cleaner			
2.	Check free movement of module shutter assy. and ACB shutter assy			
3.	Remove shrouds from module compartments and remove shutters from dropper contacts			
4.	Check conditions of the dropper contacts and replace the contacts required replacement			
5.	Clean the vertical busbar chambers by vacuum cleaner and then by blower			
6.	Remove red shrouded covers from main bus and check tightness of main busbar joints			
7.	Check the tightness of horizontal / vertical busbars			
STEP-5 ASSEMBLY OF FIXED PORTION OF THE SWITCHBOARD AFTER TIGHTNESS CHECKING				
1.	Tighten all dropper busbars, dropper contacts, main busbar joints & ACB cradle terminals & check contact resistance			
2.	Clean the contact surfaces of air circuit breaker contacts and dropper co0ntacts			
3.	Apply invisible layer of anti corrosion contact grease (LICOM) on contact surfaces			
	a) Dropper contacts			
	b) Outgoing contacts			
	c) Cradle terminals of ACB			
4.	Fix all shutter assy. and shrouds			

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	to its original position in vertical and horizontal busbars.			
5.	Clean the tray surface and check the racking nut fixed on the tray for alignment with module in isolate, test & service position			
6.	Inspect the outgoing cable connections for any heating spot etc. and check for tightness			
7.	Check healthiness of sic's (sliding contacts) for any breakage and loose termination of control wires mounted on fixed member of switchboard and 6 way sic's mounted in ACB's			
8.	Apply invisible layer of anti corrosion contact grease (LICOM) on sic contacts			
9.	Check freeness of sliding telescopic rails of modules and operation of safety shutter			
10.	Check freeness of sliding telescopic rails of ACB's and racking rack out mechanism			
SERVICING OF AIR CIRCUIT BREAKERS AND MODULES				
1.	Check & clean incoming and outgoing contact of modules			
2.	Check tightness of module accessories			
3.	Clean the contacts of power & control contactors and bi-metallic relays & check for free operation of contact movement			
4.	ACB shall be serviced separately as per ACB OEM maintenance check list / guidelines			
STEP-7 ASSEMBLY OF SERVICED SWITCHBOARD				
1.	Re-fixing of air circuit breakers and draw out modules at its position and checking for free rack in and rack out operation			
2.	Checking for alignment of door operated mechanism mounted on door with isolators and MCCB's of modules			
3.	Cleaning and fixing of ventilation box and louver covers			

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4.	**Check tightness of control bus connections**			
STEP-8 TESTING OF SWITCHBOARDS & HANDING OVER TO CUSTOMER				
1.	**Check and record the megger values after fully assy. of switchboards**			
2.	**Take the contact resistance of ACBs**			
3.	**Clean the switchboard again with vacuum cleaners**			
4.	**Return of shutdown / permit**			
5.	**Energization of switchboard and handing over**			

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New Points Annexure-IX
Ref. Pt.10.10 of Ch.10

SWITCHGEAR FAILURE CONTRIBUTORS

Failure Contributing Causes forSwitchgear Bus and Circuit Breakers	**Most Probable Initiating Cause of Failure(Contributor)**
Thermocycling	Loose connections, load current, internal temperature, ambient, cubicle heaters, etc.
Mechanical Structure Failure	Fatigue, vibration, electrical loose components
Mechanical Damage From Foreign Source	Accidental action during maintenance / Enclosure Openings
Shorting by Tools or Metal Objects	Accidental action during maintenance / Enclosure Openings
Shorting by Snakes, Birds, Rodents, etc.	Enclosure Openings
Malfunction of Protective Relays	Excessive mechanical/thermal stresses during abnormal system operation
Improper Setting of Protective Device	Excessive mechanical/thermal stresses during abnormal system operation
Above Normal Ambient Temperature	Ambient Temperature
Exposure to Chemical or Solvents	Corona or Surface Tracking / Enclosure Openings
Exposure to Moisture	Corona or Surface Tracking / Enclosure Openings / Cubicle Heater Circuit Failure
Exposure to Dust or Other Contaminants	Corona or Surface Tracking
Exposure to Non-Electrical Fire or Burning	External activity
Obstruction of Ventilation	Clogged door or other filters
Normal Deterioration from Age	Normal deterioration: corona or surface tracking of the insulation; contacts, interrupters, springs, mechanisms.
Severe Weather Condition	External activity
Testing Error	External activity
Lubricant Loss, or Deficiency	Overheating of the equipment and lubrication, aged lubricants or loss-of lubricants
Lack of Preventive Maintenance	External activity

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METHODOLOGY OF ARRESTING FAILURES IN SWITCHGEARS

Most Probable Initiating Cause ofFailure (Contributor)	Available Solutions to address Initiating Causes
Loose connections, load current, internal temperature, ambient, cubicle heaters, etc.	Infrared Thermography for Hot Spots
Fatigue, vibration, electrical loose components	Infrared Thermography for Hot Spots
Accidental action during maintenance / Enclosure Openings	Maintenance Training, Quality Control & Visual Inspections
Accidental action during maintenance / EnclosureOpenings	Maintenance Training, Quality Control & VisualInspections
Enclosure Openings	Visual Inspections
Relay failure	Periodic Relay Testing
Improper relay settings	Periodic Power System Study
Ambient Temperature	Design
Corona or Surface Tracking / Enclosure Opening	Partial Discharge Detection & Visual Inspection
Corona or Surface Tracking / Enclosure Opening/ Heater Circuit Failure	PD Detection, Inspection and Heater Ammeter
Corona or Surface Tracking	Partial Discharge Detection (External visual inspection can not address internal defects)
External activity	Inspection of External area
Clogged door or other filters	Infrared Thermography for Hot Spots
Normal deterioration: corona or surface tracking the insulation; contacts, interrupters, springs, mechanisms, etc.	Partial Discharge Detection and Infrared Thermography for Hot Spots
External activity	Design
External activity	Design, Maintenance Training, Quality Control & Preventive maintenance
Overheating of equipment and lubrication age orloss-of lubricants	Infrared Thermography for Hot Spots
External activity	Preventive maintenance

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CHECKLIST FOR OPERATIONAL MAINTENANCE PRACTICES, DOCUMENTATION AND FAILURE ANALYSIS
(Reference Chapter-10 of original Reliability report)

Further to the recommendations indicated in Chapter-10 of the original Reliability report, for ensuring sustenance of system practices etc. during maintenance and testing, checklist have been prepared, which are enclosed as Annexure.

A. Operating Practices

SNo.	Reference	Description
1.	Pg. no. 194, point (i)	System available for review of critical parameters of boilers, STG, GT, DM plant & critical utility drives in power plant on daily basis.
2.	Pg. no. 194, point (ii)	Review of alarms prevailing for more than 24 hours on daily basis.
3.	Pg. no. 194, point (iii)	Review of performance of critical auxiliaries (auto-changeover, reacceleration, auto mode selection, load shedding scheme) on weekly basis.
4.	Pg. no. 194, point (iv)	Daily recording of abnormal state of relays and other protection related indication flags of critical equipment / feeders by Shift-in-charge.
5.	Pg. no. 194, point (v)	Taking printout from DCS / ECS for review of records.
6.	Pg. no. 194, point (vi)	Availability of isolation / shutdown procedure of each HT switchgear in switchgear room.
7.	Pg. no. 195, point (c)	System in place for communication to the concerned person / dept. for alarms for corrective measure.

B. Failure Analysis

SNo.	Reference	Description
1.	Pg. no. 196, point (a)	Failure analysis carried out by dedicated task force involving Operation & Maintenance within in a week.
		Following identification done in each of the failure analysis: • Failure initiator • Failure contributor • System requirements for taking care the consequences of fault • Underlying causes of failure (root cause failure)

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SNo.	Reference	Description
		• **Areas for potential design improvement** • **Lapses i.e. system failure, monitoring failure, etc.**
		Review by HOD on weekly basis for monitoring & liquidation of corrective measures.
		System in place for sharing the failures & learning within working groups and available on Intranet.

C. Systems / Procedures / Documentations

SNo.	Reference	Description
1.	**Pg. no. 197, point (a)**	**System in place for updation of all equipment operation & maintenance manual on annual basis.**
		Availability of index for all drawings (with revision status) and system of annual review for ensuring availability of all drawings.
2.	**Pg. no. 197, point (d)**	**Availability of structured management of change (MOC) system through a designated group of expert from Operation, Maintenance for operational reliability & safety and approved by competent authority for implementation.**
3.	**Pg. no. 198, point (e)**	**Availability of updated records of distribution system with "fault levels" & "relay settings" and system of review at least once in two years.**
4.	**Pg. no. 198, point (f)**	**Availability of dossier containing all relevant data of equipment for each plant i.e. OEM manual, CCE certification etc.**
5.	**Pg. no. 198, point (h)**	**Availability of procedure stressing "safety rules" and "permit to work" for any work in electrical equipment / system.**
6.	**Pg. no. 198, point (i)**	**Availability of permanent record for testing & inspection of all equipment / circuits.**
		Availability of permanent operation history including details of operational history i.e. faults, repairs, modification etc.
7.	**Pg. no. 198, point (j)**	**System of conducting in-house annual electrical audit.**
		The scope of audit to include the following: • **Safety audit as per OISD guidelines.** • **Preventive / predictive maintenance compliance.** • **Revisit of reliability recommendations.**
		System in place for ensuring communication to the management for any deviations.
		System in place for monitoring of the audit observations corrective measures.

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SNo.	Reference	Description
8.	Pg. no. 199, point (m)	Availability of maintenance and test records of all scheduled / unscheduled maintenance on critical equipment / systems including protection system, earthing etc.
9.	Pg. no. 199, point (n)	System in place for trending & analysis of critical parameters measured during maintenance and testing.

D. Maintenance Practices

SNo.	Reference	Description
1.	Pg. no. 200, point (a) - i.	Healthiness of jaw contact of circuit breakers especially for incomer / high rating feeders through visual inspection.
		Monitoring of cable compartment temperature during maximum load condition.
2.	Pg. no. 200, point (a) – ii.	Measurement of contact resistance using digital micro ohm meter during shutdown.
3.	Pg. no. 200, point (a) – iii.	Availability of non hygroscopic phase barriers between phase to phase and phase to earth in breaker trolley and outgoing box of HV switchgear.
		Exposed bus bars in the cable box to be provided with HT paint
4.	Pg. no. 200, point (a) – iv.	Bus bar joints of switch boards / ducts torqued as per OEM recommendations and contact resistance measured during M&I shutdown.
5.	Pg. no. 201, point (b) – i to vi.	Inclusion of the following in the inspection checklist of HT switchgears during visual inspection during M&I shutdown. • Boundaries between two adjoining insulators • Boundaries between an insulating member & the grounded metal structure • Taped or compounded splices or junctions • Bridging paths across insulating surfaces, either phase-to-phase or phase-to-ground • Hidden surfaces such as the adjacent edges between the upper & lower member of split type bus supports or the edges or a slot through which a bus bar protrudes • Edges of insulation surrounding mounting hardware either grounded to the metal structure or floating within the insulating member • Visual examination of CTs/PTs for symptoms of electrical tracking, arching and change in color

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SNo.	Reference	Description
		due to time & temperature effect.
6.	Pg. no. 202, point (c)	Availability of structured rodent control system
		Sealing of openings in panels, panel covers & close inspection of gaskets ensured
7.	Pg. no. 202, point (d) – i	Monthly monitoring & trending of motor body/terminal box, temperatures, using non contact thermometer suitable for hazardous areas.
8.	Pg. no. 202, point (d) – iii	Monitoring & trend analysis of insulation resistance of motors
9.	Pg. no. 202, point (d) – vi	Current signature analysis for critical motors.
		Implementation of corrective actions based on the current signature analysis results.
10.	Pg. no. 202, point (d) – vii	Capital overhauling of motors as per OEM recommendations
11.	Pg. no. 203, point (e) – i	Availability of check list for online inspection of transformers, i.e. distribution transformers on weekly basis and generator / tie transformers on daily basis.
12.	Pg. no. 203, point (e) – iii	Sealing of transformer bushing chamber in addition to terminal box.
13.	Pg. no. 203, point (e) – v	Annual BDV testing of transformer oil and DGA testing preferably every 3 years
14.	Pg. no. 203, point (e) – vi	Capital overhauling / core lifting of transformers through expert agency / OEM once in 10 to 15 years based on loading and diagnostic test results.
15.	Pg. no. 203, point (e) – vii	Checking of oil conservator level of transformers for 70% level before onset of winter.
16.	Pg. no. 203, point (f) – ii	Availability of cable route drawings for HT systems and cable markers along the route.
17.	Pg. no. 204, point (f) – iii	Availability of checklist for preventive maintenance of HT cables for end termination tracking, cable connections, excessive tension, corroded cable supports, grounding connection. (to be carried out during preventive maintenance of connected equipment)

SNo.	Reference	Description
18.	Pg. no. 204, point (f) – iv	Record of insulation resistance & PI value testing during preventive maintenance of HT cables with proper documentation for trending and analysis.
19.	Pg. no. 204, point (f) – vi	Ensuring armour earthing in single core power cables at one end only.
20.	Pg. no. 204, point (g) – i, ii, iii	Ensuring performance of DVR as per the recommended practices for ensuring reliability.
21.	Pg. no. 206, point (h) – ii	Physical monitoring of critical UPS / VFD / Battery chargers for abnormal heating, noise, alarms, ventilation air filters etc. on daily basis and on weekly basis for non critical services.
22.	Pg. no. 206, point (h) – iv	Replacement of critical components like cooling fans, cards, capacitors based on OEM recommendation during planned preventive maintenance. (for UPS / VFD / Battery chargers)
23.	Pg. no. 206, point (h) – v	Root cause analysis of card failures of UPS, VFD, soft starters and chargers.
24.	Pg. no. 206, point (h) – vii	Availability of critical spares like CTs, PTs, cooling fans, capacitors, cards for replacement during planned unit shutdown.
25.	Pg. no. 206, point (h) – viii	System of monitoring boost charging of batteries to prevent over charging (to be available in the operations log sheet)
26.	Pg. no. 206, point (h) – x	Availability of instructions for critical alarms / operations / cautions near UPS / VFD for ready reference.
27.	Pg. no. 206, point (h) – xi	Battery discharge test during planned unit shutdown and checking of battery connections using thermography. Records to be maintained.
28.	Pg. no. 207, point (i) – i	VRLA batteries not to be used in UPS / DC systems of units & power plants.

E. Shutdown related issues

SNo.	Reference	Description
1.	Pg. no. 207, point (a)	Availability of updated standard shutdown job list for electrical jobs unit wise / sub-station wise with zonal engineers. This should also form the part of the Refinery shutdown manual.
		Availability of checklist for critical jobs during shutdown.

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SNo.	Reference	Description
		Review and updation of job list 2 to 3 months in advance.
		Structured system for 2nd level of checking & verification of critical jobs carried out during shutdown.

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Chapter-10

OPERATIONAL/ MAINTENANCE PRACTICES, DOCUMENTATION AND FAILURE ANALYSIS

10B - EXPLANATION TO RECOMMENDATIONS

Reference	Explanation
10.17	**To avoid entry of water / moisture in the transformer terminal box / bus duct through a corroded breather connection, connection for breather shall be made from the bottom part of terminal box / bus duct only.**

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Chapter-AC1

GAS TURBINES (O&M) SYSTEM MONITORING / DOCUMENTATION

The operation & maintenance related recommendations based on the GT tripping analysis and GT technical audit are as under. The recommendations need to be ensured by operations during normal running / maintenance.

1. Monitoring & Documentation

1.1 A system of maintaining start up failure log to be developed and made available for analysis as and when required. This shall provide information on the performance of systems critical for GT operations.

1.2 Trip log display, real time plot, alarm display must be saved and printed after every tripping of GT.

1.3 Time synchronization between the GT control system and sequence of event recorders to be ensured.

1.4 For ensuring adequacy in knowledge/ skill among operating group, it is recommended to conduct in house quarterly refresher course/ training for specific functions/ systems of Gas Turbine on continuous basis. The Power Plant Incharge shall be responsible for ensuring and monitoring of the same.

1.5 A team consisting of operation, mechanical, electrical and instrumentation engineers should be formed who would be the core group responsible for the continuous monitoring the performance and health of the gas turbines but also troubleshooting and problem solving. A weekly MIS on the health of the Gas Turbine with abnormalities of any, on physical condition, control system parameters etc. to be prepared by the group.

1.6 Checking of control systems parts and its maintenance like diaphragm, stem packing etc. to be ensured during the gas turbine schedule maintenance. All soft parts are to be replaced at least once in six years.

1.7 To avoid lube oil ingress in generator air circuit labyrinth clearances, gear box baffle conditions, Rubber sealing between LG compartment & Generator and Exciter compartment & generator to be checked & ensured.

1.8 All compartment doors of turbine, LG compartment, accessory compartment should be in closed condition. Proper maintenance of doors, latches must be carried out for ensuring proper closure. This is essential to avoid thermal shock and for effectiveness of fire extinguishment through the inbuilt CO_2 system.

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1.9 Frequency of cleaning/ replacement of fuel oil filter to be closely monitored. Accordingly, the fuel quality/ fuel lines to be checked for corrosion etc. A monthly check of the fuel quality at the TPS battery area is to be carried out.

1.10 Use of readymade gasket as per OEM specs and not gaskets cut out of gasket sheets to be used for fuel nozzles.

1.11 Flow divider replacement to be carried out every 8000 hrs. of operation (coincide with CI). Removed flow divider to be overhauled (by replacing parts like bearings / 'O' ring kit etc.) After overhauling the same to be preserved by using preservative oil as recommended by OEM.

1.12 Moog valve last chance filter to be replaced once a year or at every replacement of the Moog valve.

1.13 System for review regarding normalization of forcing be held by the person who has authorized the forcing (to be done once a week). Records for such changes with reasons, date & time to be maintained. However, any forcing should be avoided.

1.14 HSD tanks for diesel engine be drained and cleaned once in a year.

1.15 Replacement of main hydraulic oil filters is to be done once a year regardless of the pressure drop.

1.16 All exhaust gas leakages / radiation from the exhaust plenum walls are to be attended on priority.

1.17 It is recommended to monitor temperature inside turbine compartment and load gear compartment and take necessary actions to stop leakages / radiation which can increase compartment temperatures which in turn can lead to damages/ premature failures of instruments, fuel check valves, fuel nozzles etc. This also would help in preventing coke formation in the liquid fuel line (when not in use) for duel fuel machines.

1.18 It is recommended to maintain the inlet temp of the atomizing air compressor between 100 to 110 deg C. Monitoring of this temperature is necessary and it is recommended to have a thermocouple installed at next opportunity in the inlet and hook it up to Mark V. This would facilitate trending of the parameter and also a low temp alarm. Suitable software modifications are to be done in Mark V/VI, if not done already. Since temperature will be dropped across the cooler, condensation is very common in the pipeline between AA cooler and inlet of the AA compressor. Continuous drain is to be ensured especially in places like Haldia due to higher RH.

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1.19 It is recommended not to remove the inlet air filters while the turbine is in operation. Replacement of filters to be taken up during machine shutdown. To overcome the problem of high DP during monsoon / winters replacement of the filter elements to be done before the onset.

1.20 To minimize the effect of coke formation on fuel nozzle tips, it is recommended that the units be taken to higher load (>90%) periodically (at least once in a month). Regularly monitor the exhaust spread pattern and fuel nozzle pressures and initiate action at the first indication of irregular behavior.

1.21 The liquid fuel filters sealing elements provided by the OEM must be replaced by the same part whenever the filters are opened for maintenance. Also, holding down springs of the filter elements originally installed must be in place.

1.22 A list of critical spares necessary for sustained GT operations is to be prepared and their availability to be reviewed jointly by Operations & Maintenance group on quarterly basis.

1.23 General guidelines/checklist of OEM for Gas Turbine start up testing and initial operation after an inspection with the list of critical parameters to be monitored is enclosed as Annexure-AC1 for reference. System to be available for ensuring that checks are carried out.

1.24 Some of the additional jobs to be ensured during CI, HGPI, MI, in addition to the standard scope of work are as under:

Focus at Combustion Inspection

Liquid Fuel	Auxiliaries
• Test stop valve for passing	• Inspect IGV
• Replace flow divider	• Lubricate couplings
• Install calibrated fuel nozzles & check valves	• Replace hydraulic last chance filter elements
• Check integrity of liquid fuel tubing	• Offline compressor wash
• Check false start drain valves	• Replace of lube oil of diesel engine

Focus at Hot Gas Path Inspection

• Inspect IGV bushes & replace
• Hand clean compressor blades as far as possible
• Follow with compressor wash
• Calibrate critical instruments
• Replace dresser couplings
• Clean diesel tank of diesel engine

Focus at Major Inspection

• Assess compressor condition at second MI
• Replace all soft parts like valve diaphragms, O rings etc.
• Calibrate critical instruments
• Check condition of lube, hydraulic, fuel pumps
• Overhaul/ calibrate fuel pump and injectors of diesel engine
• Check bleed valves

1.25 Effectiveness of mist eliminator operation to be ensured and the lube oil tank pressure to be kept around 50mm water column vacuum at base load condition. A pressure switch in this suction of the mist eliminator may be provided to announce loss of vacuum.

1.26 SOP shall be developed for naphtha day tank draining and sampling for lab analysis.

1.27 **Monthly trial run of the Diesel engine of Gas Turbines shall be explored to ensure its reliability. Preventive maintenance/over hauling of Diesel engine shall be carried out during each CI/BI, HGPI and MI.**

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Gas Turbine Startup, Testing and Initial Operation after An Inspection

BHEL-GE GAS TURBINE SERVICES

HYDERABAD

INTRODUCTION

These Guidelines are prepared with intent to be used as a guide during startup after a HGP / Major Inspection. Some of the guidelines in this can be used even for normal startups also.

These Guidelines are typical and are not Frame specific and Customer Specific. Users are advised to check the specific equipment installed at the site and use these guidelines judiciously.

It is responsibility of Customer to address each of the points listed in these Guidelines, irrespective of the fact that an inspection might have been carried out by an outside agency.

CONTENTS

CHECKS DURING AN INSPECTION

After completion of an inspection it is the responsibility of plant owner (both operations and maintenance) to conduct the following checks even though a contractor is engaged.

1.1 LUBE OIL SYSTEM

1 It is a good practice to clean the lube oil tank during every Major Inspection.

2 During cleaning of the tank, ensure that **you are not leaving cotton fibers, cloth etc which can contaminate the lube oil once fresh oil is filled**.

3 During cleaning of the tank, ensure that all tubing is checked for its integrity and leaks. If necessary, replace the fittings and tubing. Similarly, all the pipelines inside the tank also need a check for its integrity.

4 Ensure that all lube oil lines have been restored after inspection. Special attention to be paid for locking and tacking of the bearing feed lines inside the concentric drain pipes.

5 Ensure that Insulators (washers and tubes) are installed at rear end bearing of generator so as not to ground the bearing, in case generator bearings are opened during the inspection.

6 Ensure that Lube oil filters, hydraulic oil filters, coupling oil filters have been replaced with new set of filters.

7 After cleaning of the tank, ensure that lube oil is filled through a Centrifuge. **Do not mix two different brands of oil in the lube oil tank.** In India, generally Servoprime 32T grade lube oil supplied by IOC is used.

8 It is a good practice to replace soft parts at every MI (like the diaphragm of VPR-1 / VPR-2, dresser couplings in the lube oil drain pipes of bearings etc)

9 Run Auxiliary Lube Oil Pump and check the system for leaks. Generally, the discharge pressure of Aux Lube Oil pump is around 5 kg/cm^2. Check that the lube oil header pressure is around 1.8 kg/cm^2. If necessary adjust VPR-1 / VPR-2.

10 Adjust the orifices in Generator bearing lines so that lube oil pressure is 1.5 kg/cm^2. Also check for good flow of oil thru the view glass in the drain lines.

11 Run Aux Lube oil pump and by operating 63 QL pressure switch check that DC Lube oil pump starts automatically on low pressure. DC Emergency Lube Oil

pump does not have auto stopping. It has to be manually stopped. It is a good practice to record the speed of the motor and current taken.

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TRIP OIL SYSTEM

1. Run Auxiliary Lube oil pump and reset the Mechanical Over Speed bolt trip. By forcing the trip oil dump valve 20 FG from Mark IV / V/ VI check that the trip oil pressure for gas fuel control builds on the trip oil pressure gauge. You may need forcing of other solenoids in the trip oil scheme which are in common system like IGV, 2nd stage nozzle etc (the common solenoid valves are 20HD, 20TV and 20NZ) in order to get trip oil pressure. If you are in doubt, check the project specific "Piping Schematic- Trip Oil".
2. Check that the trip oil pressure is more than 3.5 bar. Operate the over speed trip lever manually and check that the trip oil pressure falls to zero value.
3. Similarly check trip oil pressure for liquid fuel system by forcing 20FL solenoid valve

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HYDRAULIC OIL SYSTEM

1. Ensure that the hydraulic oil filter elements are replaced during the inspection. Filter Elements of Last Chance Filters (filters mounted just before the servo valves for SRV, IGV, liquid fuel bypass valve or 2nd stage nozzle control). These last chance filters have an in-built mechanism of bypassing the filter automatically in case the DP is more. **Hence this recommendation of yearly replacement of these elements irrespective of the condition of the filters.**

2. Run auxiliary hydraulic oil pump. Check that there are no leaks. If necessary, adjust VR 21 so that the pressure is around 1100 PSIG. Operate Gas ratio valve, Gas Control valve, and inlet guide vanes/ 2nd stage nozzles to check that they are operating smoothly

3. After stopping the aux hyd. pump, replace VR 21 with VR 22 and set VR 22 according to the Device Summary. After setting is completed, VR 22 can be placed in its own position and VR 21 can go to its original position. This procedure is extremely helpful as VR 22 can be set before running main hydraulic oil pump.

Verified by_____ Date _____

1.2 RATCHET OPERATION

1 Ensure that the axial clearance of the engaging jaw clutch has been checked and the limit switches are adjusted per Factory Alignment Procedure.

2 Check the ratchet sequence in Turbine Control system (Mark IV / V/VI). Check the motor by bumping. By using 43HR JOG push button, which is mounted near hydraulic ratchet pump, bump the motor once again to check leakage in ratchet hydraulic circuit. By loosening one of the top fittings on the tubing bleed out air from the hydraulic circuit. The hydraulic pressure in the circuit inlet of the Self Sequencer valve should be above 30 bar. It is also appropriate to clean the in line filter in the inlet of the self sequencer.

3 Check that jaw clutch engages properly and Limit switch is operated.

4 Put the machine on ratchet for about 2 hours to check the operation and leakage. During the first ratcheting operation go round the machine to listen to rubs.

5 In case` on base' cooling water pump is used, be sure that water system is full, before ratcheting, to protect water pump mechanical seal.

6 It is recommended to put on ratchet at least for about 12 hours before starting of the unit after an inspection. Please refer to “Guidelines on Ratchet” circulated by BGGTS.

Verified by_____ Date _____

1.3 DIESEL ENGINE CHECKS:

Diesel engine needs periodic checks by an expert. The fuel injectors need cleaning and adjustment, which needs to be done at an authorized service shop. Hence it is advisable to call manufacturer's representative to do servicing of the engine. The following points also need to be taken care:

1. It is advisable to clean Diesel Engine Diesel Tank during every HGP / Major Inspections by totally draining the diesel.
2. Ensure that the diesel tank is filled with correct grade of diesel as per diesel engine manufacturer's recommendations. Ensure that water is not there in the fuel. Ensure that the cover to the tank is tightly closed
3. It is recommended that lube oil in diesel engine also is replaced after cleaning / flushing the tank during inspections. Level in the crank case can be checked with the dipstick provided on the side of the engine. Remove the dipstick, wipe the lower end with clean cloth, insert and remove it again to check the oil level. Recheck the oil level after initial operation of the engine.
4. Ensure cooling water supply to diesel engine jacket cooling and circulate water continuously. Ensure that pressure does not exceed 1.5 Kg/cm2.
5. Check that jaw clutch is disengaged. Check the starting motor by bumping. And check the direction of rotation.
6. Start diesel engine on test mode and check that diesel engine runs to idling speed 600 to 700 rpm)
7. By manually operating the accelerating solenoid valve lever check that diesel engine speed reaches its rated speed (generally 2100 rpm). Check outlet cooling water temperature is not raising.
8. Run the engine for ten minutes and stop it. Check that all devices have operated as expected. Check that diesel engine stops from MARK IV / V / VI by operating solenoid valve 20 DV.
9. Recheck lube oil level after initial operation.

Verified by_____ Date _____

1.4 OTHER ON BASE SYSTEMS

During HGP/Major Inspection the following needs to be checked:

1. Remove false start drain valves and check that it is operating correctly (by simulating with air) and when the valve is closed it is holding. Do the pressure test up to 15 Kg pressure. (False start drain valves close at an air pressure of 0.6 Kg approximately after the turbine reaches around 45% speed. If these valves do not close, the hot air gases can leak through by heating the entire piping which is a fire hazard.
2. Check the pneumatic operation of VA 17 and VA 18 valves on the atomizing air and Purge air systems along with their solenoid valves, 20AA and 20PL. Clean the air filter connected to these solenoid valves.
3. Check diaphragm condition for both VA17 and VA 18 and replace them at MI time.
4. Check that drain valve bleed for the porous filter is clean and is not choked. It is extremely important that this bleed be free to drain out any condensate in the air.
5. Check the operation of both compressor bleed valves by operating them pneumatically through the solenoid valve, 20CB. Check that the limit switches also operate.
6. Check the operation of butterfly isolation valve VA 22 in the Booster Atomizing Air line along with its solenoid valve 20AB.
7. Ensure that the gap for the speed pickups (turbine as well as flow divider) are set correctly per specs.
8. Ensure that the starting clutch is adjusted per the alignment standard.

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1.5 OFF BASE COOLING WATER SYSTEM

1. Generally cooling water circuits do not need maintenance except for cleaning of the lube oil cooler tube for de-scaling. The cleaning should be taken up depending upon
2. During reassembly of the head of the cooler, ensure that the gasket was fixed properly.
3. Ensure that VTR-1 and VTR-2 (in case of dual fuel machines) are removed from pipeline during Major Inspection, and are internally cleaned. Scaling due to water can choke the internals of these valves thus restricting flow path.
4. During the restarting of the turbine, ensure that one lube oil cooler is in line and cooling water is line up. Keep a watch on lube oil temperature during running of the turbine and adjust VTR-1 if necessary.
5. For Fr 6 gas turbines, the cooling Jackets of Turbine Aft Legs need to be cleaned in every inspection to avoid scaling formation inside. After cleaning, ensure that there are no leaks. It is also recommended to install remote temperature monitoring of both the legs (you can install thermocouples and hook them to the control system so that you can have a trend whenever you want. It is also advisable to install an alarm for differential temperatures in both the legs (alarm at 20° C differential temperature)

Verified by_____ Date _____

1.6 INLET AIR FILTER SYSTEM

1. Inspect the internals of the inlet duct and inlet filter housing for pealing of paint, damaged bellows etc. It is advisable to replace the expansion bellows in the inlet duct during Major Inspection (once in five years).
2. Ensure the mechanical integrity of the bird screen. Ensure that there are no loose parts and all nuts and bolts are tack welded.
3. Ensure that Inlet Air Filter Housing and Inlet Air Duct have been cleaned.

4. Ensure that new neoprene gaskets are replaced in forward and aft walls of the inlet plenum as well as the inlet duct flanges.
5. Ensure that inlet plenum is clean before boxing up the plenum doors.
6. Ensure that the automatic filter purge sequence is working. Check that there are no leaks in the purge air header.

Verified by_____ Date _____

1.7 EXHAUST SYSTEM

During every inspection it is necessary to check integrity of exhaust system including exhaust plenum.

1. Check the mechanical integrity of exhaust diffuser, exhaust plenum, exhaust duct, exhaust stack.
2. Ensure that any damaged expansion bellows in the exhaust duct are replaced.
3. It is a good practice to take a thermograph of the exhaust duct while in service and identify weak spots so that insulation can be redone. Take thermograph of the duct after restart to keep the record for next inspection.
4. Ensure that the flex seals in the aft wall are replaced during the inspection along with the insulation pads.
5. Similarly, the pads of exhaust plenum also needs to be repaired/ replaced during the inspection.

Verified by_____ Date_____

1.8 COMPARTMENT CO_2 LEAK CHECK

During the inspection it is necessary to remove the compartment enclosures. While fixing back, these tests are to be performed so that in case CO_2 is released, it will not leak out.

1. Enter Accessory compartment. Close all doors. Check for light entering on left and right side as well as at floor where base connections are made
2. Repeat the above test for Turbine Compartment. Check turbine compartment for all incoming and outgoing pipes to be sealed around the base. Check for interconnections between bases
3. Check Load Gear Compartment similarly

Verified by_____ Date _____

1.9 COMPARTMENT FIRE PROTECTION SYSTEM DEMONSTRATION

During inspection, it is possible that the compartment roofs are lifted necessitating reconnection of connections to dampers etc.

As a Safety Measure, it is advisable to carry out this test.

1. Ensure that the Fire Detectors are reinstalled in correct places. Please check that correct sensors are installed in the various compartments (Accessory, Turbine and Load Compartments). Check that the correct type of sensors are installed in each compartment per device summary.
2. Ensure that connections to CO_2 operated dampers are connected properly
3. Check that CO_2 cylinders are full and are not empty. If weighing system is available, record the weight of each cylinder for record purpose.
4. Check free operation of CO_2 operated dampers with air pressure in
   a) Accessory Compartment
   b) Turbine Compartment
   c) Load Compartment
5. Simulate Zone 1 (Accessory Compartment) fire by shorting any of the detectors and / or pressing the Fire Push Button. Check the following:
   a) Annunciation with hooter in CO2 Panel
   b) Fire Alarm in Turbine Control Panel after 3 sec time delay

c) All the concerned solenoids have been acted in the field

d) Hooter in the field

6. Repeat the above for the other zones also.

Caution: **Remove the solenoids from the CO2 cylinders before doing this test. Otherwise the cylinders will be exhausted.**

Verified by_____ Date _____

1.10 HAZARDOUS GAS DETECTORS CHECK

1. Ensure that hazardous gas sensors are installed back in respective compartments.
2. Sequence check each detector, installed in the Accessory Compartment, during this modification, individually back to the control panel
3. Use Butane cigarette lighter. Without striking the lighter, let the gas escape in the vicinity of the detector.
4. Check for meter operation which verifies detector operation
5. **The above procedure is only a test for the working and not a calibration procedure. Please follow vendor's recommendations for the procedure. It is advisable to calibrate the system once in a year.**

Verified by_____ Date _____

2.0 TURBINE FUEL SYSTEM

2,1 GAS FUEL SYSTEM

1. If any jobs are done on fuel gas piping / gas conditioning skid, please ensure that fuel gas piping system/ gas conditioning skid is pneumatically tested for leaks at all flanged and treaded joints for a test pressure of (minimum of 6 Kg / cm2)
2. Ensure that the filter elements in the gas conditioning skid is replaced.
3. Ensure that KOD / Scrubbers are drained.
4. Check operation of the Emergency Stop Valve and vent valves if provided.
5. Check that calibration of Pressure reduction control valve is completed. Verify its operation
6. Ensure that 96FG transmitters are calibrated and devices are checked up to control system (Mark IV/ V/ VI)
7. Check operation of SRV and GCV
8. Ensure that Y strainer before the GT skid is cleaned and put back.

Verified by_____ Date _____

2.2 LIQUID FUEL SYSTEM

A. HSD Fuel Forwarding & Filtration System

1. Run HSD forwarding pumps one after the other and check that the re-circulation valve is functioning correctly. Test that the second pump starts on 'Auto' command while the discharge pressure is reduced to less than the pressure switch setting. (when the pump is running, isolate the pressure switch and drain so that the second pump can start)
2. Ensure that the suction filter elements of both the pumps are cleaned.
3. Ensure that fresh set of filter elements are installed in the off-base filters as well as on-base filters.

4. Ensure that the Y-strainer before the GT skid is opened and the element is cleaned.

5. Check the operation of pressure reduction control valve. If necessary ask customer to calibrate the transmitter and the control valve.

6. During start up, ensure that the HSD pressure before GT skid is kept between 3.5 to 4.5 bar.

B. Naphtha Forwarding & Filtration System

1. Prepare the Naphtha forwarding system and filtration as per the checks given under HSD system.

C. Priming Liquid Fuel System

1. Prior to attempting a Liquid Fuel Fire the entire Liquid Fuel System, both On and Off Base should be properly purged of air and primed.

2. Verify that the On-base Sump Drain is OPEN before attempting to prime the On-base filters. Otherwise the Sump may become pressurized.

3. Using Logic Forcing, open the Liquid Fuel Forwarding Stop Valve, 20FD1 (if used) One of the forwarding pumps should then be switched on in HAND

4. Operate the filter transfer valve and prime the filter, which will be in use for the startup. The other filter may be left unprimed (dry) as preferred by the customer.

5. Prime the filter by opening the vent valve until oil is observed being discharged the sight glass. Close vent valve when finished.

6. Open the purge drains of each of the fuel nozzles

7. Force open the On Base Stop Valve this will introduce fuel as far as the On Base Pump and the Servo-Operated Bypass Valve.

8. Crack open the vent valve on the On-base fuel filter to bleed air.

9. Check that HSD gets drained from each of the fuel nozzle purge drains.

Once the priming is completed, ensure that all vent and drain valves are closed, liquid fuel stop valves are closed, False Start Drain Valves are OPEN before attempting startup.

Verified by_____ Date _____

PRESTARTUP CHECKS

Sl No.	Field Check Activity	Status
1	Check **Lube oil tank level** is OK. (Approx **> 50% Min**)	
2	Check GTG AOP is running & Lube oil Pressure is Ok (**1.8 Kg /cm2 Min**)	
3	Check Lube oil **Mist Eliminator Fan** is RUNNING	
4	Check **Lube oil tank temperature** is approx **45 deg C**	
5	Check for any **Lube oil leakage** in all compartments	
6	Check **Warren Pump lube oil tank level** is OK (Approx **80% Min**)	
7	Clean Filter and check calibration (if required) of relief valve **for Ratchet Mechanism**	
8	Check GTG **Ratcheting is ON** (check **physical rotation** of GTG rotor)	
9	Check that the Hydraulic Oil Filters have been replaced & Last Chance Filters before the Servo valves are replaced (one for Liquid Fuel Bypass valve, one common for SRV and GCV and one for IGV, one for 2 nd Stage Nozzle Control)	
10	Run **Auxiliary Hydraulic Pump** and Check its discharge pressure (85 to 90 Bar)	
11	Check that no hydraulic oil leaks are existing when **Aux Hydraulic Pump** is running	
12	Run Load Gear Box **Oil Ventilator Fan** and check that its direction is ok	
13	**Stroke check** Liquid Fuel Bypass Valve for Liquid fuel GT's	
14	**Stroke check** SRV and GCV for NG fuel GT's	
15	**Stroke Check** IGV / 2 nd Stage Nozzle Control	
16	Ensure that **Spark Plugs and Flame Detectors** have been simulated and tested and are functioning satisfactorily	
17	**Check for Auto Cut-in of Emergency Oil Pump** in case of lube oil pressure low (0.6 bar)	
18	Check **IGV position** is Minimum position (Fr 6 &9 - 34° , Fr 5 - 42°)	
19	HSD level in **Diesel engine fuel tank** is between 1/2 to 3/4 MIN	
20	**DM Water level** in Diesel Engine Radiator is **FULL**	

Sl No.	Field Check Activity	Status
21	**Lube oil level** in Diesel Engine is OK (**At least more than MIN**)	
22	Check Atomizing Air Cooler DM water Inlet valve is CLOSE & Outlet valve is OPEN	
23	Check **Atomizing Booster Air** Compressor **lub oil level is OK** (Approx **50% Min**)	
24	Check **Atomizing Booster Air Compressor belts** are intact	
25	Check **Atomizing Booster Air Compressor inlet** air valve is **OPEN** (VA 22)	
26	Check physically the **False Start Drain** valve is open (Piston of the valve should be outside	
27	Check **Atomizing Air cooler air side drain** valve is partially **OPEN**	
28	Check **Atomizing Air Header drain Valve** in Combustion chamber is **partially OPEN**	
29	Check for any **Fuel tubing** is detached in the Combustion chamber	
30	Open all 10 purge drains and check for any fuel coming out of it. After removing all fuel in cranking mode, CLOSE all purge drains	
31	Check **start-up fuel isolation valve** after the filter is **OPEN**	
32	Check **Naphtha valve** in the filtration unit	
33	Check start-up **Pressure Control Valve (PCV)** is in line	

NOTE: Operations Shift -In-Charge has to ensure that the above checks have been performed before starting the unit after an HGP / MI inspection. It should also be noted as who has conducted these checks.

Verified by_____ Date _____

3.2 UNIT STARTUP CHECKS

CRANKING OPERATION

1. Check that jaw clutch engages smoothly and put the machine on ratcheting for at least 12 hours before attempting cranking**. ENSURE THAT D.C.LUBE OIL PUMP IS AVAILABLE AND IT IS ON AUTO START MODE**
2. By selecting `Crank' mode, start the machine to crank. Observe the acceleration sequence of diesel engine/starting motor.
3. During speeding up phase and after the machine reaches cranking speed (approximately 20% speed) observe the machine for rubs and vibration levels
4. Check for oil leakage and bearing drain temperatures (temp raise on the drains should not be more than 15 deg C). Check for lube oil generator bearing inlet pressures. Check all drain flows through sight glasses.
5. Check for operating parameters like hydraulic oil pressure, lube oil header pressure, crank speed etc. Check for overheating of starting motor/diesel engine.
6. Observe the performance of machine by running it for about 10 minutes. Also check the starting device against overheating, vibration or any other malfunctions.
7. Allow the machine to trip on low lube oil pressure protection 63 QT (only by simulation and not actual pressure drop). Make sure that starting device stops and clutch disengages. If this is not possible use “Stop” provision from the Control room.
8. Check for a gradual coast down of machine without any unusual noise. Note down coasting down time.
9. Make sure that the unit goes on ratcheting as soon as machine comes to zero speed. (This is important later with a hot machine).
10. **Starting motor or diesel engine normally should not be cranked beyond 20 minutes. It may get overheated.**

Verified by_____ Date _____

FIRING CHECKS

1. Select `Auto' mode on Mark IV / V / VI panel.

2. Check that after permissive are met, 'Firing" is displayed on the panel. Ensure that flame indication on Mark IV / V / VI is established. (Usually on can no.7 & 8. If four flame detectors are used 2 & 4 also will appear.)

3. Check that all exhaust thermocouples are indicating more or less same temperatures. Observe for a gradual rise in exhaust temperatures up to about 500°F. Check that rapid rises or surges or a drop in exhaust temperature are not occurring. **Trip immediately in case of any abnormality.**

4. Check for fluctuation in fuel supply, lift of control valves, puffs of smoke from exhaust, or whistling noise during the warm up phase

5. During acceleration phase notice the following:

   (a) Gradual speed & exhaust temperature raise.

   (b) Vibration levels are smooth (highest vibration due to static unbalance or rotor bow can occur at 75% to 85% speed).

   (c) Exhaust temperatures will begin to decrease after approximately 70% speed due to increase in airflow.

   (d) Starting Clutch disengages generally occurs at 50 to 60% speed and starting device goes to cool down cycle. Watch for drop out of L33CSE at Mark IV / V/VI panel.

   (e) Ensure that false start drain valves are closed at around 45 to 50% speed

6. At 14HS (generally at 90% speed) observe that the following happen.

   (a) Check that compressor bleed valves are closed. L20CB1X picks up and L33CB1O and L33CB2O go to logic 0.

   (b) Check the main lube oil pump takes over after 90 % speed and auxiliary lube oil pump stops after pressure is built up (88QA goes on standby)

   (c) Check the main hydraulic oil pump takes over after 90 % speed and auxiliary lube oil pump stops after pressure is built up (88HQ goes on standby)

   (d) Booster Atomizing Air Compressor isolation valve VA 22 closes (L20AB1X goes to a logic 1 and VA22-1 closes).

(e) IGV Opens to 57 deg

(f) FULL SPEED NO LOAD message on screen.

7. At full speed no load check the following:

a) Check for leaks in turbine compartment

b) Lube oil pressure and temperature at all bearings.

c) Bearing drain temperatures

d) Uniformity in Exhaust temperatures, record the spread

e) Vibration on all bearings

f) All wheel space temperatures

g) Hydraulic oil pressure with main pump in line.

h) Check for fuel system stability at FSNL. The speed of the machine should not vary.

i) Check bearing header temperatures and adjust lube cooling water control (VTR-1). The ideal Lube oil header temperatures are from 40 Deg. to 50 Deg.C.

8. Run the machine for about 30 minutes to soak the bearings.

9. The turbine is considered to have reached steady state thermal condition only when wheel space temperatures are stable

Verified by_____ Date _____

3.3 ELECTRONIC OVERSPEED TRIP

Electronic Over speed test is not necessary if the unit has mechanical over speed bolt and the same is being tested. However, if customer insists of carrying out this test, follow the procedure.

1. Bring the Unit to FSNL condition. Allow the turbine to run at FSNL condition for at least 30 minutes to allow heat soaking

2. Monitor the wheel space temperatures during this time. They should become relatively stable after 30 minutes.

3. Using the Manual Raise Switch (on Generator Panel) increase the HP speed slowly up to 110%. Verify that the unit trips at 110% speed as recorded on Control panel display. Verify alarm "ELECTRONIC OVERSPEED TRIP"

4. Measure the coast down time to Zero Speed.

Verified by_____ Date _____

3.4 MECHANICAL OVERSPEED TRIP

It is suggested that mechanical over speed test is done before shutting down the unit for a major inspection. In case the unit has not tripped due to any fault in the mechanical over speed bolt assembly or the system, it can be checked during the shut down. In such a case, the test is to be repeated after completion of the inspection.

1. Bring the Unit to FSNL condition. Allow the turbine to run at FSNL condition for at least 30 minutes to allow heat soaking.

2. Monitor all the parameters of turbine including wheel space temperatures during this time. They should become relatively stable after 30 minutes.

3. Select 'MECHANICAL OVER SPEED TRIP TEST' from the appropriate page on the control panel. This will increase the setting of Electrical Over Speed Trip setting to 113.5%

5. Using the Manual Speed Raise Switch (on Generator Panel) increase the HP speed slowly up to around 112%. Verify the speed at which the unit trips. Verify alarm "MECHANICAL OVERSPEED TRIP".

6. Measure the coast down time to Zero Speed.

	SPEC %	**TRIP RECORD** RPM	%	**COASTDOWN TIME (in minutes)**
ELECTRICAL OVERSPEED	110			
MECHANICAL OVERSPEED	112.5 +/- 1%			

Verified by_____ Date _____

3.5 ADDITIONAL STARTUP TESTS

Automatic Startup and Shut down

1. Automatic Startup was smooth _____
2. Time taken to FSNL condition from Start Command (on Auto)_____
3. Normal Shutdown is smooth _____
4. Speed at which FSR is cut off and flame is off (on gas) _____

   (on liquid) _____
5. Total time taken from FSNL to Zero speed on Normal Shutdown _____

Load Tests

After the unit is synchronized, perform the following:

1. Record full set of data from the turbine and generator and turbine gauge panels, etc. at FSNL, 25% load, 50% load, 75% load and base load.
2. If it is a duel fuel machine, please record similar set of data on the other fuel also.

Fuel Transfer (HSD To Naphtha, If Applicable)

Before attempting this transfer, ensure that there are no leaks in the fuel system piping in the turbine and accessory compartments.

1. Ensure that unit is started on HSD and loaded to about 5 mw.
2. Ensure that Naphtha fuel forwarding system has been started and system is made ready. Ensure that Naphtha pressure is between 3.5 to 5 bar before the 3 way transfer valve
3. Ensure that power for 3-way transfer valve is connected and energized.
4. Ensure that adequate level is maintained in the Hi-Tec Dozing skid tank. Start one of the Dozing pumps by keeping the other on 'Auto Standby'. Once the pressure of the dozing is equal to the Naphtha line pressure open the discharge line block valve at the Naphtha pipe line.
5. Check that Naphtha transfer permissive are OK.
6. Select 'Naphtha' and check that the fuel is getting transferred to Naphtha from HSD. Check that the transfer is bump less.

7. Transfer back from Naphtha to HSD. Check that transfer is bump less
8. Check that no alarms are annunciated during the transfers.
9. Load unit on Naphtha to Base Load. While increasing the load, record all the parameters at 25%, 50%, 75% and 100% of base load.

Verified by_____ Date _____

4.0 RECORDING OF OPERATING DATA

4.1 NO-LOAD SYSTEM PARAMETERS

	During Standstill	During FSNL
Lube Oil Pressures (Kg/cm^2)		
AOP Discharge		
Main Pump Discharge		
EOP Discharge		
Bearing Header		
Hydraulic Pressure (Main)		
Hydraulic Pressure (Aux.)		
Trip Oil Pressure (Gas)		
Trip Oil Pressure (Liquid)		
Main Lube Oil Filter DP		
Hydraulic Filter 1 DP		
Hydraulic Filter 2 DP		
Lube Oil Tank Level		
Lube Oil Tank Temperature		
Cooling Water Inlet Pres		
Cooling Water Inlet Temp		
Cooling Water Outlet Temp		
HSD Off-Base Fuel Filter DP		
HSD Pressure before GT skid		

4.2 SYSTEM PARAMETERS

Load	FSNL	25 %	50 %	75 %	Base Load
Load MW					
Turbine Speed %					
Turbine Speed Rpm					
LO Header Temperature					
Inlet Air Temperature CTIF1					
Inlet Air Temperature CTIF2					
Comp.Disch.Temp CTDA1					
Comp.Disch.Temp CTDA2					
Compressor Disch. Pressure					
Inlet Air Filter DP					
GT Brg # 1 Drain Oil Temp.					
GT Brg # 2 Drain Oil Temp					
GT T.Brg Drain Oil Temp					
LO Header Pressure					
Hydraulic Oil Pressure					
Trip Oil Pressure					

VIBRATION Vs LOAD

Device	Location of Sensor	FSNL	25 %	50 %	75 %	Base Load
BB 1	GT Brg # 1					
BB 2	GT Brg # 1					
BB 4	GT Brg # 2					
BB 5	GT Brg # 2					
BB 7	Load Gear					
BB 8	Gen Front Brg					
BB 9	Gen Rear Brg					

WHEELSPACE THERMOCOUPLES

POINT	FSNL	25 %	50 %	75 %	Base Load
TTWS1FI1					
TTWS1FI2					
TTWS1AO1					
TTWS1AO2					
TTWS2FO1					
TTWS2FO2					
TTWS2AO1					
TTWS2AO2					
CTIF					
CTDA					

Note : All above shall be recorded only after steady state condition is achieved (approximately 30 minutes after reaching each condition)

OTHER PARAMETERS ON GAS

Point	FSNL	25 %	50 %	75 %	Base Load
Gas Fuel Inlet Pressure P1					
Gas Fuel Pressure P 2					
Gas Fuel Outlet Pressure P3					
TTXD1_1					
TTXD1_2					
TTXD1_3					
TTXD1_4					
TTXD1_5					
TTXD1_6					
TTXD1_7					
TTXD1_8					
TTXD1_9					
TTXD1_10					
TTXD1_11					
TTXD1_12					
TTXD1_13					
TTXM					
TTXSPL					
TTXSP1					
TTXSP2					
TTXSP3					

OTHER PARAMETERS ON HSD

Point	FSNL	25 %	50 %	75 %	Base Load
TTXD1_1					
TTXD1_2					
TTXD1_3					
TTXD1_4					
TTXD1_5					
TTXD1_6					
TTXD1_7					
TTXD1_8					
TTXD1_9					
TTXD1_10					
TTXD1_11					
TTXD1_12					
TTXD1_13					
TTXM					
TTXSPL					
TTXSP1					
TTXSP2					
TTXSP3					
A.A. Comp Disch. Pressure					
AA Comp Inlet temp					
HSD Pressure before GT skid					
On base Pump Disch. Pressure					
Flow Divider Press. # 1					
# 2					
# 3					
# 4					
# 5					
# 6					
# 7					
# 8					
# 9					
# 10					

OTHER PARAMETERS ON NAPHTHA

Point	FSNL	25 %	50 %	75 %	Base Load
TTXD1_1					
TTXD1_2					
TTXD1_3					
TTXD1_4					
TTXD1_5					
TTXD1_6					
TTXD1_7					
TTXD1_8					
TTXD1_9					
TTXD1_10					
TTXD1_11					
TTXD1_12					
TTXD1_13					
TTXM					
TTXSPL					
TTXSP1					
TTXSP2					
TTXSP3					
A.A. Comp Disch. Pressure					
AA Comp Inlet temp					
HSD pressure before 3 way valve					
Naphtha Press before GT skid					
On base Pump Disch. Pressure					
Flow Divider Press. # 1					
# 2					
# 3					
# 4					
# 5					
# 6					
# 7					
# 8					
# 9					
# 10					

Chapter-AC2

CABLES

Reliability of the HT electrical system is dependent on the condition/ healthiness of the HT cables. The recommendations below are on the experiences of cable failures which are attributed mainly to improper laying/ cable trench design etc.

2.0 Specific Requirement

2.1 Monitoring of leakage current thru' very low frequency test voltages is presently being recommended by CPRI. It is desirable to have a base line data during testing/ commissioning of cables. (New Projects)

2.2 Presently expert agencies are available, detection of partial discharge in HT cables. For cables having low IR value/ tan delta etc. it is recommended that the partial discharge location be explored and accordingly part replacement of cable to be carried out for ensuring healthiness of the cable run.

2.3 All cables i.e. HT and LT in concrete cable trenches shall be laid on cable trays only. Verification of the design basis with respect to the cable tray loading to be carried out prior to execution.

2.4 All cables shall be laid as per IS 1255 specifications and contractors shall use rollers/ other laying tools for ensuring proper laying. It is recommended that availability of such tools and tackles for ensuring proper laying are also available with the maintenance department for day to day jobs.

2.5 For new projects, it is desirable to have a separate concrete chamber for all cable joints. This shall ensure monitoring health of the cable joints, traceability etc.

2.6 Use of colored adhesive marking tapes on cable end termination insulation for phase marking is to be avoided as reaction of the adhesive material with the end termination insulation can result in partial discharge.

2.7 **Fire proof coating shall be applied to the cable passing through electrical store room/battery bank room.**

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Chapter-AC3

UNGROUNDED SYSTEM

Considering that the requirements of ungrounded system are different from that of grounded system, some of the critical recommendations which need to be ensured are as under:

3. Specific Requirements

3.1 Bus PT and line PT should have tertiary windings also along with loading resistance. The same to be also ensured in the design basis for any expansion.

3.2 Surge arresters of suitable ratings are to be used in motor feeder having VCB. Minimum Continuous Operating Voltage (MCOV) should be at least equal to or greater than highest system voltage.

3.3 Voltage factor for the PT for HT system should be 1.9 for 8 hrs.

3.4 For detecting earth fault in the feeder, CBCT must be used in conjunction with sensitive earth fault relay for all HT feeders.

3.5 Armour of the cable should not pass through the CBCT. If it is passing through the CBCT, then, it must be brought out through CBCT only and then grounded.

3.6 Cable is to be selected one grade higher w.r.t. the system voltage.

3.7 Zig Zag transformer + ground fault neutralizer should be provided for capacitive current compensation. Sufficient capacitive current (25A) must be left uncompensated for earth fault detection.

3.8 Setting of earth fault protection of a particular feeder should be 120% of its own capacitive current contribution.

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Chapter-AC4

Electric Heater

Electric heaters application in process units have increased. Considering the criticality for process operations, the salient points identified from the failures from reliability point of view are as under:

4. Recommendations

4.1 Classifications of electric heaters to be carried out for identification of critical heaters i.e. no standby/ failure may result in reduce throughput/ affect product quality. Spare heater bundle to be available as spare for critical heaters.

4.2 Inspection of electric heaters to be included in the M&I shutdown job list of the process unit for complete inspection.

4.3 If the heater is kept idle at ambient temperature, to avoid coke formation, the shell shall be drained after ensuring safety precautions before taking the heater in service. The same shall also be informed to the Production Department.

4.4 Normally, the skin temperature sensing of heater element for monitoring is available in the heater control panel which are kept in unmanned substation. In order to improve the monitoring, same is to be made available in DCS.

4.5 Atleast 90% of heating elements need be healthy during operation of electric heater. Less number of healthy heating elements shall call for replacement/ rectification of tube bundle.

4.6 If heater is kept idle at ambient temperature, nitrogen purging of the terminal box is desirable wherever purge facility is available. The space heater provided in the terminal box to be ensured in “on” condition whenever the heater is kept idle. This shall ensure that there is no deterioration in the insulation resistance value of the heater.

4.7 Spare heater bundles to be preserved inside a dummy shell filled with nitrogen.

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Chapter-AC5

SUBSTATION AMBIENCE

Refineries to ensure that the sub-station ambience is being maintained for clean environment w.r.t. dust, moisture, sulphur etc. in order to avoid tracking/ corona and subsequent flashovers. The recommendations below are operational/ maintenance related for enhancement of the substation environment and protect the equipment from dust, moisture, etc.

5. Recommendations

5.1 Refineries to ensure that the substation ambience is being maintained for clean environment w.r.t. dust, moisture, sulphur, etc. For locations where abnormalities has been observed w.r.t. the ambience suitable actions based on specific requirements (contaminant) to be carried out.

5.2 For ensuring proper sub-station ambience to reduce the effect of dust humidity and sulphur corrosion, the following measures to be adopted.

a. Sealing of all opening, doors and windows of sub-station

b. Cleaning of sub-station floor through moping / vacuum cleaning

c. Cleaning of panels on weekly basis

d. Cleaning of pressurisation filters on monthly basis

e. Cleaning of pressurisation of air duct once in three years through mechanised system

f. Explore the possibility of providing and additional filter unit in the existing filtration unit

g. Sealing of panel openings, panel doors

h. Monitoring of pest control effectiveness

i. Ensuring operation of panel space heaters in HT switchgears

j. Availability of FLP exhaust fans in battery rooms and ensuring continuous operation

k. No openings for exhaust fans.

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5.3 Substation monitoring/ audit shall be done by Senior Manager and above as per the checklist attached as Annexure-VI.

5.4 The following points to be considered for sub-stations in new projects:

- The air filtration unit air suction inlet shall be located at a higher elevation instead of ground level to minimize the ingresses of dust (New Projects).
- The environment conditions indicated in the specifications of the switchgear and relays shall be suitable for environment conditions of dust humidity and sulphur.
- Conformal coating should be provided on relay cards, if they are to be located near process units for protection against sulphur corrosion.
- A detailed design basis calculation of the sub-station ambience w.r.t. the heat load, required ambient temperature / humidity i.e. 35 deg.C. / 55 to 60 Rh is to be prepared during the engineering stage. Accordingly, suitable additional measures to control the temperature/ humidity to be provided.
- The pressurization ducts shall not be laid above the switchgear panels.
- Substations shall have double door provision (new projects).

5.5 Critical **HT sub stations (Eg. Power plants, unit sub stations having low shutdown frequency) may be provided with air conditioning system.**

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New Point Annexure-VII
Ref. Pt.5.3 of AC Ch.5

CHECKLIST FOR SUBSTATION UPKEEP/HOUSEKEEPING

Substation No. & Name: _____

Date of Checking: _____

Name & Designation of the person visiting substation:
_____

Note: **Kindly put a tick mark (√) under the appropriate box against "Yes" or "No". In case of any remark/deviation, kindly indicate the exact point of your observation against "Observation/ Remarks" column. If there is any space limitation, please use separate sheet.**

Sl. No.	Equipment	Checklist Points	Yes	No	Observations/ Remarks
1	**Transformer Yard**	**Easily Accessible**			
		Wild grass/vegetation			
		Cleanliness (inside/outside)			
		Properly fenced and danger board provided			
		Gates are locked			
		Both the terminal boxes completely sealed			
		Gap/hole in cable entry bottom plate			
		Silica gel OK			
		Transformer oil level ok and leakage if any			
		Filled sand buckets/tested fire extinguishers available			
2	**Sub-station**	**All doors and windows locked**			
		All doors/shutters opening and closing smoothly			
		All windows opening and closing smoothly			
		L-drops/Tower bolts available on each door, both from inside as well as outside			
		Window panes of all windows are in order			

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Sl. No.	Equipment	Checklist Points	Yes	No	Observations/ Remarks
3	HT switchgear	Any gap beneath the fully closed door/shutter			
		DC Emergency Lights working			
		Pressurization system working & date of last filter cleaning			
		Do's and Don'ts board available			
		Updated SLD board available			
		List of authorised persons/entrants available			
		Shock treatment chart available Cable trench openings fully covered Filled sand buckets/tested fire extinguishers available Hole/cut-out in front/back side of the panel Front/back covers of all the feeders/breakers closed properly Relay modules/control cabinets of all the feeders/breakers closed properly Any gap through front/back covers/relay modules/control cabinets of all the feeders/breakers All panel screws found in place and tightened Extra holes/cut-outs or part of these holes/cut-outs on panel are completely sealed?			
		Any gaps at the panel door hinges/side covers/ top covers			
		Any dust/spider web on any part of the panel			
		All extra holes in the bottom cable entry plate and gaps through existing cable completely sealed (Applicable for panels under shutdown)			
4	LT Switchgear/ DCDB/ Chargers/ VFD panels/ Heater panels etc.	Hole/cut-out in front/back side of the panel			
		Front/back covers of all the feeders/breakers closed properly			
		Relay modules/control cabinets/cable alleys of all the feeders/breakers closed properly			
		Any gap through front/back covers/relay modules/control cabinets/cable alleys of all the feeders/breakers			
		All panel screws found in place and tightened			

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Sl. No.	Equipment	Checklist Points	Yes	No	Observations/ Remarks
		Extra holes/cut-outs or part of these holes/cut-outs on panel are completely sealed?			
		Any gaps at the panel door hinges/side covers/ top covers			
		Any dust/spider web on any part of the panel			
		All extra holes in the bottom cable entry plate and gaps through existing cable completely sealed (Applicable for panels under shutdown) (Observations can be given for Russian panels similar to that in S/S-4 & 5.)			
5	**Battery Room**	**Light fittings & exhaust fan are flameproof and working**			
		No abnormal temperature of cells			
		No leakage from cells			
6	**Critical Relay Settings**	**Hi set is in line**			
		Cable differential in line			
		Bus differential in line			
		Load shedding is in line			
6	**Rodent Control Measures**	**Rodent control measures (RCM)**			
		RCM in the form of powder only			
		RCM in the form of cake only			
		RCM in the form of both powder & cake			
		Any spillage of RCM material			

Signed

Random Checking by Higher Official / Manager

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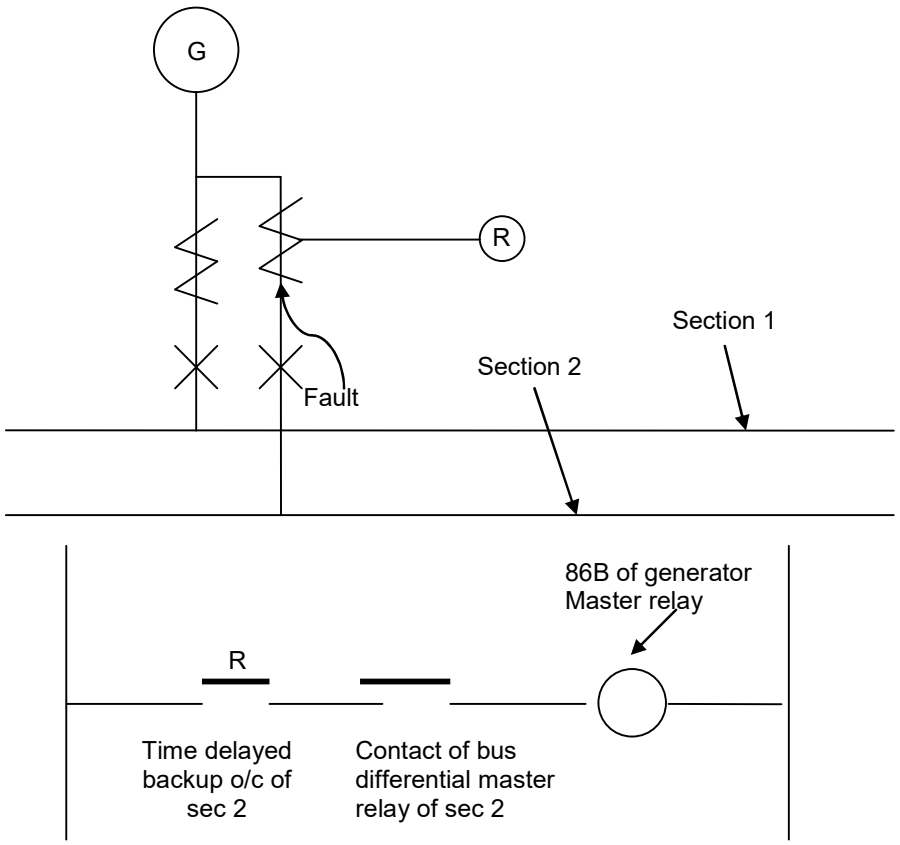
Chapter-16

NEW PROJECTS RELATED

16.1 A core group should be made at the initial stage itself of new project who will review the tender document and ensure the specification as per reliability recommendations.

16.2 Project related new points from each chapter:

16.2.1 During fault on incoming pole of the generator breaker, bus differential relay operation will not isolate the fault. In view of this following scheme is to be implemented to trip the generator and avoid wide spread affect.



Note: Current transformer (CT) – 'R' normally should be on the downstream side of the circuit breaker for achieving overlapping. However, it is observed that in most cases, it is provided in the upstream of the breaker and hence, the above mentioned scheme is desirable as overlapping is not available.

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6.1.1 Proven schemes are to be used for generator differential/overall differential protection. If high impedance scheme is used, stabilizing resistances of correct ratings are to be used.

6.1.2 Static excitation system, which derives power from generator terminal is to be avoided. If the system voltage drops below 70%, then the static excitation system may not provide the required excitation to clear the fault and maintain the system voltage healthy.

6.1.3 DVR dual auto channel with dual PLC to be considered for enhanced reliability.

6.2 Local breaker back-up (LBB) protection for circuit breaker failure at generation bus should be provided to prevent collapse of the system during non-tripping of any circuit breaker in the generation bus on faults.

6.3 Master trip relay shall be of VAJH type.

6.4 The surge arrestors provided in the vacuum circuit breakers of Motor Feeders shall be rated for maximum continuous operating voltage. The maximum continuous operating voltage should be equal to the highest system voltage i.e. equal to the line to line voltage plus 10%.

6.5 The surge arrestor installation in some cases are before the CTs, that is in the event of surge arrestor failures bus differential protection shall trip the entire bus section which is not desirable. In new projects, the installation of surge arrestors to be done after the CTs so that in the event of surge arrestor failure particular motor feeder shall trip only without affecting other feeders. In the existing system wherever such type of surge arrester is provided, necessary modification after suitable engineering / OEM consultation to be carried out. (Pt. no. 2.3.44).

6.6 Time synchronization of sequence of event recorders (SOE), generator relays, distribution relays, chartless recorders on generation bus need to be ensured. This is necessary to facilitate fault analysis.

6.7 For ensuring reliability of generator breakers, and for 33KV circuit breakers double trip coil to be provided. (Pt. no.2.3.47)

6.8 HT switchgear at TPS i.e. generation bus and distribution bus shall be rated for short circuit current of 3 second duration. The short circuit current rating of HT cables from TPS to downstream sub-station shall also be rated for 1 Second. (Pt. no.2.3.48)

6.9 For enhanced reliable protection co-ordination, it is recommended that the number of levels in the HT system should be limited to three (to the extent possible) including the generation bus.

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6.10 In view of the failure experiences of flash over in metal enclosed switchgear, it is desirable that all HT switchgears shall be of metal clad type. (Pt. no.2.3.51)

6.11 In critical HT motors facility of bearing temperature and winding temperature measurement shall be included in the specifications. The same shall be wired to the numerical relays for alarm only.

6.12 Availability of online temperature monitoring like IR (Infra Red) windows in HT switchgears shall be a part of the standard specifications i.e. incomer/ bulk current feeders.

6.13 The protection devices for air circuit breaker in PCC shall be numerical relays. Use of releases shall be avoided.

6.14 Power supply to auxiliary services board where single phase / lighting loads are connected shall be through lighting / isolation transformer only.

6.15 MCC modules i.e. motor, starter / contactor with holding coil type shall have its control voltage derived from individual module phase and neutral. Individual module isolation transformer may be used for limiting fault current value. (Pt. no.4.5.5)

6.16 All LT motor feeders of motor rated above 55KW shall be fed from air circuit breaker with motor protection relay. (Pt. no.4.5.6)

6.17 Use of VRLA batteries shall be avoided for switchgear DC system, instrumentation DC / UPS system.

6.18 Each UPS in parallel redundant configuration shall be provided with static switch in the output to avoid failure of the UPS in the event of fault in one of the UPS. (New Projects). (Pt. no.7.11)

6.19 For higher rating UPS, UPS systems selection shall be based on standard ratings of reputed makes having proven track record for that particular rating & model. Failure of high rating UPS i.e. output transformer failure etc. have taken place due to inadequacy of design/ heat dissipation etc. (New Projects). (Pt. no.7.12)

6.20 Redundancy of drive run signal to DCS shall be provided for critical VFD applications. (Pt. no.8.20)

6.21 Monitoring of leakage current thru' very low frequency test voltages is presently being recommended by CPRI. It is desirable to have a base line data during testing/ commissioning of cables. (Pt. no.12.1)

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6.22 All cables i.e. HT and LT in concrete cable trenches shall be laid on cable trays only. Verification of the design basis with respect to the cable tray loading to be carried out prior to execution.

6.23 All cables shall be laid as per IS 1255 specifications and contractors shall use rollers/ other laying tools for ensuring proper laying. It is recommended that availability of such tools and tackles for ensuring proper laying are also available with the maintenance department for day to day jobs.

6.24 Surge arresters of suitable ratings are to be used in HT motor feeder having VCB. Minimum Continuous Operating Voltage (MCOV) should be at least equal to or greater than highest system voltage.

6.25 Classifications of electric heaters to be carried out for identification of critical heaters i.e. no standby/ failure may result in reduce throughput/ affect product quality. Spare heater bundle to be available as spare for critical heaters.

6.26 Availability of IR (Infra Red) windows in all HT switchgears shall be a part of the standard specifications especially for generation bus circuit breakers and incomer/ bulk current feeders.

6.27 All MCC modules shall be designed for type 2 co-ordination. The degree of enclosure for LT switchgear shall be preferably IP54. (Pt. no.4.5.2)

6.28 The protection devices for air circuit breaker in PCC shall be numerical relays. Use of releases shall be avoided. (Pt. no.4.5.3)

6.29 A detailed design basis calculation of the sub-station ambience w.r.t. the heat load, required ambient temperature / humidity i.e. 40 deg.C. / 55 to 60 Rh is to be prepared during the engineering stage. Accordingly, suitable additional measures to control the temperature/ humidity to be provided.

6.30 All cables i.e. HT and LT in concrete cable trenches shall be laid on cable trays only. Verification of the design basis with respect to the cable tray loading to be carried out prior to execution.

6.31 For new projects, it is desirable to have a separate concrete chamber for all cable joints. This shall ensure monitoring health of the cable joints, traceability etc.

6.32 The following points to be considered for sub-stations in new projects:

- The air filtration unit air suction inlet shall be located at a higher elevation instead of ground level to minimize the ingresses of dust (New Projects).

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- The environment conditions indicated in the specifications of the switchgear and relays shall be suitable for environment conditions of dust humidity and sulphur.

- Conformal coating should be provided on relay cards, if they are to be located near process units for protection against sulphur corrosion.

- A detailed design basis calculation of the sub-station ambience w.r.t. the heat load, required ambient temperature / humidity i.e. 35 deg.C. / 55 to 60 Rh is to be prepared during the engineering stage. Accordingly, suitable additional measures to control the temperature/ humidity to be provided.

- The pressurization ducts shall not be laid above the switchgear panels.

- Substations shall have double door provision (new projects).

6.33 VFD specific requirements

i. For critical performance aspects like critical speed & pulsating torque, the VFD vendor shall advise on the critical speed, if any inside the operating range and the same shall be documented to avoid these critical speeds. The VFD vendor shall also give information about any pulsating torque in the low speed range as well as the operating speed range.

ii. A torsional analysis is required for all large VFD systems. The definition of “large” depends on the nature of the driven equipment, i.e. pump, compressor, fan, gear, etc. The torsional analysis be performed for large systems, carefully including all sources of excitation. Torsional excitations which must be considered include: harmonic torques caused by the VFD, dynamic torques from the motor and transient torques from electrical short circuits. These excitations must be examined for both startup and normal operating conditions.

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Chapter – 11

INSTRUMENTATION POWER DISTRIBUTION SYSTEM

11- A RECOMMENDATIONS

For any instrumentation system the reliability of its power distribution system is very important. The power distribution system shall be adequately designed for a system with respect to its capacity and redundancy. The system / practices recommended for adoption in instrumentation power distribution system at refineries are given below. These recommendations have been arrived from failure analysis in the past and experienced gathered from day to day operation / OEM / Specialists. Detailed explanation to these recommendations marked as (🔈) has been enclosed at Section 11B of this chapter.

11.1 Two separate AC distributions boards (Dual ACDB), fed from parallel redundant UPS are desirable for instrumentation power distribution system for the improved reliability of instrumentation system. (Refer Schematic- 11C- 1A). However, if the installation of additional ACDB is not feasible because of space constraints in the control room, or any other reasons, then Schematic- 11C- 1B may be implemented.

11.2 The UPS supply shall not be used for the utility supplies like cooling fans, lighting power sockets in the consoles / panels / cabinets / Local Control Panels, etc. A separate non-UPS supply shall be used for the same.

11.3 A summery (common) alarm of all critical UPS alarms shall necessarily be provided in the DCS / hardware annunciation in the control room or any manned location.

11.4 Copper cables and tin-plated copper lugs are preferable for Instrumentation power distribution system i.e. from ACDB/ DCDB to down stream distribution systems.

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11.5 UPS Battery back up should be available for a minimum period of 60 min at full load condition. The same to be ensured during capacity discharge test of the battery bank during planned shut down.

11.6 Protection coordination with respect to the fuse/MCB ratings from the supply source ACDB / DCDB to the downstream distribution panels should be as per the recommendation of the OEM / supplier of the system. However, if such recommendation is not available, a joint review by an identified group of electrical and instrumentation people shall be carried out to ensure the same.

11.7 Power supply to all critical devices like, PLC, DCS, operator console etc. shall be drawn through individual feeders and not by "looping in" or "looping out" from a common source (Refer Schematic- 11C- 2).

11.8 It is desirable to segregate the DC power supply source, for instrumentation emergency shut down system, from emergency lighting system.

11.9 Minimum two numbers of Bulk Power Supplies (BPS) with diode Oring shall be configured for powering all critical instrumentation systems. (Refer Schematic- 11C- 1A & 1B)

11.10 Such redundant BPS shall be fed from two separate AC feeders. Power looping in and looping out shall be avoided / eliminated. (Refer Schematic- 11C- 1A & 1B).

11.11 The loading of individual BPS should be such that the failure of single BPS shall not result in loading of the other operating / redundant BPS beyond 70% of their individual rated capacity.

11.12 "BPS failure" alarm shall be provided in hardware annunciation system / DCS pop up alarm. BPS failure shall be monitored on daily status display.

11.13 Auxiliary power supply to the individual flame scanners to be wired from separate sources.

11.14 Elimination of unwanted fuses (multiple fuses in same circuit) & use of proper fuses in power distribution to be ensured.

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11.15 Unit wise segregation of power supply distribution to facilitate necessary maintenance during individual unit shut down to be ensured.

11.16 Use of multiple set of BPS (Bulk Power Supply) of smaller capacity in place of single redundant set of higher capacity per unit shall be preferred

11.17 Proper segregation of data bus / prefab cables & power cables below false floor shall be ensured.

11.18 Power supply from redundant power source is to be ensured for all subsystems where facility is available for accepting redundant supplies, like:

a. Machine Monitoring System – 3500 Systems (To be followed strictly for all new systems)
b. Governor Control System.
c. TMR Over-speed trip system (e.g. woodward protect system).
d. Where Overspeed trip is generated by using any other method (Like using Frequency to current converter & fed to PLC as AI or through trip amplifier) – Ensure that power supply is not common.
e. Package PLCs, wherever used (Like Compressor PLCs, PSA PLC etc).

11.19 Load of individual BPS/RPS, Power distribution Downstream of MCBs/ Fuses for both UPS Supplies & Charger supplies shall be checked and recorded once in every M&I or when the load is changed because of additions. Any discrepancy observed of loading w.r.t. rating of fuse/ MCB/ BPS to be corrected.

11.20 Fuses, if any, from Digital Outputs going to MCC for starting/ stopping of motors shall be replaced with high rating fuse / short

link (fuse rating / short link to be decided in coordination with P&U ensuring that over current protection to ensure INST relay contact safety is ensured) to eliminate chance of fuse failure leading to unreliability in pump auto start / stop.

11.21 Monitoring of Status of all power feed modules shall be ensured once in a week and record of the same to be maintained. If possible, the status can be wired to DCS DI for easier monitoring and alarm.

11.22 Redundant power feed modules shall be provided for each set of barriers.

11.23 For all new projects ensure that all power cables from UPS ACDB/DCDB to instrumentation power distribution panels (PDB) are direct run copper cables with no joints in between. (P&U Scope, for information to Instrument Group)

11.24 Each zonal instrument team shall have a detailed Power Supply distribution drawing for each UPS system, Charger, BPS , this should include at least the following details:

a. Incomer details.
b. Single line diagram Downstream of Power Source (Include cable size, MCB rating, Isolators, fuses with rating etc.).
c. Details of Spare feeder should also be available in the document.
d. Individual distribution upto all individual consumers/ groups.

11.25 Monitoring with trending of voltages of all types of Power Supply sources (110V AC-From UPS, 110V DC/ 24V DC- From Charger etc) shall be done in DCS by providing suitable voltage

transducers. The tags shall be provided with alarms based on the load regulation of the Power Source (UPS System/ Charger), this will provide early warning signal for UPS degradation.-P&U and Inst.

11.26 Earth leakage detectors to be provided for all the DC sources from Chargers. (P&U Scope, for information to Instrument Group)

11.27 Active Life of UPS battery bank to be ascertained by taking help from OEM and replacement may be considered depending on longevity. (P&U Scope, for information to Instrument Group)

11.28 The Power source to UPS is to be taken from separate sections. (P&U Scope, for information to Instrument Group)

11.29 Life cycle based replacement of RPS/BPS/Power supplies shall be carried out typically with a periodicity of 8 years / OEM recommendation, with appropriate plan of implementation during shutdown.

11.30 Where 24 V power is sourced from battery charger, it shall be ensured that the instrumentation system is capable of handling the rated ripple. Where any component is not rated for the ripple, RPS shall be used.

11.31 Power supply redundancy shall be ensured at all levels including any board mounted power supplies

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Chapter – 11

INSTRUMENTATION POWER DISTRIBUTION SYSTEM

11B Explanation to Recommendations

Reference	Explanation
11.7	In case of power looping in and looping out, the multiple equipments get affected for a single failure of power feeder. Moreover, the section-wise isolation for maintenance work becomes difficult.
11.8	This is required to reduce the possibility of DC ground fault, in the instrumentation system.
11.9,11.10, 11.11	Redundancy in BPS and AC feeder is essential for un-interrupted powering for the critical instrumentation systems even in case of failure of one BPS or a feeder. The redundant BPS should be capable in sharing the load in the case of failure of one BPS.
11.12	In the past we have experienced that one BPS failed without generating any alarm, and after some time, the process plant interruption took place when the other had failed.

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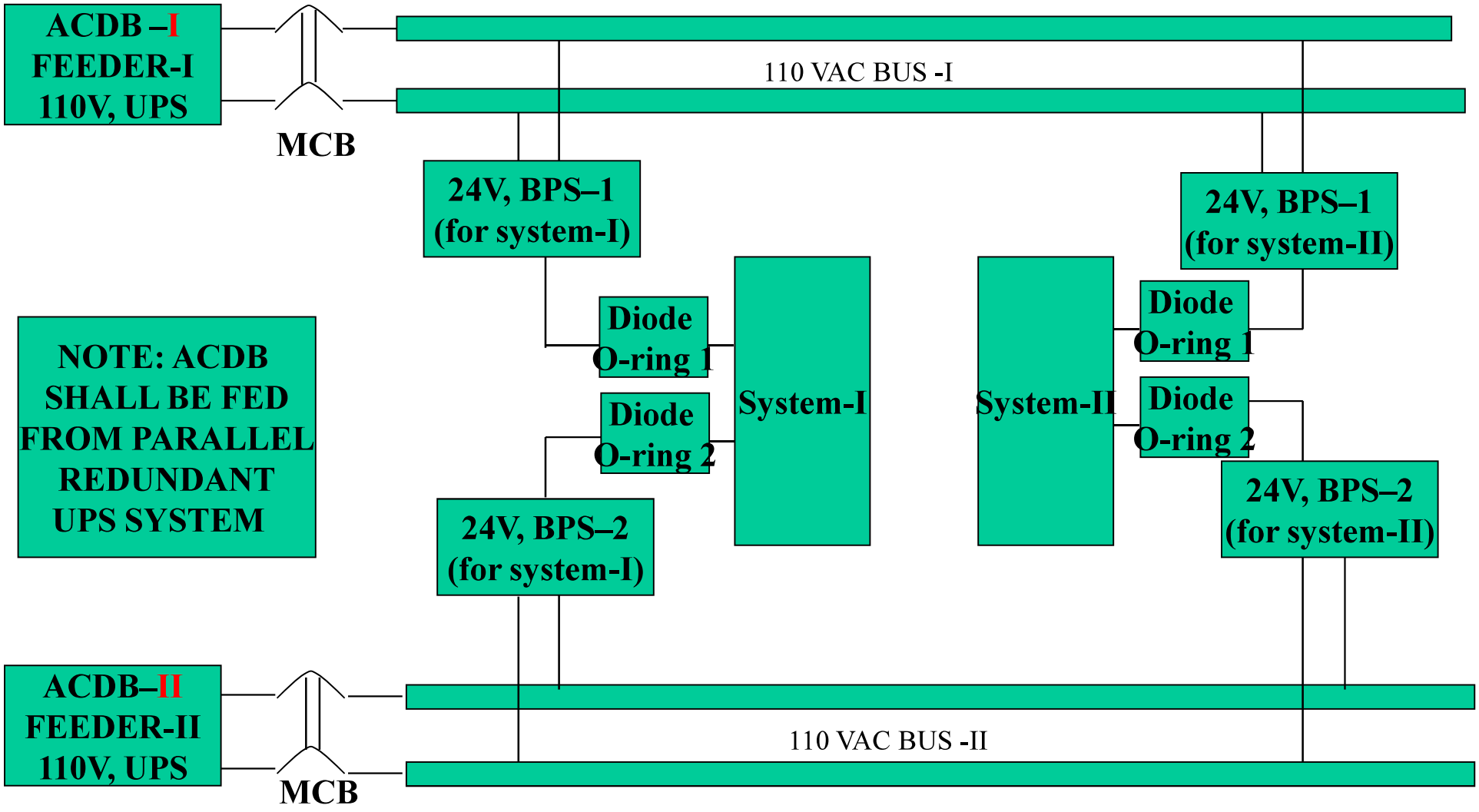
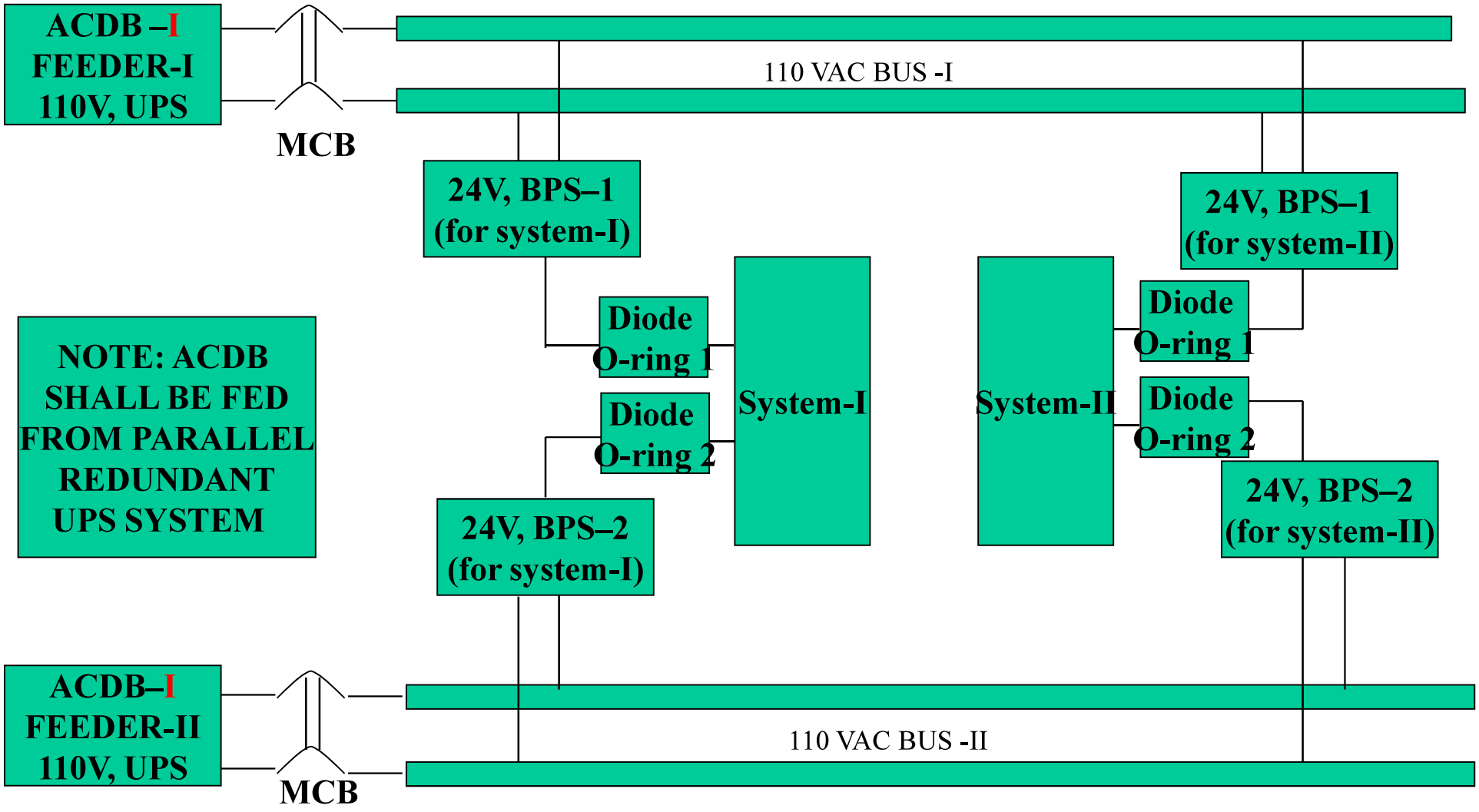
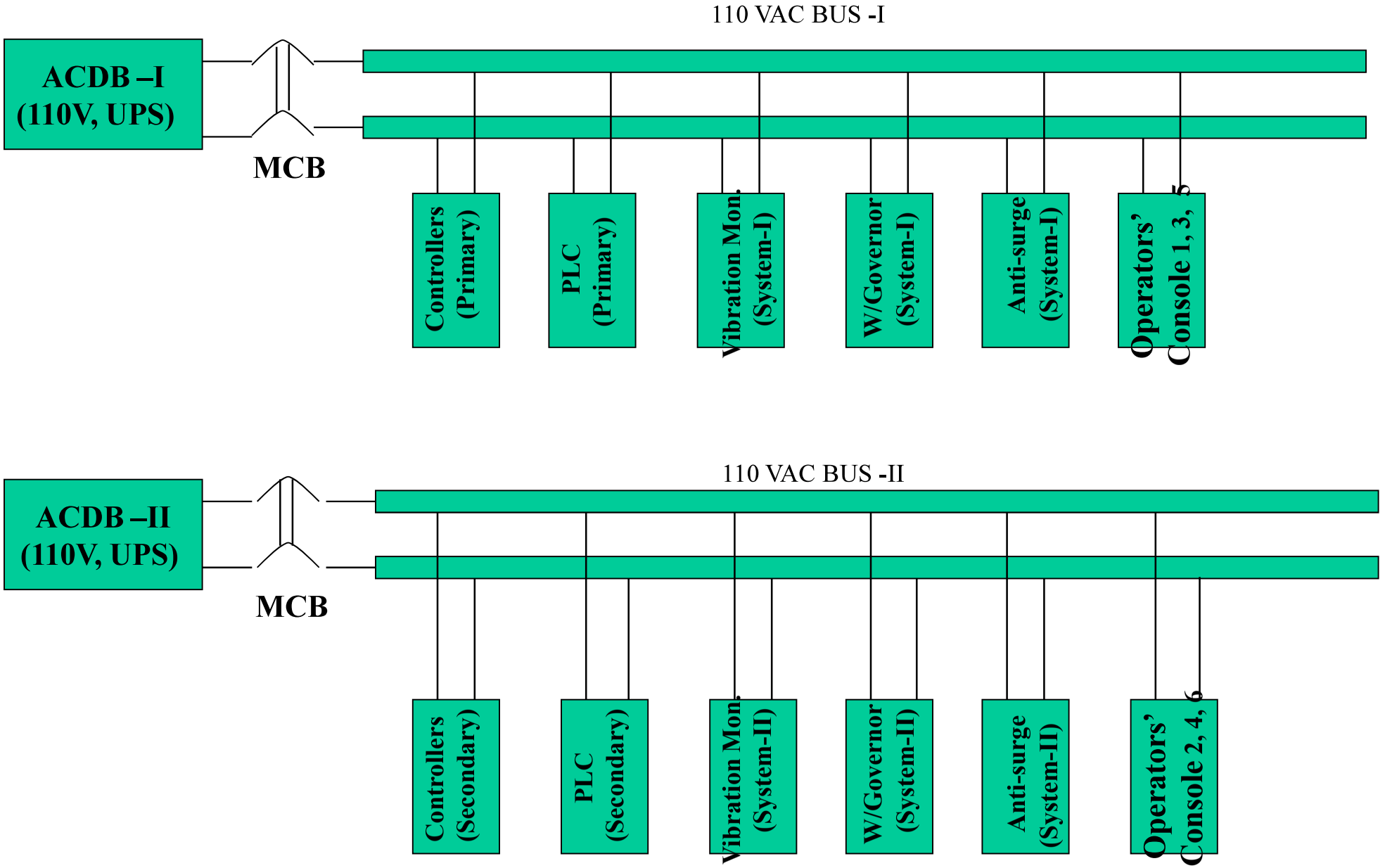


BPS (24VDC) distribution (typical) system (Scheme – 11C- 1A)



BPS (24VDC) distribution (typical) system (Scheme – 11C- 1B)



AC distribution (typical) system (Scheme – 11C-2)

Chapter – 12

FAULT-TOLERANT AND REDUNDANT EMERGENCY SHUT DOWN SYSTEM

12A RECOMMENDATIONS

It is very important to design an emergency shut down system (ESD) for reliability (availability) as well as safety. The safety aspect is important for process control but so is the economic impact of a spurious or nuisance trip of an ESD. Reliability or availability does not mean that a system remains on-line in an unsafe mode, but it means that a system can remain on-line, tolerating one or more failures and still be capable of producing the appropriate outputs for safe shut down until the failures are detected and repaired. A well-designed instrumentation system for critical control applications shall have a balance of safety and reliability by considering appropriate voting philosophy, adequate failure analysis and self-diagnostic features in the input sensors, logic controllers, and the final control elements. The following are the recommendations for design considerations. Detailed explanation to these recommendations marked as (🔈) has been enclosed at Section 12B of this chapter.

12.1 Redundancy philosophy in ESD system should be implemented at all levels for the critical loops (process inputs, logic solvers (PLC) and out puts) to achieve both, safety and reliability. 🔈

12.2 For emergency shut down system, all the input signals for the existing critical loops should be analog (taken from transmitters rather than from switches), except for those signals where the OEM does not recommend it. However, the same shall be followed in totality for the new projects. 🔈

12.3 The emergency shut down system shall be implemented in a dedicated PLC and the regulatory control / monitoring in the controller sub-system of DCS. 🔈

12.4 The transfer of data between the logic solver and the controller sub-systems through soft link (that is, transfer of data between PLC and DCS controller and vis-à-vis) should only be used for monitoring purpose and not for control and trip, unless

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recommended by licensors / statutory bodies like TUV etc. Logic reset actions may be accepted through Modbus, with feedback

12.5 The “Common Mode Failures” shall be eliminated or minimized. (The common mode failure is the failure of multiple equipments in a system, because of failure of single equipment).

12.6 An effective alarm system with sequence of event recording shall be configured considering the process requirements and also human factor.

12.7 Input signal voting shall be configured for all the tripping interlocks without degradation of safety.

12.8 All the inputs and outputs related to a trip circuit shall be configured in the SOE with comprehensive description.

12.9 Emergency shutdown push buttons for all the electrical drives shall be connected directly to the MCC and not through PLC. For such PBs mounted on H/W console which are direcly wired to MCC, monitoring of alternate contact shall be considered for logging. For critical motor driven equipment, where emergency shutdown is configured through PLC, there shall be an additional field PB which shall be directly wired to MCC.

12.10 For existing emergency shutdown systems, the following signals should be taken through transmitters only (except for those signals where the OEM does not recommend):

a) Pressure switch with setting less than 0.5 Kg/cm2g

b) Temperature switches.

c) Flow switches.

12.11 All the input signals for new projects shall be taken from transmitters, except for those signals where the OEM / Licensor do not recommend.

12.12 The individual tags of a redundant group (Like 2 out of 3 group) shall be configured in separate cards.

12.13 In case Remote I/Os are used in Control/ Interlock application (or if the system is such that the failure of the link will lead to tripping of plant), the communication link between the remote I/O with the main DCS/PLC/Processor should be redundant and no common component should be used (Including cable, Power supplies for RS485/232 or OFC converters etc.).

12.14 Monitoring of healthiness of both communication links of a system shall be done with high priority alarm assigned to the same.

12.15 Time Synchronization shall be provided for all the systems/ subsystems (Like DCS, PLC, GT Control Systems) in Power plant. In case of time synchronization of multiple systems, for monitoring of healthiness of time synchronization – One pushbutton shall be provided, its contacts multiplied based on the number of different independent systems available in Power plant, and one contact shall be wired as DI to each system. This shall be checked by actuating the pushbutton and checking the time stamping of individual system SOEs. Time synchronization configuration & maintenace practice shall ensure that there are no process actions / system failures on account of loss of time synchronization.

12.16 For Process plants, Time synchronization is to be done between DCS and all PLCs of the particular plant.

12.17 Sequence of Event recording shall be First in First Out type with availability of SOE data preferably in PLC processor for maximum number of SOE points configurable in the installed PLC system (Preferably 10000 process alarms & 5000 Diagnostic alarms). This will ensure that even if the communication with SOE PC is not healthy in any particular time, the latest SOE data can be retrieved by establishing communication with PLC.

12.18 All common system status/ faults of each and every PLC/ DCS/ Package PLC/ Compressor local PLCs/ Machine Monitoring Systems/ Governors etc shall be monitored on daily basis. The same may be taken to DCS and configured in a DCS graphic page for ease of monitoring. For new projects Graphics is to be necessarily generated.

12.19 The tags of a two out of three group are to be monitored for discrepancy to avoid operation of the system in degraded mode.

So that if any tag in a 2 out of 3 group is not matching with other two tags, the same is detected in time. This is to be monitored on daily basis. Graphics in DCS may be prepared for faster and easier monitoring. For new projects Graphics is to be necessarily generated.

12.20 Sufficient spares are to be stocked, so that no DCS/PLC system runs in degraded mode.

12.21 Up-gradation of DCS / PLC system may be considered as per the active life cycle of the product/ version by the OEM.

12.22 The common system interlocks of Power Plant shall be segregated in different PLCs, so that tripping/ problem in one PLC does not lead to tripping of entire power plant.

12.23 The Control Valve/ other instrumentation in common fuel to Power plant (e.g. NG/ IFO Supply to GTs/Boilers) is to be reviewed in coordination with process/ Operations department and necessary steps to be taken to avoid tripping of entire power plant on account of any failure of the Control Valve/ other instrumentation.

12.24 For very critical drives (Tripping of which can lead to plant shutdown), if run feedback is used in interlock for tripping, multiple run feedbacks to be provided or separate signal derived from process condition to be used in addition to run feedback to avoid spurious tripping. It shall be ensured that there is no degradation of safety intent while carrying out any modification. Such modifications shall be implemented after following Hazop / failure mode effect analysis by multi-disciplinary team including process and following change management.

12.25 For Very critical Compressor, tripping of which leads to plant shutdown (Like MAB, RGC of Hydrocracker etc), Autostart of auxiliary drives (Like Lube Oil Pump) should be taken from at least two independent signals so that auto start of standby pump is ensured. Such modifications shall be implemented after following Hazop / failure mode effect analysis (eg whether 2 lube oil pumps can run in parallel on full load) by multi-disciplinary team including process and following change management.

12.26 Multiple ESD systems with data transfer over network for a single application (eg utility boiler) to be avoided (for new projects)

12.27 Fuse coordination to be ensured at field termination board (eg higher rated / slow blow fuse at board power supply level, lower rated fuse at channel level).

12.28 Toggling alarms on ESD SOE to be resolved through suitable Hazop process and approval (may call for actions like set point change). SOE alarms shall be checked once in a week for toggling alarms.

12.29 For all parameters which initiate trip / auto start action, the corresponding tag on DCS shall have suitably configured alarm values. Eg for lube oil header pressure low trip at 0.8 kg/cm2g and normal operating value of 1.5 kg/cm2g, low alarm value can be 1.2 kg/cm2g and low low can be 0.8 kg/cm2g. Pre alarm shall be configured as a pop up.

12.30 MOS/POS override active shall be annunciated on aux console.

12.31 Trip / auto start parameters shall be on fast scan historical trend on DCS and where possible on RTDB – all tags connected through modbus to DCS and the corresponding direct tag to DCS for the same service.

12.32 Any interlock modification shall be carried after following Hazop process with following change management.

12.33 Any interlock modification shall be verified from input field element to output field element at the earliest opportunity and record maintained.

12.34 The following updated, controlled documents shall be maintained:-

a) Loop wiring diagram

b) Logic diagram / cause and effect diagram including packages

c) Alarm / trip list including packages

Chapter – 12

FAULT-TOLERANT AND REDUNDANT (ESD) SYSTEM

12B Explanation to Recommendations

Reference	Explanation
12.1	All the input parameters, which are considered in the tripping logics, or used for controlling of the critical process parameters, shall be implemented with input voting logic of (2-O-O-3). All these sets of critical inputs shall be isolated from each other as far as possible (like: separate power supplies, separate I/O cards, chassis, etc.) Voting system: - Depending on the criticality of process various levels of redundancy are introduced. There are single systems and voting system available in various parts of our refineries. The single system (no voting) is unsafe and unreliable. The popularly used voting systems are dual redundant and triple redundant. The dual redundant systems may be configures in 1-O-O-2 or in 2-O-O-2. The 1-O-O-2 is a safe system but the spurious trip rate is higher than the single systems. On the other hand the 2-O-O-2 systems are reliable, and having low spurious tripping rate, but not safe (dangerous). However, the triple module redundant (TMR) systems, having 2-O-O-3 voting configuration, provide an acceptable balance of safety and reliability. The failure alarm of any of the TMR element shall be monitored and action to be taken on priority if any element fails.
12.2	The process input signals to the logic solver (PLC) shall be taken from the transmitter rather than from switches, because of higher reliability, and accuracy. This will also improve the monitoring of the parameters through out the range of measurements.
12.3	The regulatory control and logic control shall be configured separately in the controller sub-systems and the logic solver (PLC) respectively. Although it is possible to implement logic interlocks in DCS controllers and also regulatory control in PLC, but this shall never be done.
12.4	The data from the logic solver (PLC) may be transferred to DCS for better monitoring but not for control. Similarly, the data from DCS shall not be used in PLC for any interlock unless it is unavoidable. Otherwise the scan time and the reliability of the safety loops get

	affected.
12.5	During selection, design and engineering of an ESD system, the “common mode failure” shall be avoided. However, In the existing system architectures, this aspect may be identified and removed.
12.6	This aspect is elaborated in chapter-13 (Alarm management system, Process monitoring & control).

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Chapter – 13

PROCESS MONITORING AND ALARM MANAGEMENT SYSTEM

13A RECOMMENDATIONS

The latest DCS of our refineries have powerful features of process monitoring and alarm management with respect to the safety and reliability of a process plant. All such features of the DCS must be optimally exploited to the best of their capability for an un-interrupted and safe operation of process plants. Following are the recommendations for process monitoring and alarm management system. Detailed explanation to these recommendations marked as (🔈) has been enclosed at Section 13B of this chapter.

13.1 The number of process alarms shall be optimized. 🔈

13.2 Process alarms shall be judiciously prioritized (emergency / high / low etc.) on the basis their criticality.

13.3 Health of critical instrumentation systems connected which are not being monitored / controlled by HMI based on DCS/PLC shall be connected to nearest available system for monitoring.

13.4 The description of the alarms shall be configured in simple language, especially for the alarms which are non-related to process plants like “BPS failure”, “UPS trouble” etc.

13.5 Process monitoring and control

To strengthen monitoring of critical equipments, it is desirable to configure the following critical status / parameters in the existing graphics or in the form of additional graphics in the DCS:

- Prevailing status (Auto / Manual) of the critical controllers.
- Prevailing status (Auto / Manual) of the critical drives.
- FOCUS (high light) on non-selection of “Desired” mode for critical drives and controllers.

- RUN status of the critical drives.
- "Manual Bypass" selection.

13.6 Process control

The operators change the process set points and the controller outputs through "keyboard" of the operator's console. It has been experienced that, the improper punching of digits through the "Keyboard" lead to undesirable consequence and, and even plant interruptions. To avoid such incidents, ***all critical loops should be configured for "Output tolerance alarm" and "Set Point Tolerance alarm***". This feature will generate an alarm when an operator changes "Set point" or "out put" beyond the pre-defined tolerance percentage.

13.7 Structured review of prevailing process alarm may be carried out on regular basis. (Prod. Deptt Scope, for information to Instrument Group)

INTERFACE:

13.8 Interlock graphics shall be configured on DCS / PLC HMI to monitor status of logic flow. On very critical equipment, loop back of DO relay (output command) to input can be considered for monitoring / logging.

13.9 Alarm management system to be provided for alarm monitoring and frequency analysis in all process plants and Power plant. Review of high frequency alarms may be done based on the frequency analysis in active coordination with Process/ Production to judiciously reduce number of alarms. AIMS shall give daily report of the following types:-

- Top 10 alarms with frequency
- Chattering alarms
- Standing alarms
- PSPI excursion

Chapter – 13

Alarm management system, Process monitoring & control:

13-B Explanation to Recommendations:

Reference	Explanation
13.01	Presently the critical process plants are having a large number of alarms configured and it is practically impossible for an operator to handle such a large number of alarms judiciously. As a result, the operator may “Acknowledge” or “Silence” alarms without any analysis, and leads to interruptions. The operation group of the respective plants shall review the number and priority of the existing process alarms keeping in mind that too many process alarms diminish the importance of such a powerful process monitoring tools.

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Chapter – 14

CONTROL ROOM AMBIENCE

14 A RECOMMENDATIONS

The control room environment plays a very important role in the reliability of the instrumentation hardware placed in the room. A well designed air-conditioning system and an effective rodent control system is essential for ensuring control room ambience suitable for instrumentation system. However, the control room discipline must be followed by keeping the eatables, and shoes, outside, and keeping the control room doors always closed etc. The following practices are recommended for achieving higher reliability of the total system.

14.1 The air conditioning system of a control room shall always be in operating conditions (specially in winter) to maintain a desirable control room temperature of 22~24 Deg C. ◄ (P&U Scope, for information to Instrument Group)

14.2 The filters for the fresh-make-up air and recirculation of the air conditioning system should be cleaned / replaced at a specified interval depending upon the environmental condition to prevent dust ingress in the control room. (P&U Scope, for information to Instrument Group)

14.3 Air curtain is to be installed at the first entry to the control room. All entries to control/ rack rooms shall be with double doors.

14.4 Control room environment temperature should be configured in the DCS for alarm and monitoring of the trends of this parameter. ◄

14.5 Continuous corrosion monitoring systems shall be provided in each control room. It is to be cross checked with external agency once in every year. Monthly report of control room environment shall be generated based on online instrument

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14.6 Normally the control room ambience shall be of G1 category. If the result of the copper-silver coupon test / online monitor data of a control room confirms that the control room is falling in G2 category or beyond, then alternative measures (inclusive of installation of recirculation type chemical filter) inside the control rooms may be considered.

14.7 For control systems installed in corrosive environments (SRU, ARU etc), OEM hardware shall have the necessary protective coating (conformal coating) suitable for G3 category environment.Protective coating may be considered for other unit system also.

14.8 All the cooling fans in the cabinets / panels / consoles etc. shall be in operation to avoid failure of cards due to high temperature. “Fan failure” alarm/ panel temperature indication/ alarms on DCS shall be ensured and must be attended on priority. The same has to be provided on all cabinets with active components

14.9 Rodent Control System

Proven rodent control treatment system should be in practice throughout the year. The same also has to be provided below false flooring.

14.10 Sealing

All the left over cable entries of the control room must be sealed and the spare cable gland holes of the control room cabinets / Panels must be plugged properly. This is required to prevent the entry of the rodents.

14.11 Water Logging / Ingression

Water logging under the false floor of the control room and roof leakage must be attended on priority, because, the water droplets or the water vapors damages the DCS / PLC hardware to a large extent. Water ingress through cable entry point to be sealed.

14.12 Shoe Rack

Shoe rack to be kept out side each control room with provision of “Chappals” for the use of employee and the visitors.

14.13 Air Conditioner ducts

Separate dampers for the rack room and console room shall be considered for the new projects and the doors of the rack room shall be kept closed. (P&U Scope, for information to Instrument Group)

14.14 False flooring:

Rack rooms shall have false flooring to facilitating cable entry to the panels, but in the console rooms very few cables are entered. Hence, for the new project it is recommended to have cable trenches in the console rooms to avoid poor flooring quality. For the new projects need not have separate air conditioner ducts for the rack room and console.

14.15 Eatable inside the control room:

No eatables should be allowed in side a DCS control room. Lunch-room shall be having a separate AC.

14.16 Rack rooms shall have false flooring to facilitating cable entry to the panels, but in the console rooms very few cables are entered. Hence, for the new project it is recommended to have cable trenches in the console rooms to avoid poor flooring quality.

14.17 H2S detectors are to be provided in make up inlet of Control Rooms in the vicinity of Sulphur Recovery Units/ ARU/ SWS units or any other unit where such leakages are expected.

14.18 Daily monitoring and maintenance of all Air Conditioners (Control Rooms, Satellite Rack Rooms, Analyser shelters etc) shall be ensured by A/C Maintenance group. (P&U Scope, for information to Instrument Group)

14.19 Redundant AC/ HVAC systems may be considered for all analyzer shelters in upcoming projects to ensure continuous availability of analysers.

14.20 Cleaning of filters of all cabinets is to be ensured by time based checking, at least once every year.

14.21 For heat dissipation of panels, Forced draft systems to be avoided, instead conventional induced draft type scheme shall be used.

14.22 Rectification of False flooring in control rooms and rack rooms for personnel safety, blocking of gaps, dust ingress, rodent entry and loading of AC systems etc to be taken up at the earliest.

14.23 Dusting/ sweeping inside the control/ rack room to be avoided. Instead mopping/ vacuum cleaning to be ensured twice in a week.

14.24 Fresh air make up shall be if possible from clean area (away from plant side) (P&U Scope, for information to Instrument Group)

14.25 Fresh air make up shall be through chemical filter, media replacement shall be carried out prior to performance degradation. (P&U Scope, for information to Instrument Group)

14.26 Control room shall be kept pressurized. (P&U Scope, for information to Instrument Group)

Chapter – 14

CONTROL ROOM AMBIENCE

14 B Explanation to Recommendations

Reference	Explanation
14.1	In the summer of the control temperature is 24 deg C with the Air conditioning system in operation is much better than in winter the temperature is 22 deg C without the Air conditioning system in operation. Because in the case of winter, the control room temperature is being maintained by the "heat" generated in the instrumentation system. Hence, Air conditioning system of the control room shall be kept in operation throughout the year.
14.4	The temperature sensor should be RTD and shall be installed in any of the system-cabinets. From the alarm and trend of this parameter, the performance of the air conditioning system can be accessed.

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Chapter – 15

INSTRUMENTATION EARTHING SYSTEM

15A *RECOMMENDATIONS*

The earthing system in the instrument control and communication plays an important role for reliable operation of DCS / PLC systems. The inadequacy in this system may generate spurious tripping signals for the plants without generating comprehensive alarms. Major failures of DCS / PLC hardware have been experienced due to non-availability of an effective earthing system. The following actions are desirable for the reliability of the instrumentation earthing system. Detailed explanation to these recommendations marked as (◄) has been enclosed at Section 15B of this chapter

15.1 A single earth pit shall not be used for any system. Instead, an Earth-grid (earth-pit network) shall be made of minimum two numbers of earth pits connected in parallel. (Number of earth pits required for an earth-grid will depend on the permissible earth-resistance specified by the respective system manufacturer). Suitable distance shall be maintained between various earth pits (minimum 3 meters) as per guidelines of API RP550. ◄

15.2 Separate earth-pit networks is desirable for various instrumentation sub-systems like DCS / PLC earth, cable-screen earth, chassis earth, power earth etc. so that the problem in one system is not affecting the other system. ◄

15.3 Unit wise dedicated of earth-pit network is desirable for the Mark –IV / V / VI / VI E / Hitachi HIACS / VMS systems / Air compressor control systems etc. for higher reliability and ease of shut down maintenance of these earth-pit networks. (Refer Schematic- 15C.1, 15C.2 & 15C.3)◄

15.4 Earth-pit head must be covered properly, and clearly visible identification tags are in place as indicated in the system documents. ◄

15.5 Periodic checks of each earth pit shall be carried out and maintenance record must be kept.

15.6 The earthing cables from the earth-pit to the respective systems shall be insulated and use of bare cable / strips shall be avoided. Such cable shall be laid away from power cables etc.

15.7 OEM guideline on earthing shall be followed for each system.

15.8 Interconnection / wiring drawings showing looping of earthing cables, connections to intermediate bus-bars (including location of the bus-bars) and connections to the final earth pits shall be available.

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Chapter – 15

INSTRUMENTATION EARTH-PIT SYSTEM

15-B EXPLANATION TO RECOMMENDATIONS

Reference	Explanation
15.1	An adequate earth-pit network will improve the reliability of the system and also increase the ease of maintenance.
15.2	Separate earth-pit network is required for various systems, as the severity of consequence, and the capacity of handling fault currents are different for different systems.
15.3	The fault of the common earth-pit network will cause simultaneous interruptions of all the units connected to it.
15.4	In the past, tripping of multiple units and also series of hardware failure is observed of because of mis-utilization of system earth pits for welding purpose.

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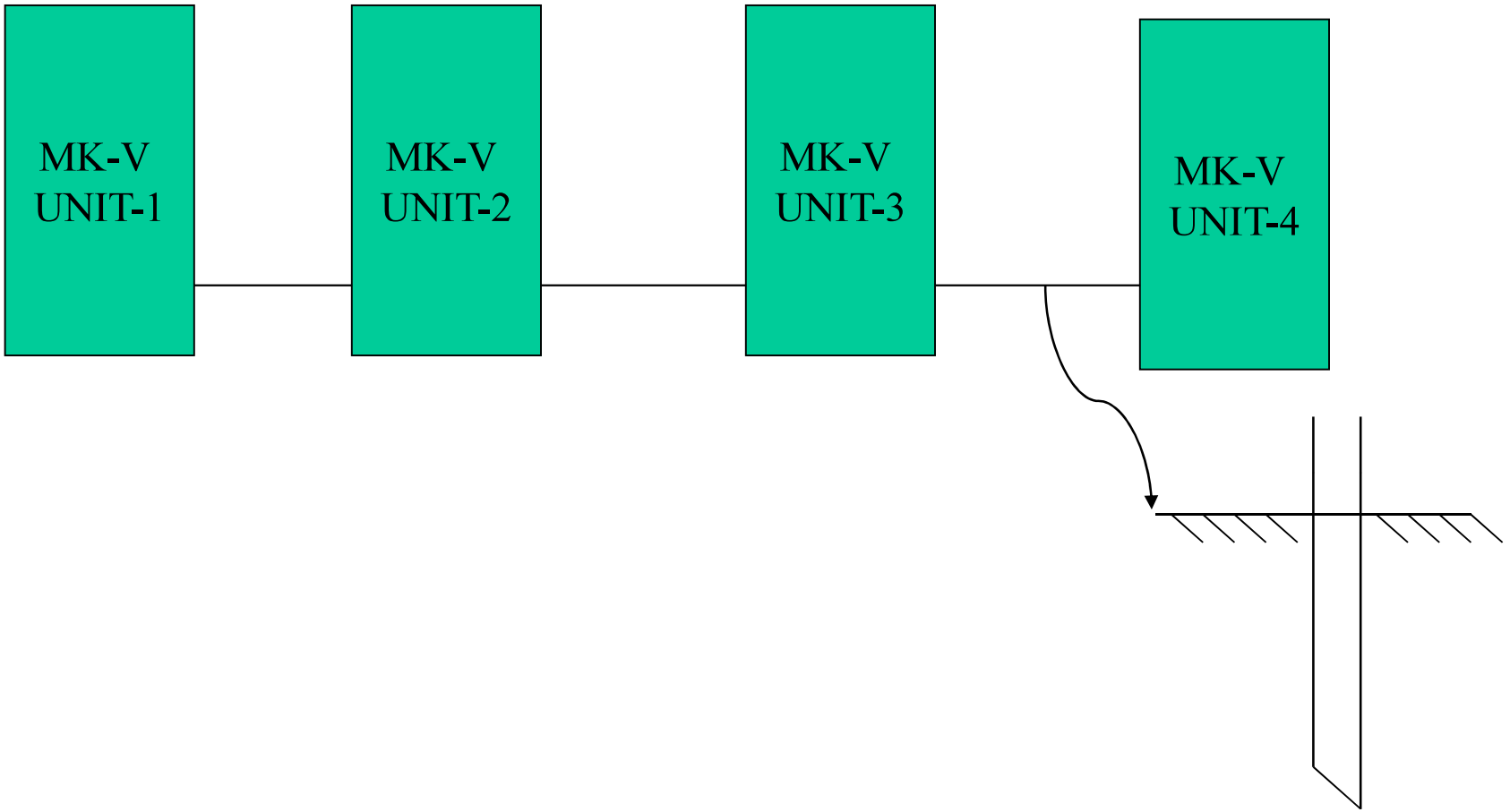
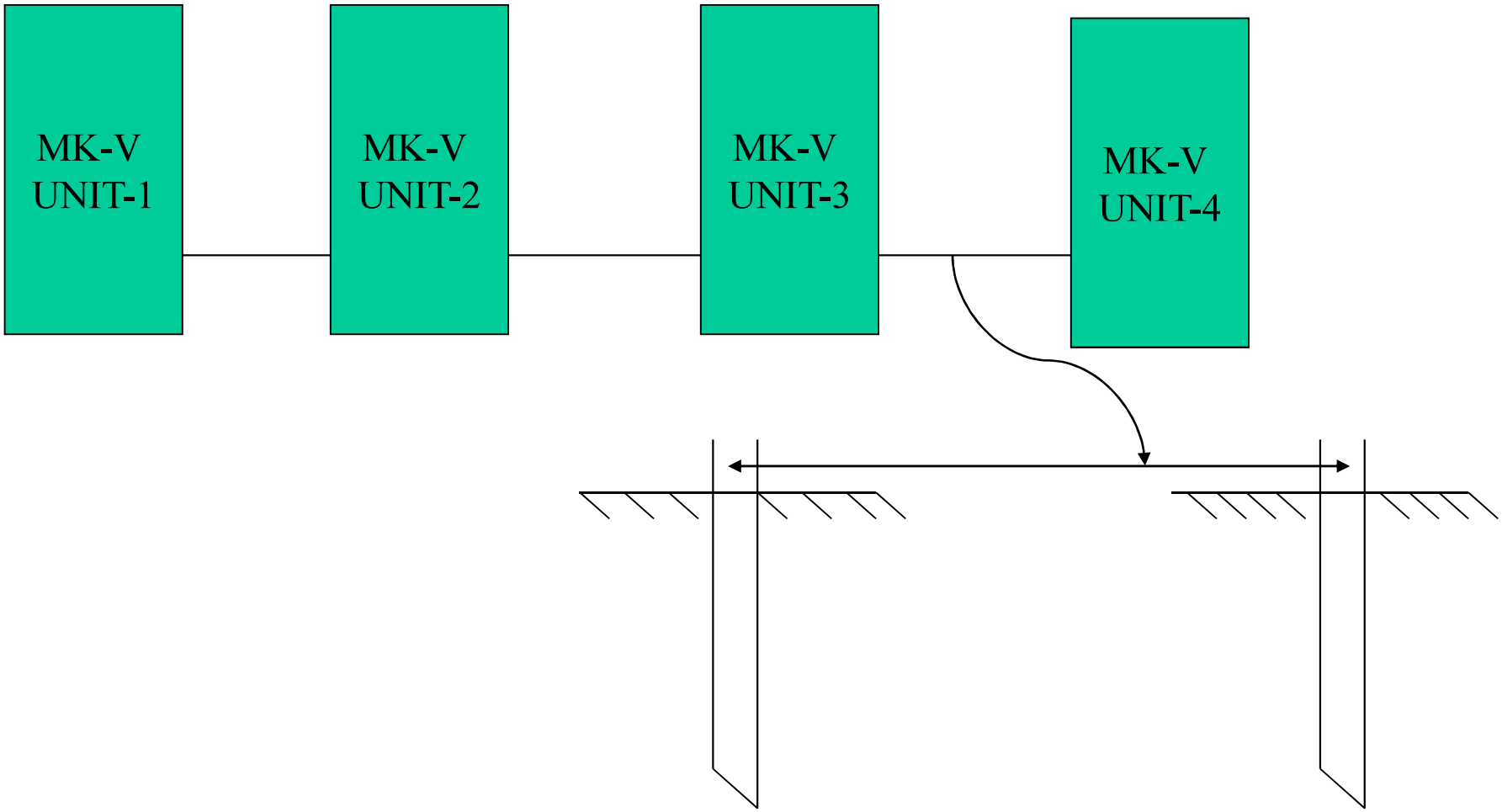


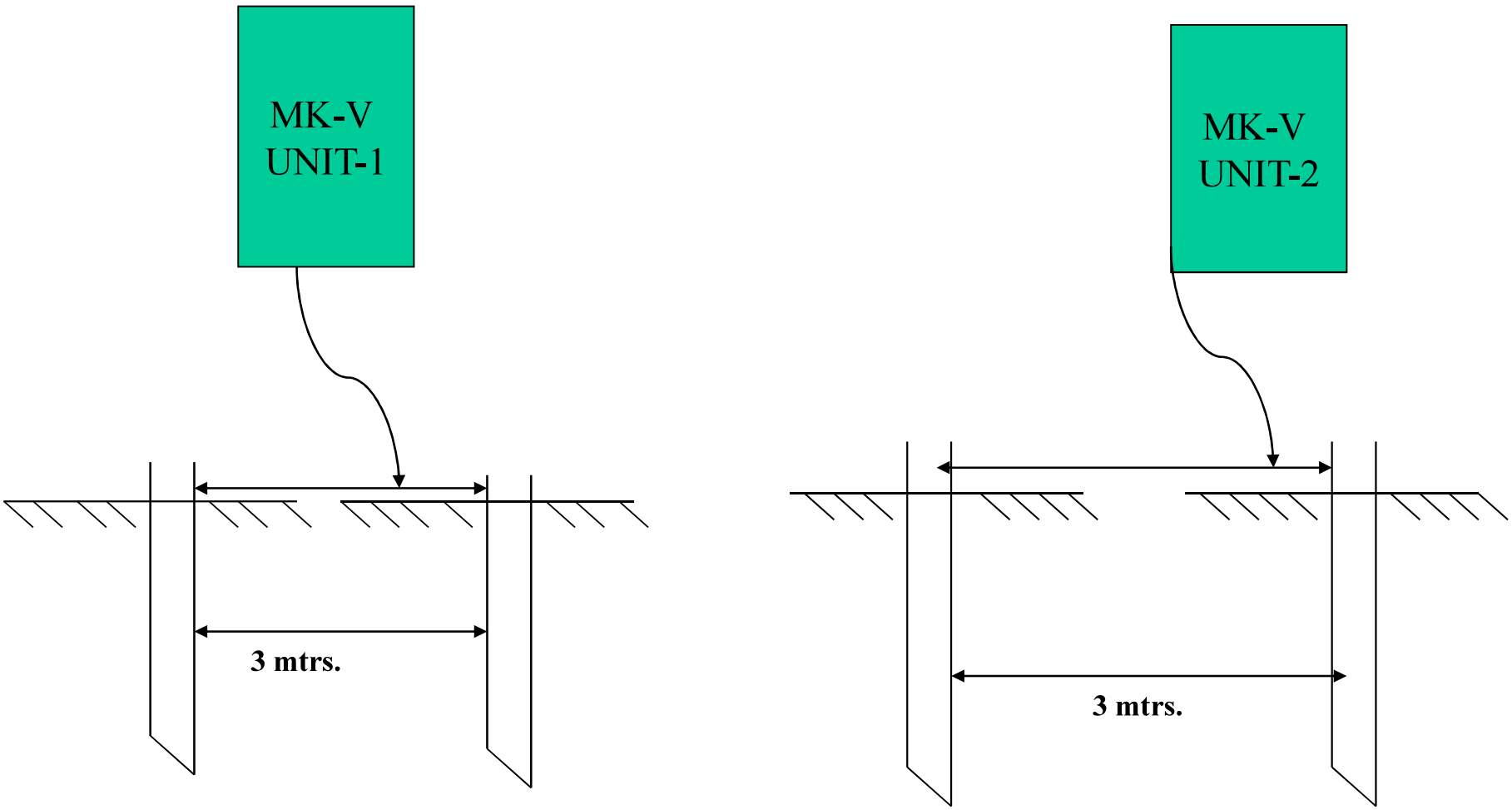
MULTIPLE UNITS WITH SINGLE EARTH-PIT *(NOT RECOMMENDED)*

Schematic- 15C- 1



MULTIPLE UNITS CONNECTED WITH EARTHING NETWORK *(NOT RECOMMENDED)*

Schematic- 15C- 2



PROPOSED EARTH-PIT NETWORK *(RECOMMENDED)*

Schematic- 15C- 3

Chapter – 16

GAS TURBINE

16A RECOMMENDATIONS

In the present operating scenario, the gas turbine /HRSG are of vital importance in providing utilities (Steam & power) to the refinery operation. Therefore, it is very important to take special care on the maintenance and operation of the instrumentation system for these equipments. The following recommendations may be considered for implementation to improve the reliability of the control and monitoring of gas turbine / HRSG system. Detailed explanation to these recommendations marked as (🔈) has been enclosed at Section 16B of this chapter.

16.1 2-O-O-3 voting logic shall be implemented for the following parameters: 🔈

- ***Gas turbine low liquid fuel pressure (63-FL-1) trip,***
- ***Warren pump lube oil pressure low temp. high. This also results in fuel change over to gas (if available) or trip.***

16.2 LUBE OIL HEATER:

GT Lube oil "heater-on". At very low Lube Oil temperature (< 10 Deg. C). mal-operation of this single temperature switch will increase Lube oil temperature, which may lead to tripping of the GT on High Lube oil temperature. The alternate solutions are:

1) The lube oil heater cut-off may be implemented with generator breaker "ON".

2) Low lube oil temperature alarm may be implemented in place of heater "ON" because this logic is needed for very cold countries

16.3 Separate isolation valves shall be installed for all the three pressure transmitters installed for measuring the GT-compressor discharge pressure and all the three pressure switches for measuring the GT-Exhaust pressure.

16.4 **The low drain point (LDP) valve on the inlet line of the booster air compressor shall be kept open during running of the gas turbines to avoid bearing damage of the booster air compressor due to moisture accumulation.**

16.5 The <I>-station (GT console) networking is recommended for implementation in multi-GT operation to facilitate in operating a GT when its respective <I>-Station (console) of that machine has failed (not available). (Refer Schematic-16C.1 & 16C.2).

16.6 Dedicated PLC & DCS controller sub-system preferably be considered for each GT BOP, to avoid tripping of multiple machines due to single PLC failure.

16.7 Provision of duplex HP filter should be made in the GT operating with liquid fuel, to avoid stoppage of the machine for filter replacement. (Mechanical Scope, for information to Instrument Group)

16.8 The OFF-SKID pressure control valve on liquid fuel service, which maintains the upstream pressure of the GT SKID, should be installed on the return line for better control and to avoid stagnation of oil in the line for a long period. (This modification is implemented in Gujarat Refinery). (Refer Schematic- 16C- 3)

16.9 Pressure tapping of this OFF-SKID control valve shall be taken from the downstream of the LP duplex filters. (Refer Schematic- 16C- 3).

16.10 Provision of power from different sources / sub-station to be made for the following devices: (P&U Scope, for information to Instrument Group)

- GT jacket cooling fans (88- TK 1 and 2). {For frame-6 machines}

- Naphtha pumps.
- HSD pumps.

16.11 In certain installation dedicated DM water-cooling system (with pumps) is used for the atomizing air cooler. A separate service water line shall be laid up to the atomizing air cooler, with draining facility, to avoid interruption of GT in case of failure of the dedicated DM water pumps. (P&U Scope, for information to Instrument Group)

16.12 **The ON-SKID instruments like naphtha purging SOV, Flame scanner JB etc., are located in the turbine compartment. Failure of instrumentation cables insulation has tripped the machine in the past. To avoid such tripping these cables need to be relocated at safe zone.**

16.13 For multiple GT installation, separate earth-pit-network is recommended for individual GT. Effort should also be made for physical separation of the Mark –IV / Mark – V panels to maintain the integrity of the separate earth-pit networks. Thus the problem of one unit shall not affect in other units.

16.14 Following audio-visual alarms are desirable in the DCS to enhance safety and monitoring of the running GT:

i) Failure of any Fire Detectors,

ii) Fire alarm of Gas Turbine,

iii) Vibration alarm of Bently System for Load Gear Box of GT.

iv) Communication-failure of <I>-Station (Console). This alarm is essentially required where the Mark-V panel is installed in the rack room (un-manned location) and away from the control room. In case <I>-Station communication fails, no change in the I-station will be visible, and the <I>-Station will show the last graphics display with the last values of all the parameters. This may create an unsafe condition

16.15 Care needs to be taken during re-filling operation of Hi-tech additive in the tank while GT is running on naphtha. It is experienced that the “LOW LEVEL SWITCH” of the Hi-tech tank gets actuated during manual re-filling operation and initiates a fuel change over. A longneck funnel shall be located, away from the level switch, in the vessel for periodic re-filling of the Hi-tech additive.

16.16 **Heat shield shall be provided to protect the exhaust thermocouple junction box to protect the cables and the sensors (thermocouples) in case of leakage from exhaust plenum bellow.**

16.17 Necessary modification in the logic is desirable to avoid tripping of Gas Turbine on low lube oil pressure protection of warren pump, when GT is running on Gas fuel. An alarm should be provided at low lube oil pressure of the warren pump.

16.18 Facility may be provided to start jacket-cooling fans (88-TK1 & 2) of GT from their respective control room manually.

16.19 **A temperature indication and high temperature alarm for monitoring the atomizing air temperature after the cooler to be provided in the control room.** (to be discussed with P&U)

16.20 **A temperature indication and high temperature alarm for monitoring the GT leg cooling system to be provided in the control room.** (to be discussed with P&U)

16.21 Following additional monitoring facilities with alarm may be provided in the control room (DCS / Mark console):

- Differential pressure across the Inlet Air filter,
- Liquid fuel DP across the HP filter,
- Bypass stack temperature (additional point).
- Atomizing air temperature after the air cooler.
- Leg-cooler temperature (for Frame-VI machines)

- Turbine compartment temperature indication in DCS, especially near flame scanners. Excessive temperatures causes failure of flame scanners, which may lead to tripping of gas turbines

16.22 Inspection and replacement (if needed) of the fire detectors/cables during HGPI. Replacement of all Fire detectors, High temp cables and Terminal blocks for load gear compartment area to be carried out during HGPI. This area is not approachable when GT is at running condition. Spurious alarm/trip observed in the past due to cable damage, Terminal Block damage due to corrosion.

16.23 UPS supply shall be provided for GT damper control system.

16.24 Swage lock / Parker make fittings may be used for all tubing connections of Gas Turbine.

16.25 Technical Audit of Instrumentation and control system of Gas turbines to be carried out by lining up OEM. The same is to be done as a one time activity to ensure correctness of installed & running application.

16.26 The Moog valves are provided with three independent coils. Healthiness of each coil is to be checked during shutdowns. If any coil is found damaged, the servo is to be replaced.

16.27 In some of the newer Gas Turbines, the bleed valve is located inside the turbine compartment. This leads to failure of soft parts of the valve & limit/proximity switches used because of high temperature. For all such GTs, the piping has to be modified and the bleed valve to be located outside the turbine compartment.

16.28 Separate level indication is to be provided for GT Main Oil Tank level.

16.29 Passing of 3 way valve is to be checked on regular intervals, at least once in a year during scheduled Maint.

16.30 The Self actuated valves shall be checked in every Major Inspection. The diaphragm compartment has to be opened and inspected. Spares are to be sourced from OEM only.

16.31 Last Chance filter has to be replaced every year during scheduled maintenance.

16.32 Flame scanners to be properly insulated to prevent moisture formation, which may result in flame scanner reading fluctuations.

16.33 CPD pressure transmitter impulse line to be made of 12 mm, instead of 6 mm to prevent chockage.

16.34 Failure of Exhaust thermocouple may lead to unplanned shutdown. Procurement Exhaust thermocouple from reputed vendors/ OEM only.

16.35 2-o-o-3 Pressure switches to be installed for NG pressure OK service.

16.36 LVDT difference alarm to be configured to ensure healthiness of both LVDTs. Display of both LVDTs values (GCV, SRV, IGV) at HMI for effective monitoring.

16.37 Excessive moisture content is observed in compressed air. Use of Instrument air in place of compressed air for actuation of valves at combustion chamber VA-18, VA-19 through SOV 20-AA, 20-PL. This prevents jamming of plunger assembly of SOV's 20AA, 20PL due to excessive moisture. (Implemented in GT1, 2 at JR.)

Chapter – 16

GAS TURBINE

16-B Explanation to Recommendations:

Reference	Explanation
16.02	This will increase the reliability and ease of on-line maintenance of gas turbines.
16.03	For continuous draining of the condensate of the main compressor is essential. It is experienced that the accumulation of the condensate spoils the atomizing booster compressor.
16.09	The availability of these critical drives shall be increased in such type of power distribution.
16.10	An additional advantage of running the GT shall be available even when the DM cooling pumps are not available for a small span of time.
16.11	In the past tripping of gas turbines is experienced number of times due to the failure of the cable insulation in the hot zone.
16.15	Tripping of Gas Turbine is experienced in the past on failure of exhaust thermocouples on excessive heat. Hence heat shield shall be provided on the exhaust thermocouple JB (towards the stack).
16.16	During operation of the gas turbine in gas firing mode, the warren pumps do not run. Hence, tripping of the gas turbine on low lube oil pressure of warren pumps is not logical.
16.17	This will facilitate to handle emergency in a better way.
16.21	This will provide added advantage for better monitoring of gas turbine.

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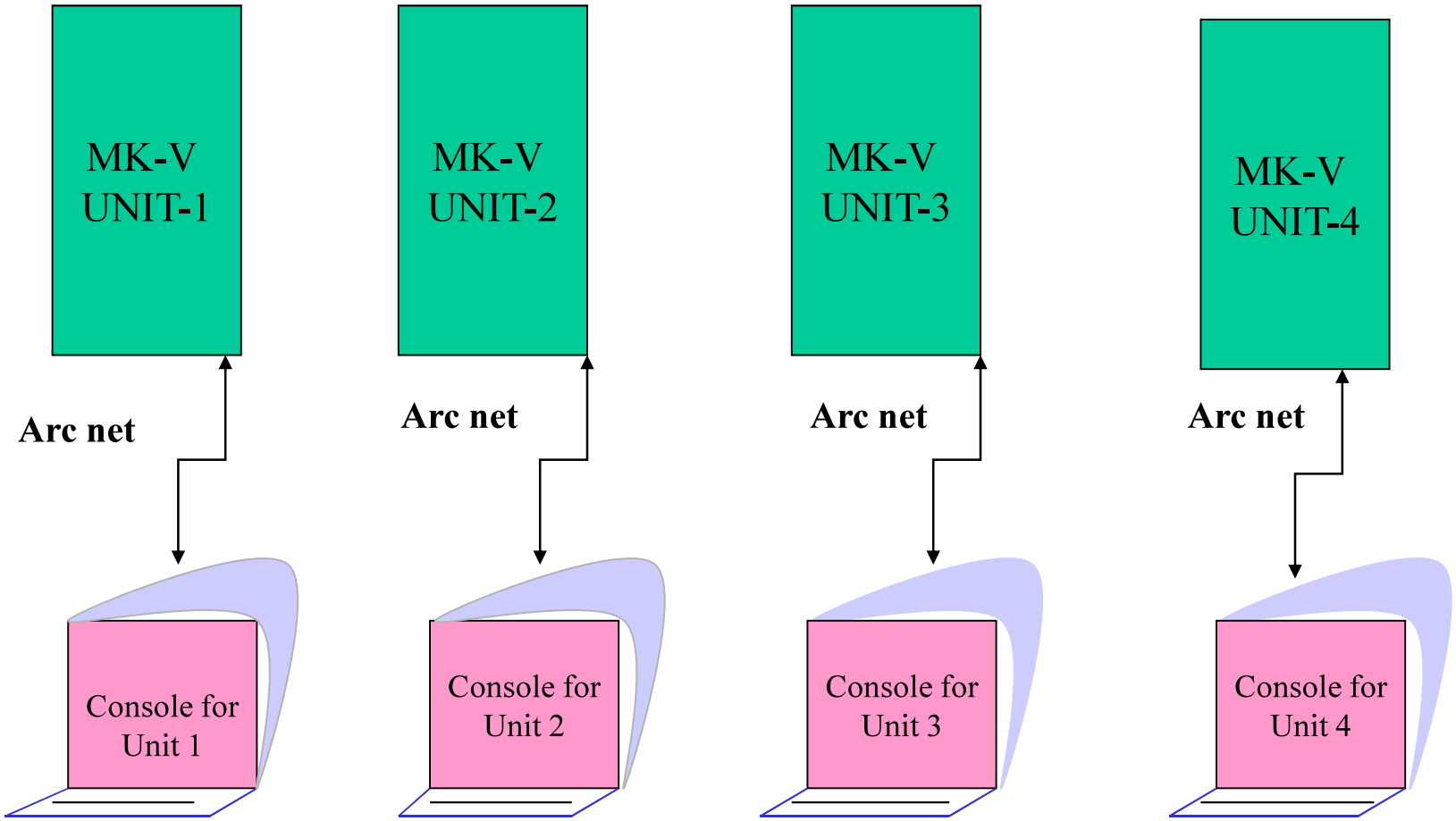

TYPICAL (EXISTING) CONFIGURATION

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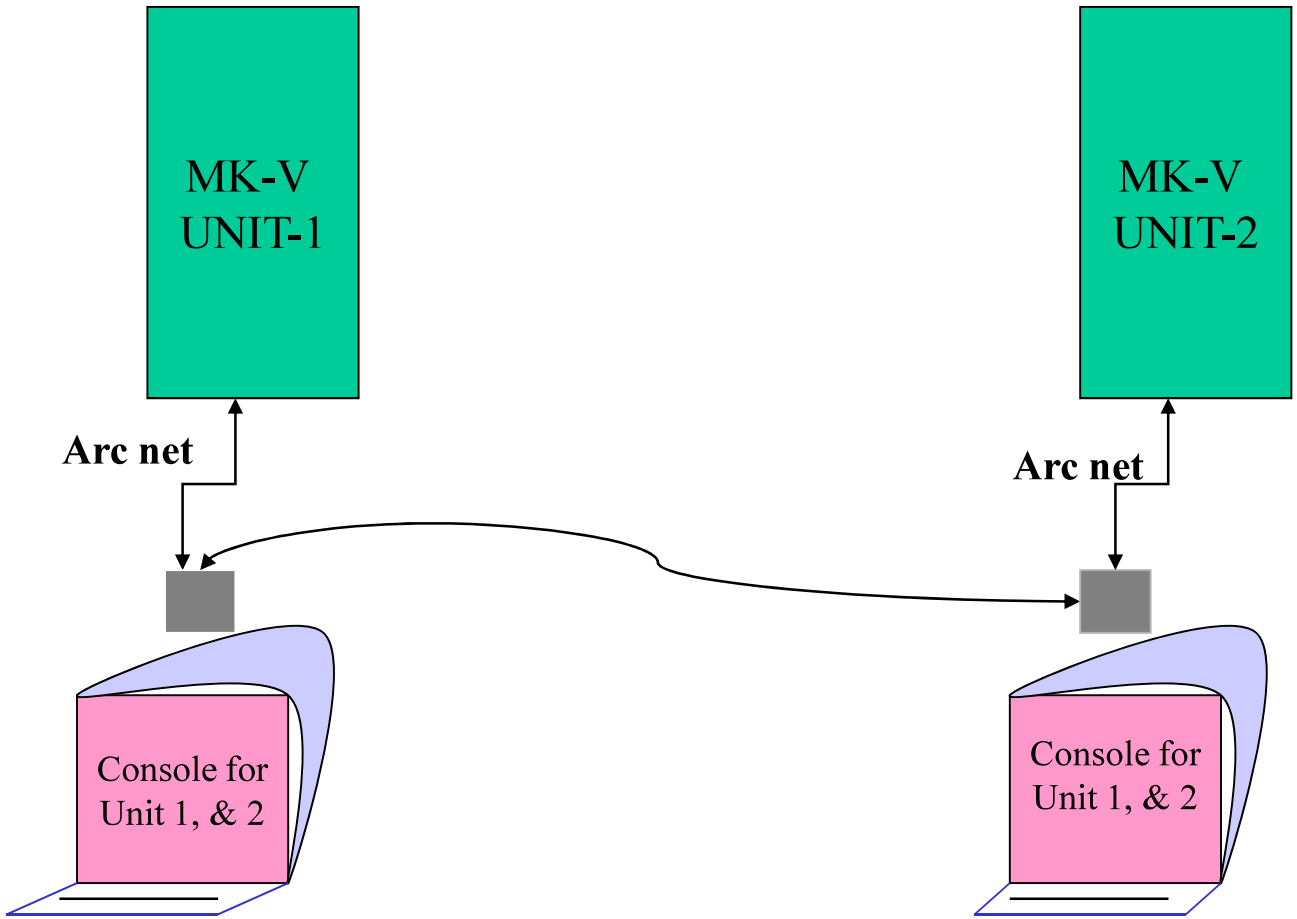
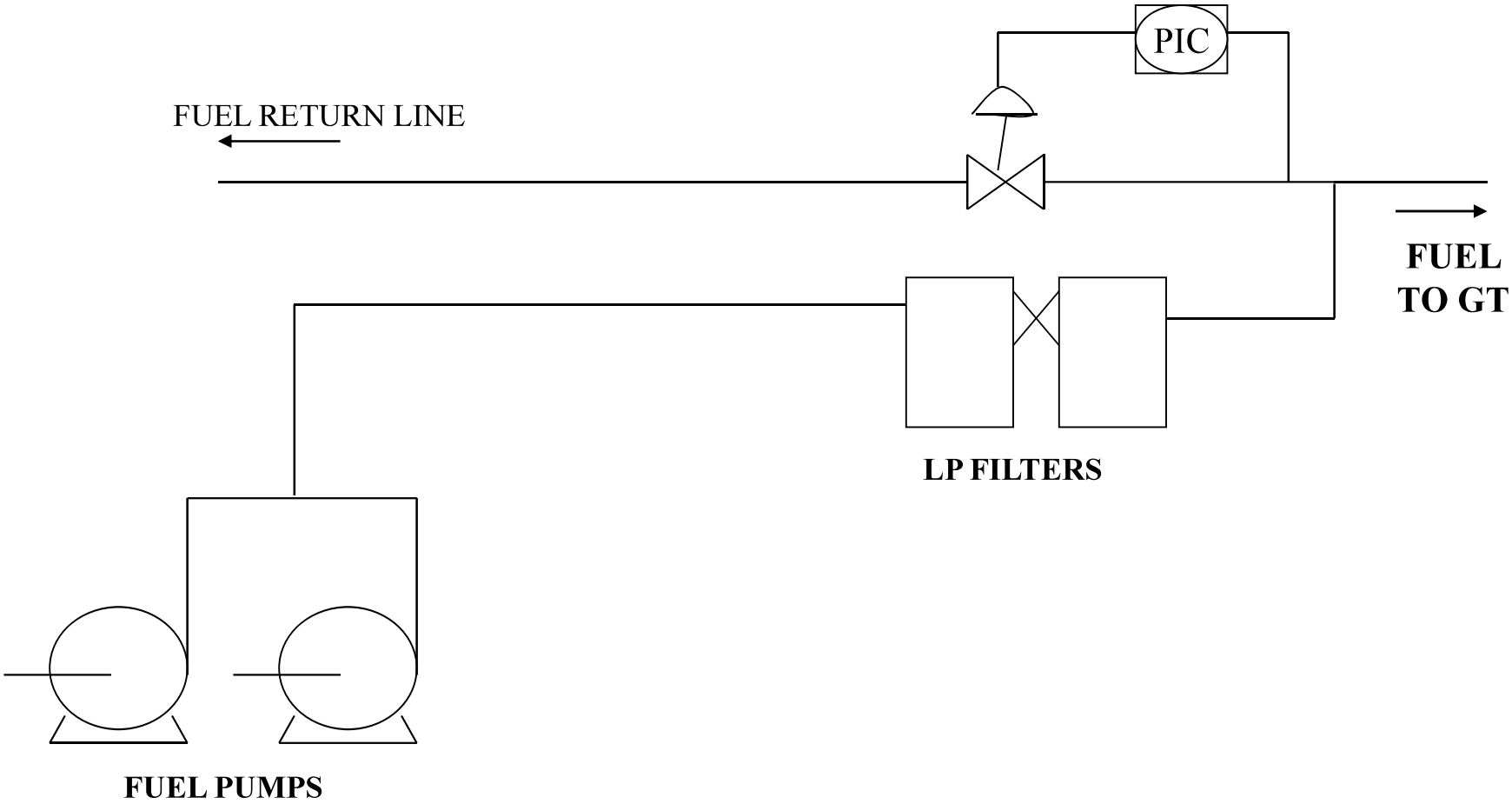
Schematic- 16C.1



TYPICAL RECOMMENDED CONFIGURATION

Schematic- 16C.2



GT LIQUID FUEL FORWARDING PUMP

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Schematic- 16C.3

Chapter – 17

FIELD INSTRUMENTATION

17A RECOMMENDATIONS

On the basis of the study of our previous failures, some critical issues are considered for further improvement, which is furnished below for implementation in the in-house projects and also for phase-wise implementation in the existing systems as far as possible. Some recommendations are furnished below for implementation. Detailed explanation to these recommendations marked as (◄) has been enclosed at Section 17B of this chapter.

17.1 SOLENOID OPERATED VALVES (SOV)

The Solenoid valves are non-redundant and probably the most critical element of an emergency shut down system. Failure of SOV leads to plant interruption in most of the cases. Following is recommended for the reliability improvement of this critical device.

17.1.1 In case UPS supply is being taken to field, it is desirable to route it through an isolation transformer.

17.1.2 Considering the criticality of this device (SOV), it is recommended to procure SOV from reputed manufactures only.

17.1.3 The cable entries in the JB and the SOV shall necessarily be routed from the bottom / side of the JB and the SOV. All the possibilities of the water ingress inside the JB and the SOV shall be prevented. (MP).

17.1.4 Following is to be noted regarding various configurations of SOVs:

17.1.4.1 For critical solenoid valves in safety applications which lead to complete plant shutdown: - where single SOVs are installed, multiple SOV configuration which will qualify overall SIL3 rating may be considered so that failure of one SOV does not trip the plant.

17.1.4.2 For critical solenoid valves in safety applications which lead to complete plant shutdown: - where multiple SOVs with overall SIL3 certification are installed, the same shall

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be without manual bypass for the individual SOVs.

17.1.4.3 2oo2 solenoid valves shall be used where it is recommended by process licensor.

17.1.4.4 TMR Solenoid valves with overall SIL3 rating may be used in supercritical applications like Dump valves.

17.1.4.5 All the above SOVs are to be necessarily checked for their healthiness in every M&I S/D.

17.1.5 Vent port of all solenoid valves are to be provided with SS/ Brass bug screens, to prevent blockage of port because of bugs and to save the port from dust. All such bug screens are to be checked for choking at regular intervals.

17.2 I/P CONVERTERS

The current to pneumatic (I/P) converter is also very critical device in instrumentation system. In most of the cases the failures of an I/P converter leads to plant interruptions. There are two basic reasons for failure of these elements and the following recommendations may be adhered to:

17.2.1 Quality of Instrumentation air is the prime factor for failure of I/P converters. Oil-free, and water-free air shall be used for I/P converters.

17.2.2 For I/P converters five-micron filters must be used.

17.2.3 It is recommended to procure I/P converter from reputed manufactures only, considering the criticality of use of this device.

17.3 FLOW METERS

17.3.1 Dedicated orifice-tapings shall be used for each transmitter, for the installation of multiple transmitters from a common orifice.

17.3.2 Closed-couple installation is preferred for high viscous services, or hydrocarbons contain water,

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17.3.3 In the new projects the size (NB) of Impulse line shall be ¾" in place of ½" for corrosive / congealing, and high-pressure service.

17.3.4 Dedicated orifice-tapings shall be used for each transmitter, for the installation of multiple transmitters from a common orifice. This shall be followed for all new projects. For existing installations in critical flows leading to plant shutdown, replacement of existing orifice flange with multiple tapping orifice flanges may be planned for execution in M&I Shutdown provided space for installation of the same is available. If multiple tappings are not possible, multiple impulse lines from same tapping may be considered.

17.4 TEMPERATURE

In refineries more than 90% temperature sensors are thermocouple. Other than thermocouples, RTD sensors and very few optical pyrometers are also used. Depending on the various ranges of measurement, there are six types of thermocouples available for industrial temperature measurement. It is difficult to maintain so many types of thermocouple. However, considering our requirement, it is recommended to minimize the variety to K-type, E-type, and R-Type.

17.4.1 In the new projects temperature transmitters shall be used for measurement of all the temperature parameters, except for the purpose of data acquisition system (DAS).

17.5 MISCELLANEOUS ISSUES

17.5.1 For new projects, all the instruments and on the Local Control Panel (LCP) should preferably be intrinsically safe. Air purged type panels should be avoided.

17.5.2 Root valves for all high-pressure applications shall be of double isolation type, typically class 600 piping and above.

17.5.3 *Proximity switches to be considered in place of limit switches.*

17.5.4 For all new projects, Smart positioners to be considered for all control valves along with smart positioner diagnostics software for enabling advanced diagnostics with valve signature. For critical service, control valve position feed back may be configured in the DCS with trend recording if necessary.

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17.5.5 To improve the reliability of the de-salter level, more than one numbers of RF-Capacitance type level transmitter shall be used.

17.5.6 Field Transmitters shall be used in place of switches for all the PLC inputs used in process interlocks.

17.5.7 For all the control / block and bleed valves connected to flare shall be of leakage class V or better.

17.5.8 For PSA ON / OFF valves replacement of the soft seats and overhauling of the actuators shall be carried out during planned shut down as recommended by the OEM / Supplier. Only OEM spares are to be used. The overhauling is also to be preferably done through OEM.

17.5.9 For the shelter analyzers, provision for monitoring the shelter temperature with high temperature alarm in the control room to be provided.

17.5.10 Periodic cleaning / flushing of the analyzer sample handling system to be carried as recommended by the OEM.

17.5.11 The availability of consumables, calibration gases and reagents of each analyzer shall be ensured. (These items may be kept as “IC items”).

17.5.12 The on-line data of all the critical analyzers to be made available in a centralized location (Inst W/Shop / refinery LAN / respective control room) for better monitoring. However, this has to be considered in the new projects.

17.5.13 During planned shut down, all the critical control valves / dampers’ actuators to be checked for operation and if any corrective aciton is necessary, the same shall be taken.

17.5.14 For new projects, if HART instruments are considered, the DCS system may be considered with HART pass-through modules. So that the diagnostic capability of HART instruments can be utilized.

17.5.15 Wherever dual coil servo valves are used for compressor governor systems, the healthiness of individual coils shall be checked & ensured during S/D by operating the governor valve with the cable to other coil removed. If one coil is faulty the same should be repaired/ replaced.

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17.5.16 Generally two separate inputs are available in Governor Control Systems for measuring speed. Healthiness of both the circuits is to be checked during Shutdown.

17.5.17 All the control/ shutdown valves are to be checked for availability of necessary rain protection for diaphragm vent ports. If not available/ damaged the same to be provided (1/4 inch SS tube formed to inverted U shape with necessary fitting can be used).

17.5.18 Plugging of all extra/ unused entries of Junction Boxes, transmitters, thermocouples heads shall be ensured.

17.5.19 All cable glands to be checked for correct glanding so that entry of water (weatherproofing) is ensured.

17.5.20 All emergency trip push buttons (EPB) located in field are to be checked for healthiness of contacts, sealing of the Push button station. The EPB is to be provided with suitable canopy. The Push buttons are to be properly painted and lettering is to be done for easy identification. A consolidated list with location shall be available with zonal instrumentation group.

17.5.21 Steam tracing of impulse lines are to be reviewed for proper heat transfer and availability of steam traps.

17.5.22 Power supply to Local controller panel of individual air compressors shall be taken through separate power supplies with its independent Fuse/ Isolator/ MCB from source. The LCP shall be powered preferably through UPS.

17.5.23 For all furnaces, arch pressure transmitters to be provided above the tapping point. The LP tapping shall be extended to pot with pebbles.

17.5.24 Impulse lines with SS fittings shall be avoided for hydrocarbon lines. Wherever, complete impulse lines are done with tube and tube fittings, the same is to be replaced with impulse piping. Maximum two nos of ferrule fittings shall be used.

17.5.25 For reliability and safety high quality fittings and tubes like Swage lock / Parker make may be used for all hydrocarbon lines.

17.5.26 For all new projects, the Junction boxes preferably shall be considered with cable entry from bottom for all

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multipair and single pair cables. Junction boxes may be provided with suitable canopy.

17.5.27 All Fieldbus Junction boxes located in field are to be provided with suitable canopy.

17.5.28 In case of Machine monitoring systems, independent racks/chassis are to be considered for individual machines

17.5.29 For all impulse lines in Hydrogen / Hydrocarbon service in upcoming / new projects, union is not to be used. Instead, suitable break flanges are to be used.

17.5.30 Flexible unarmored cables in skids may be replaced with armoured cable.

17.5.31 Fire proofing of cable in hot zones / fire prone areas

17.5.32 Periodic overhaul of electro-hydraulic actuators of governor valves

17.5.33 Hydraulic oil quality to be maintained as per OEM recommendation for FCC slide valve actuators

17.5.34 Valves / actuating elements in high temperature areas shall have high temperature seal kits and life cycle/ experience based replacement of seal kits shall be carried out

17.5.35 Life cycle based replacement shall be shall be considered for solenoid valves in critical services based on OEM recommendation (5 years for continuous energized and 7-8 years for intermittently operated).

17.5.36 Remote mounting of I/P or positioner in high temperature areas may be considered.

17.5.37 Where LP side filled systems are in use and where problems are being faced, replacement with diaphragms seal type capillary type field instruments to be considered eg in compressure suction drums.

17.5.38 Unit wise there shall be a list of thermowells which are in severe service (temperature and erosion) eg FCC reactor top, DCU vapour line etc.. These shall be checked before re-use (hydrotesting / DP testing) or replaced with suitable & correctly manufactured, tested (verify test certificate, do hydrotest, DP test before installation).

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17.5.39 Where field mounted power supplies/ barriers are improperly installed (poor heat dissipation etc.), if the same can be shifted to control room – the same to be considered.

17.5.40 Where failure of actuator diaphragm has been experienced especially in critical services, root cause to be identified (water ingress / high temperature / aging) and replacement of the same with new OEM diaphragm to be carried out. It may be noted that rubber / soft parts in storage for a long time may be hard and britlle, hence these are not to be used.

17.5.41 Where motor purge systems are installed with field mounted switches / timers, replacement with low pressure transmitter to be considered.

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Chapter – 17

FIELD INSTRUMENTATION

17 B *EXPLANATION TO RECOMMENDATIONS*

Reference	Explanation
17.2.2	Normally 25-micron filters are used for the controls. On many occasions it is observed that the control valve filter (25 micron) is used for I/P converter filter against its requirement of 5 micron
17.3.3	The available inner diameter of ½" impulse pipes is less especially for heavy schedule pipes, hence frequent choking of impulse pipes are experienced.
17.4.1	However, the temperature transmitters shall not be head mounted type, especially where, the surrounding temperature is very high.
17.5.1	The reliability and maintainability of the intrinsically safe panels are very high with respect to the air-purged panels.
17.5.3	The reliability of the proximity switches are high very with respect to the (spring loaded) limit switches.

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Chapter – 18

MAINTENANCE PRACTICES

18A RECOMMENDATIONS

On the basis of our previous experience and failures, some critical issues are considered for maintenance practices. Some recommendations are furnished below for following.

18.1 Thorough checking of power supply system redundancy during M&I s/d of individual units is to be carried out & replacement of glass fuses in critical services (power supply system) during M&I shut down may be considered.

18.2 It is essential to identify the outstanding problems / issues related to DCS / PLC before shut down & addressing of the same during shut down. These shall be captured in the shutdown job list.

18.3 It is required to monitor the system status / diagnostics on daily basis and to do the needful accordingly.

18.4 Ensure conducive control room ambiance and carry out cleaning of the DCS / PLC modules during shutdown (Shutdown maintenance of DCS /PLC). Where modules are old, possibility of failure after maintenance / cleaning to be considered / evaluated and adequate spares to be kept in hand before undertaking shutdown maintenance activity.

18.5 The access to the Engineering Station shall only be permitted to the competent instrumentation person, and any change in the system shall be systematically implemented and documented.

18.6 The system back-up of DCS / PLC shall be taken at least once in three months or after any modification in the system and shall be documented properly.

18.7 Irrespective of process interruption or not, any instrumentation failure (major or minor) or near-miss events shall be documented properly.

18.8 Proper identification of cables / MCB / ferrules, etc. shall be ensured during shut down where as-built documents are not available.

18.9 The list of identified critical instruments must be maintained for calibration / overhauling during planned shutdown. Calibration record of these instruments to be maintained.

18.10 Care shall be taken to protect all field instruments from steam leakage / hot exposures / water ingress etc.

18.11 Each unit shall have a unit specific shut down list.–The shutdown job list shall, inter alia, shall include :

a) Pending jobs of previous shutdown job list that could not be executed

b) Jobs that were identified during plant operation, which needed plant shutdown

c) Preventive checks that can be carried out only during shutdown eg redundancy checks, aux console integrity checks, critical final element operation check etc.

18.12 Regular auditing of steam tracing of the impulse lines, healthiness of the steam traps, fixing of JB covers, cable glands shall be carried out.

18.13 All the field transmitters, I/P converters, shall have canopies, properly mounted to protect them from the Sun and rain.

18.14 Adequate numbers of all types of tools (including non-sparking tools) shall be made available so that proper tools are used at proper places.

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18.15 Loading of all DCS/PLC systems shall be checked and recorded. If loading is found very high, steps to be taken to reduce the loading to acceptable figures.

18.16 The Self actuated valves in compressors shall be checked in every M&I Shutdown. The diaphragm compartment has to be opened and inspected. Replacement may be considered based on specific experience / criticality. Spares are to be sourced from OEM only.

18.17 All the Optical fibre links are to be checked in each M&I and if necessary (signal reduction), required action to be taken.

18.18 Checking of all connections for tightness shall be done for Power Supply distribution during M&I Shutdowns

18.19 All DCS/PLC systems are to be audited by respective OEMs once in every M&I Shutdown.

18.20 The Machine monitoring systems of all Critical compressors are to be checked in detail by respective OEMs once in every M&I Shutdown. All suspected components are to be replaced.

18.21 The Antisurge controller, Performance Controller and Governor Control system are very critical and are generally non redundant. For critical compressors, the controllers are to be replaced based on OEM recommendation. Redundancy may be considered for critical applications.

18.22 The critical controllers installed in field (like critical FCCU slide valves) are to be upgraded/ replaced based on OEM recommendation.

18.23 Junction boxes with Interlocks related critical control signals should be marked separately. These JB's shall be checked in next available M&I for condition of terminals & lugs, water ingress, improper glanding, tightness and shall be boxed up properly with suitable gaskets/ o-ring/ greasing, sealing of all entries. This shall be repeated based on experience but in minimum 5-6 years.

18.24 Some failures have been observed because of oil seepage inside Junction Box through RTD cables for compressors. RTD Junction

boxes are to be checked for any oil traces and necessary corrective action to be taken.

18.25 The list of critical instrumentation of each unit shall be reviewed and suitable maintenance scheduling shall be done. Instruments to be put under Super critical category – if failure of a single instrumentation leads to tripping of the complete Plant. For such items, instrumentation with very high reliability shall be used.

18.26 Any Junction box with cable entry from top shall be avoided.

18.27 Scheduled plant visit to be carried out by the unit instrumentation engineer for each plant in a view to physically inspect each and every instrument installation and Junction boxes at least once in a year, identify and correct any abnormality. Record shall be maintained with date. The following are some of the points to be checked:

a. Cable Gland is proper.

b. Instrument cover properly fixed to avoid water ingress.

c. Nearby steam leakage.

d. Healthiness of steam tracing.

e. Inadequate/ damaged Support

f. Control valve – Gland leakage, Healthiness of Positioner linkage.

g. Availability of all positioner & regulator gauges.

18.28 One document should be available in each unit which exactly specifies (Name of Graphic page, where to be seen, what to be observed etc) the details of daily monitoring of health. This monitoring should cover each and every system and redundancy. Graphics in DCS may be prepared for faster and easier monitoring. Daily monitoring should include at least the following:

a. System status of all systems/ subsystems/ package systems

b. Availability of all redundancies including communication redundancy

c. Status of all Power Supplies (UPS, Chargers, Bulk Power Supplies, Power Feed Modules)

d. Earth leakage detectors.

e. Discrepancy of signals from 2 out of 3 group.

f. Status of all Fans

g. Cabinet temperatures

h. Control Room ambience (On line corrosion monitors, Control room temperature, Humidity)

i. Temperatures of Analyser Shelters

18.29 Availability of the following documentation to be ensured in all the units:

a. Power Supply distribution starting from each UPS system, this should include at least the following details:

1. UPS Incomer details.

2. Single line diagram Downstream of UPS (Include cable size, MCB rating, Isolators, fuses etc.).

3. Individual distribution upto all consumers

b. Data sheet of all field instrumentation

1. Control Valves

2. Orifice plates, Venturi meters, Flow nozzles

3. Annubars,

4. Field instrumentation

5. Thermowells/ Thermocouples

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6. Skin Thermocouple drawings

7. Reactor thermocouple drawings

c. DCS/PLC Documentation

d. Package System documentation

e. Documentation of Local Control Panels, Machine monitoring system etc.

f. Document to be prepared (if required by taking help from OEM) and maintained in respective units, which exactly specifies the step by step method of loading a new system (example for DCS System, Operator station, OPC Gateway, Advance Control system etc.) and taking the same in line.

18.30 Two sets of System backup of all systems/ subsystems shall be taken whenever there is a change or every six months whichever is earlier and to be maintained in two different locations.

18.31 All licensed copies of System softwares to be listed and maintained in respective units for quick retrieval in case of requirement. Master list of all such softwares shall be available with the HOD.

18.32 In event of system upgrade new hard disk should be used and old hard disk to be preserved till stabilization of system.

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Chapter – 19

INSTRUMENT AIR QUALITY

19 A RECOMMENDATIONS

The Instrument Air Quality plays a very important role in the reliability of the final control element. Proper quality of Instrument Air with required Dew Point is essential for ensuring reliability of final control elements. The following practices are recommended for achieving higher reliability of the total system.

19.1 Online Dew Point meters are to be provided at the outlet of each individual air driers and the same has to be historized.

19.2 The dew point meters are to be calibrated at the frequency as per OEM guidelines.

19.3 Alarm is to be provided if the dew point reduces below -35 Dec C.

19.4 Checking and disconnection of any cross linking of Instrument Air header and plant air header.

19.5 Instrument air pressure indication at battery limit, of individual unit, to be provided in control room.

19.6 Flow meters to be provided at the battery limit of all units to asses consumption.

19.7 Installation of air receiver vessel at unit battery limits to be considered for all new projects.

19.8 Installation of redundant on line air filters (common) with manual changeover arrangement to be provided for all PSAs or similar applications.

19.9 It is to be ensured that Air compressor discharge is never lined up to instrument air header without drier in service.

19.10 Ensure that instrument air tappings for sub headers are taken from the top of main header.

Chapter – 20

SKILL ENHANCEMENT

20.1 Zonal Instrumentation team is to be given training on:

1. Process, control and interlock of the unit
2. DCS/PLC of the unit
3. GC/Analyzer for officers responsible for the same.
4. Control Valve maintenance along with Operation / Maintenance of Positioners.
5. DCS / PLC System maintenance.
6. Machine monitoring system
7. PSA
8. Governor, anti-surge controller

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Chapter – 21

Distributed Control System

RECOMMENDATIONS

21.1 Online Dew Point meters are to be provided at the outlet of each individual air driers and the same has to be historized.

21.2 DCS data loss in client-server based machines upon server failure have been experienced. OEM wise configuration verification, improvements that may be carried out, procedures that need to be followed during server repair etc.. need to finalized.

21.3 Spare configured operator station shall be available for immediate replacement.

21.4 Power to operator stations has to be segregated

21.5 Aux console devices healthiness check shall be carried out during shutdown – especially cable connections beneath push buttons and selector switches

21.6 Devices like PA system, telephone etc are not be placed near aux console

21.7 Need to incorporate guidelines related to field bus systems

21.8 It is desirable not to have the same system for multiple plants (on the same network)

Chapter – 22

Petrochemical Instrumentation

RECOMMENDATIONS

22.1. Online Dew Point meters are to be provided at the outlet of each individual air driers and the same has to be historized.

22.2. Instruments must not to be located in dead zone where powder/ material accumulate. For e.g., PT/TT located above the baffles support and radioactive detector located behind the baffles in reactors/vessels with agitators.

22.3. Tuning Fork type level switches must be avoided for powder application. Instead capacitance type level switches may be preferred.

22.4. For powder/pellet silo's weight transmitter or capacitance type rod detectors must be preferred against level switches.

22.5. The shutter for radioactive source housing must be checked in every shut down.

22.6. Flexible type radioactive LT's must be avoided in polymer application due to its inherent low sensitivity and susceptibility to high temperatures. Instead solid scintillation type detectors may be preferred. Detectors must be air or water cooled.

22.7. For vessels/silos involving length greater than 10 meters, radar of higher frequency of the order of 68 GHz must be preferred.

22.8. For high temperature applications such as extruder, proximeters with high temperature rating must be installed or else proper cooling arrangement such as air purging etc must be used. Life Cycle based replacement of Proximity sensors installed in high temperature zone and connected to Extruder Interlocks should be done during M&I shutdown.

22.9. For teal/IPRA/CAB/CAB2 applications, RPTFE gland packing and RPTFE/PEEK seats should only be used.

22.10. For all radioactive level switches, 4-20 mA must be taken as a signal in place of only relay contacts.

22.11. For level measurements of teal/IPRA/CAB/CAB2 vessels, extended type diaphragm seal level transmitters must only be used

22.12. The JB's must not be installed in any vibration prone area. Special care must be taken for extruders/ conveying compressors.

22.13. The pulsation SOV's used in bag filters must be configured for operation from DCS/PLC instead of locally installed timer cards.

22.14. All slurry applications must have eccentric ball valves without any noise reduction to avoid choking. If required higher CV rating valves must be installed.

22.15. All the rotary feeders must have speed indications in DCS to detect timely failure.

22.16. Nitrogen purging in all rotary feeders must be continuous and should not have any stop logic to avoid smooth rotary operation

22.17. The nitrogen purging in all rotary feeders are provided through rotameter. As nitrogen purging is very important in all rotary feeders and so DCS/PLC indication for nitrogen flow must be available in the system.

22.18. The valves used in critical powder service must be asked with internal finish superior than 125RMS to avoid jamming.(flash drum bottom LV , metal to metal seating)

22.19. Delay of 1 sec. to be configured in the Extruder PLC inputs actuated by Proximity sensors.

22.20. Electronics of Nucleonic Level LT detectors to be given adequate protection against high ambient heat(>50 degC) from Vessel by suitable re-location, air purging

Unit Specific Points

HDPE:

22.21. Still well not preferable in case of slurry or applications where material has tendency to stick (For e.g. Radar LT was provided in an still well at HDPE waste pit and frequent cleaning was needed to avoid erroneous reading.)

22.22. Diaphragm with continuous flushing arrangement via flushing ring arrangement must be preferred in Reactor/vessels where there is tendency of powder coating instead of extended diaphragm seal measurement.

PP:

22.23. Pressure control valves of Pre-poly and main loop reactors should have high flow positioners with contact less feedback link for quick action to prevent polymer deposits.

22.24. Direct acting type SOV's are preferable against pilot acting type for Reactor Dump valves.

22.25. Detectors of Low intensity radioactive sources of nucleonic LT's should have adequate protection to prevent interference in measurement due to extraneous radiation (typically from radiography sources)

NCU/BDEU:

22.26. Radiant section Thermo-wells of Heaters should be of shorter length to avoid breakage of thermowells and fire scenario due to impact of falling refractory.

22.27. For critical Compressors i.e. CGC/ PRC /ERC / MRC the seats of Lube Oil Pilot PCV's should be metal seated.

22.28. Heater Drum IBD control valves body should have WC9 metallurgy and SS440C trim assembly.

22.29. High Flow Positioners with simple pneumatic accessories should be considered for ANTI-SURGE control valves of critical compressors. The Valves should have equal opening and closing speed i.e. < 2sec.

22.30. For BDEU RGC ,suction pressure measurement transmitters(for low suction trip interlock) should be installed close to the Compressor and downstream of the suction strainer.

MEG:

22.31. Complete Body (one of each size) should be kept as spare for the Oxygen Mixing Station ON-OFF valves- recommended by Licensor.

22.32. Services of the Valve vendor to be taken for servicing any valve in OMS . Accessories for cleaning the valves i.e. Tri-Chloro Ethylene, Dark Light , fine brush & Neoprene gloves should be kept ready at site

22.33. All the spare valve internals should be cleaned properly i.e. no dust , grease ,contaminant before installation.

22.34. All the Instruments in OXYGEN service should be certified for the application.

22.35. Extended Diaphragm type level transmitters in Wash Tower Carbonate service should have proper extension length matching with the inside surface of the vessel

Part- D

SKILL ENHANCEMENT

IN

ELECTRICAL & INSTRUMENTATION SYSTEM

PART- D

Reliability improvement in Electrical & Instrumentation

ISSUES ON SKILL ENHANCEMENT

1. The right knowledge skill and aptitude of an individual are vital factors for successful and effective function of a system.

   During discussion and information sharing with units, it is felt that in the present scenario, the mix of Graduate and non-graduate engineers is loosing equilibrium which has its effect in the efficient working of the P&U and Instrumentation functions. The situation is getting difficult with the increasing complexity and sophistication (state of art technologies) in the systems, new dimensions of digitization of protection systems and advanced controls. In view of above there is need is to have adequate proportion of qualified graduate engineers for effectively handling the new challenges of operation and maintenance of these complex system with better understanding

   Some of the areas which have been identified and should have minimum strength of qualified engineers along with other officers in Grade A/B/C as per present set up in P&U and instrumentation of each refinery unit are as below. The requirement given below can be managed from within the sanctioned manpower strength at each location by replacing the existing strength with newly inducted qualified officers in a phased planned manner by utilizing the non qualified officers in other productive areas/ new facilities as coming up time to time, where they can be better utilized.

   P&U

   - Electrical Testing - At least three / four for units and one for TPS/ CGP
   - Electrical Planning / documentation and FA - At least two
   - TPS operation- (At least four) and shift in charge for refineries having GT .
   - Sub-station operation -At least one
   - Telecommunication - At least one
   - Electrical Maintenance – At least one for each cluster of new technology units (HCU, FCC , LUBE, CRU, HGU, MSQ-DHDT/DHDS etc a).
   - Engineering Services– at least Two to take care of design aspects/ engineering in the new facilities

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Instrumentation

- Instrument Planning / reliability cell - At least two
- Process Units – At least one each for every three process units
- TPS - At least one (two where GTs are installed)
- Instrument workshop / analyzers - At least one
- Offsites (O M&S) - At least one
- LPG Filling & storage etc - At least one
- Engineering Services– at least one to take care of design aspects/ engineering in the new facilities

2. Career Progression Planning for officers in P&U & Instrumentation to be introduced for timely exposure in all major working areas. It is desirable that a graduate officer should given job rotation in following areas by the time he is promoted to D grade

P&U

- Electrical Testing / project Commissioning (Core group)
- Power Plant operation
- Engineering Services (preferably in C grade)

Instrumentation

- Process units/ offsite
- Planning / reliability improvement (After getting units exposure)
- Projects (After getting units exposure, preferably in C grade)

3. Old redundant electrical panels available in refineries are to be tailor made as training simulator where all the control and protection schemes, as build drawings should be available to enable hands on experience of testing / maintenance / operation and trouble shooting

4. Encouraging participation of workmen in the departmental developmental / failure analysis / other improvement issues through structured participative forums and encouraging good technicians to work as faculty in training sessions meant for workmen to built in the sense of ownership & belongingness, as the focus now a days has shifted from **"TO OPERATE "** to **"TO OPERATE & TO OWN "**

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5. In order to provide suitable skills to P&U personnel in their respective area of work, set of functional training have been identified for each group which should be provided to all concerned, as a minimum requirement, in a phased manner.

(A) Officers in P&U Operation

- Electrical Protections, Control schemes & relays (by M&I)
- Sub station operation / Reading of drawings
- Power Plant Operation (GT, TG operation etc) (by M&I)
- Generator excitation system
- AVR (with OEM)
- DC System
- DCS, ECS , MMI (with OEM)
- UPS(with OEM)
- Failure analysis
- Electrical Safety
- Hazardous Area Classification

(B) Officers in Electrical Testing

- Electrical Protections, Control schemes & relays (by M&I)
- Generator excitation system
- Power system study /Protection coordination (by M&I)
- Reading of drawings / Schemes
- Numerical relays (with OEM)
- Testing of Feeders / primary secondary injection
- AVR (with OEM)
- DC System
- UPS (with OEM)
- VSDs/ soft starters /Synchronous motors (with OEM)
- Failure analysis
- MMI
- Electrical Safety
- Specialized periodical skill input from OEMs and demonstration at site.

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(C) Officer in Electrical Maintenance

- Generator operation and maintenance (by M&I)
- Reading of drawings / Schemes
- Basics of electrical protection
- Numerical relays (with OEM)
- DC System
- VSDs/ soft starters /Synchronous motors (with OEM)
- MOVs (with OEM)
- Bearings selection/ handling /Vibration monitoring
- Maintenance of Transformers / Motors/ HT&LT switchgears
- Failure analysis
- EOT cranes (with OEM)
- Electrical Safety / Earthing
- Hazardous Area Classification
- Specialized periodical skill input from OEMs and demonstration at site

(D) Workmen in Operation

- Generator / excitation system operation and control (For power plant)
- Sub station operation
- Reading of drawings / Schemes
- DC System
- UPS operation
- Basics of Electrical Protections, Control schemes & relays
- Operation of DCS, ECS (with OEM)
- Electrical Safety / earthing
- Hazardous Area Classification

(E) Workmen in Electrical Testing

- Electrical Protections, Control schemes & relays (by M&I)
- Reading of drawings / Schemes
- Numerical relays (with OEM)
- Testing of Feeders / primary secondary injection
- AVR (with OEM)
- DC System
- UPS (with OEM)
- VSDs/ soft starters (with OEM)
- Synchronous motors
- MMI
- Electrical Safety
- Hazardous Area Classification
- Specialized periodical skill input from OEMs and demonstration at site

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(F) Workmen in Electrical Maintenance

- Generator operation and maintenance
- Reading of drawings / Schemes
- Basics of electrical protection
- DC System
- Maintenance of Synchronous motors (with OEM)
- MOVs (with OEM)
- Bearings selection/ fitting /Vibration monitoring
- Maintenance of Transformers / Motors/ HT&LT switchgears
- EOT cranes (with OEM)
- Electrical Safety / Earthing
- Hazardous Area Classification
- Specialized periodical skill input from OEMs and demonstration at site

(G) Officers in Instrumentation

- Maintenance and Implementation of (respective) DCS / PLC.
- Gas Turbine and Mark-IV / V. (By M&I)
- Vibration monitoring system. (By M&I)
- Antisurge controllers (CCC). (By M&I)
- Woodward governor. (By M&I)
- Maintenance / selection of (respective) Control valves / special control valves.
- Maintenance of (respective) analyzers.
- Training on PSA. (By M&I)
- Hazardous Area Classification
- Specialized periodical skill input from OEMs and demonstration at site

(H) Technicians in Instrumentation

- Maintenance of (respective) DCS / PLC.
- Mark-IV / V. (By M&I)
- Vibration monitoring system. (By M&I)
- Antisurge controllers (CCC). (By M&I)
- Woodward governor. (By M&I)
- Maintenance of (respective) Control valves / special control valves.
- Maintenance of (respective) analyzers.
- Hazardous Area Classification
- Specialized periodical skill input from OEMs and demonstration at site.

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Part- E

IOCL's SPECIFIC REQUIREMENT

FOR

P&U AND INSTRUMENTATION SYSTEMS

IOCL's SPECIFIC REQUIREMENTS

FOR RELIABLE P&U SYSTEM

IOCL's SPECIFIC REQUIREMENTS FOR RELIABLE P&U SYSTEM

CONTENTS

IOCL's SPECIFIC REQUIREMENTS FOR RELIABLE P&U SYSTEM

1. Scope

This document highlights some of the specific requirement of IOCL, which are to be adopted by the contractor/ agency in interpreting minimum requirement for the Power & Utilities (P&U) Systems, along with other project specifications, before detailed design/ engineering is taken up.

The guidelines deal mostly with front-end engineering design, which does not necessarily provide complete design basis. As such, the focus is on what is to be produced as an end result and not on how this is to be achieved. It is, therefore, a communication document to obviate interface difficulties. The requirements outlined hereunder are to ensure reliable and safe operation of the electrical system. However, the statutory requirements/ regulations for the electrical system need to be complied with during the engineering and execution.

The scope covered is typical for a Grass Root Refinery Project. The guidelines shall also be applicable for P&U systems of new refinery project, New plants and extensions / modifications in the P&U systems of existing refineries/plants.

2. Control / Deviations

The IOCL specific requirements laid down herein below are to be strictly followed for all the new jobs as mentioned above. Any project specific deviation to the laid down requirement shall be with the prior approval of the Head of the Project at HQ or Unit Head depending upon the type of project. The reason for deviations along with its merits / demerits should be clearly spelled out while seeking the approval for any such deviation.

3. IOCL Design Concepts

The objective in designing new and revamped plant is to achieve performance comparable with, or exceeding that of, leading refineries in the region. The design shall be based on the most cost effective and commercially proven technology, applying the most appropriate philosophy and methodology to each individual project situation. In this respect, the contractor/ agency will be expected to expand upon, and

improve where possible, the design approach indicated in this document, and other project specifications.

4. Plant Availability

It is the IOCL's objective to maximise (i)duration between major shutdowns and (ii) onstream availability factors, within the bounds of safety and economy.

Onstream availability factor shall be optimised by

- Designing to minimise turnaround times
- Maximising the degree to which equipment can be monitored, and safely inspected, cleaned and repaired, while units are on-stream
- Applying appropriate principles of reliability engineering and total plant reliability to system design, equipment specification, material selection, and sparing philosophy.

5. Design Philosophy – Utility Systems

5.1 General

Utility systems shall be designed for high degrees of reliability since they normally support the entire plant and failures have broad safety and economic consequences. Systems design and material selection, therefore, shall provide for extended operation even though components must be separately shut down for periodic maintenance, or inspection.

Adequate utilities and services must be available for start up, normal and emergency conditions (such as electric power failure) and to provide services as required during shutdown and turn around periods.

5.2 Power Failure and Other Outages

Unless otherwise required by the PROJECT SPECIFICATIONS, it is not intended that the processing facilities will operate through a complete power failure.

However, the facilities shall be designed with enough steam drivers, heat tracing, alarms, warning devices, emergency shutdown systems, emergency back up power, automatic steam cut ins and the like so that, in the event of a complete power failure,

all processing facilities can be shutdown in an orderly manner without injury to personnel or damage to any facilities or equipment.

Plant design, including equipment capacities, and necessary piping connections, shall provide for safe shutdown and fail safe operation on power or cooling water outage, off test operation and other unusual but the inevitable operating conditions or upsets.

5.3 Utilities Plant

Steam boilers, water treating and boiler feed water facilities, power generation equipment instrument and utility air compressors and driers, fuel oil supply facilities, and emergency electric power generators shall be located in one contiguous area designated as the Utilities Plant.

The plant layout shall, in general, conform to the same standards as for process plants. In addition, provision shall be made, such that the capacity of the facilities for each utility can be expanded at some future date without major modification and/or relocation of existing major equipment.

Part of the steam required may be met by the generation of steam in process waste heat recovery units. The balance shall be generated in independent direct-fired boilers, and, with OWNER's agreement, by waste heat recovery from gas turbine exhausts.

If process requirement justify availability of steam for safe shut down in case of total power failures then, a minimum of two direct-fired utility boilers along with one set of steam driven auxiliaries for the sustained operation of the boiler shall be installed.

All steam generators (UBs/ HRSGs) shall be sized such that the steam demand can be economically met under following conditions:

a) Refinery operating at full capacity with
   - the largest boiler shutdown
   - the process unit waste heat generators operating at normal capacities, and
   - an online boiler tripped out

b) Maximum peak requirements (usually associated with electrical power failure), with the largest boiler out of service, and no process unit waste heat generators

operating. In this instance, automatic steam load shedding may be adopted to reduce the maximum peak.

c) A contingency margin of 20% –25 % of the normal steam load or 50% of the capacity of the highest rating steam generator (which ever is less) is to be kept in the steam generators in operation. The available margin on the running boiler should be arrived after accounting for the internal consumption of the boilers.

Under condition (a), only the maximum continuous rating of boilers shall be considered. Under condition (b), the peaking capability of boilers shall be considered.

The boiler and all its essential auxiliaries shall be so arranged as to ensure continuity of steam generation for essential requirements (which will be specified or agreed) in the event of loss of normal electricity supplies or decaying steam pressure to auxiliary drives.

The furnace proportions and burner arrangement of shop-assembled boilers shall be such as to permit satisfactory firing up to 110% MCR, irrespective of whether the overall boiler design is suitable for the overload condition or not.

5.4 Steam Distribution

Steam distribution systems connecting the high, medium and low pressure steam sources to the points of utilisation shall be provided to accommodate steam demand and steam quality for the various plant operating conditions, in such a manner that the leakage outage of particular section shall not affect that operation of the power plant.

Pressure reducing stations shall be located in the Boiler Plant. The PRDS should be capable of supplying to 100% process steam requirement on continuous basis and shall have with parallel redundant philosophy.

Facilities shall be provided to ensure that the high pressure steam level within the boiler Plant is maintained at all times and is not lowered due to excessive steam demands in other parts of the refinery. If medium pressure steam is needed to maintain operation, similar facilities shall also be provided.

The main steam distribution systems shall be designed such that specific process units can be isolated and shut down without disruption to other users, and that main header sections can be shutdown for maintenance.

5.5 Power Generation

(a) Processing plant power stations must be self-sufficient and should be designed to supply 100 per cent of plant peak electrical loads after the loss of any single largest component of the power generating system / power source. In case of Power plants having GTs the black start facility for at least one GT shall be provided

(b) The generating units should meet the load requirement, after Automatic Load Shedding, when the single largest machine is out of service and the second largest single source has coincidently tripped or shut down due to unforeseen circumstances in line with API Standards & practices of multinational companies

(c) A contingency margin of 15% –20 % of the normal power loads or 50% of the highest capacity machine(which ever is less) is to be kept, as spinning reserve in power generation to take care of staring of large motors and other system disturbances, even if the largest machine is out of service.

(d) In case number of generating machines in operation, in a new power plant/ grass root refinery, is more than three, ECS is to be adopted for smooth and efficient operation control.

(e) The output of the generators shall be connected to separate generation bus with double bus configuration and having sectionalising in between by sectionalising breakers. The number of sections in each Generation bus shall not be more than the total number of generators connected to it.

(f) Out put of each Generator shall be connected in parallel to both identical generation buses through breakers and synchronizing facility. Each bus shall be rated to carry 100% of plant loads continuously. No interconnection to be given between the two-generation buses.

(g) The sectionalising breaker in the generation bus shall be with manual closing through check synchronization relay. In order to eliminate the complexity in relay coordination and spurious tripping, the sectionalizing breaker should have only bus differential protection with cross- over zones between two adjacent buses.

(h) The load distribution shall be through separate distribution buses in the double bus configuration. Two distribution buses shall be connected through a bus coupler with auto manual changeover facility and permanent paralleling feature.

(i) Two adjacent distribution bus sections shall not be fed from same generation bus / two adjacent sections of the same generation bus

(j) Emergency tripping of generator shall be through a set of two Emergency Push buttons connected in series at Generator Control Panel.

(k) The manual opening of the field breaker shall be blocked in case either of two the generator breakers is ON.

(l) In case of generators having "Auto Synchronizer", its breaker closing command shall be through a check synchronization relay contact in series.

(m) Generator High Temperature tripping shall be taken through series combination of 100 deg Contact in series with the 80deg. C alarm contact else in case of temperature sensors to incorporate the logic of 2-o-o-3

(n) In case the Generator High Temperature trip command has been routed through a Fire Alarm Panel, The control supply to Fire Alarm panel shall be DC / UPS supply

(o) The space heater supply shall be through generator breaker contacts.

(p) The trip commands from the generator master relay and TNC switch to the breaker shall be separately wired up.

(q) Single core armoured cable in the generator output shall be laid in TRIFOIL formation and shall be earthed only on one side.

(r) Generator bus duct (phase & neutral side up to switchgear) shall have window type CT's. The PD value of these CT's shall be less than 20 pc.

(s) Non-essential equipments e.g. light fittings etc. shall not be installed in the LA / PT/ NGR panel / HT Chamber of the generator.

(t) It is essential for the complete Generator including Bus Duct, HT cables & generator breaker shall be provided with differential protection scheme. The scheme shall have overlapping protection zone with the bus differential scheme at switchgear level

(u) Numerical relays with 3- phase online monitoring of spill current shall be used in the Generator Differential protection

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(v) The HV cable differential protection, if provided, shall be connected to the Unit Master trip Relay (86U), if provided separately.

(w) The DC control supply to Generator Controls & Relay Panel shall be redundant with supply failure alarm.

(x) Generator protection relay shall be of numerical type. Two such relays in parallel mode are to be installed. Generator Numerical relay faulty alarm must appear in control room.

5.6 Power Station Excitation Systems

(a) The reliable generation of reactive power is a vital task performed by the generator field. The field is powered from an excitation system monitored by a voltage regulator when operated in isolation and, in some cases, by a reactive power or power factor regulator when operated in parallel with a utility. Adequate means should be provided to ensure continued generator fault-current output for faults in close electrical proximity to the generator terminals, since these faults will severely depress the generator bus voltage.

(b) DAVRs shall have "Dual Auto channel "

(c) DAVR reference supply should be taken from reliable source i.e. PMG, UPS or DC source.

(d) In the DAVR's auto- manual changeover during under voltage condition shall be with a time delay

(e) Alarm for DAVR internal power supply failure is to be provided at manned location & healthiness of the supplies to be ensured before synchronization.

(f) Generator shall trip instantaneously in case of AVR stage–3 faults (AVR Trip condition).

(g) DAVR cards shall have in built protection to prevent accidental resetting of the processor cards during resetting alarms by operator. This may be provided either by flushing the card resetting knob or blocking by mechanical device (pin etc) to prevent pressing.

(h) Harmonic suppression filters shall be used in the PT input circuits to take care the harmonics in the power supply

(i) The heat Run Test of DAVR shall be mandatory in the factory Acceptance Test (FAT)

5.7 Gas Turbine

(a) In GTG's, proper care to be taken to avoid GTG tripping while drawing out the Unit Master Trip Relay (86U) of the generator. If required, the NO contact of 86U relay should be inverted inside GT controller for using as NC (Fail Safe Mode)

(b) 2-O-O-3 voting logic shall be implemented for the following parameters:

- Gas turbine low liquid fuel pressure (63-FL-1) trip,
- Warren pump lube oil pressure low- temp. high. This also results in fuel change over to gas (if available) or trip.

(c) GT Lube oil "heater-on". At very low Lube Oil temperature (< 10 Deg. C). mal-operation of this single temperature switch will increase Lube oil temperature, which may lead to tripping of the GT on High Lube oil temperature. The alternate solutions are:

- The lube oil heater cut-off may be implemented with generator breaker "ON".
- Low lube oil temperature alarm may be implemented in place of heater "ON" because this logic is needed for very cold countries

(d) Separate isolation valves shall be installed for all the three pressure transmitters for GT-compressor discharge pressure and all the three pressure switches for measuring the GT-Exhaust pressure.

(e) The <I>-station (GT console) networking is recommended for implementation in multi-GT operation to facilitate in operating a GT when its respective <I>-Station (console) of that machine has failed (not available).

(f) Dedicated PLC & DCS controller sub-system shall be considered for each GT BOP, to avoid tripping of multiple machines due to single PLC failure.

(g) GT operating with liquid fuel shall be provided with duplex HP filter.

(h) The OFF-SKID pressure control valve on liquid fuel service, which maintains the upstream pressure of the GT SKID, shall be installed on the return line for better control and to avoid stagnation of oil in the line for a long period.

(i) Pressure tapping of this OFF-SKID control valve shall be taken from the downstream of the LP duplex filters.

(j) Following shall be provided power from different sources / sub-stations
- GT jacket cooling fans (88- TK 1 and 2). {For frame-6 machines}
- Naphtha pumps.
- HSD pumps.

(k) In case dedicated DM water-cooling system (with pumps) is used for the atomising air cooler. A separate service water line shall be laid up to the atomising air cooler, with draining facility, to avoid interruption of GT in case of failure of the dedicated DM water pumps.

(l) ON-SKID instruments like naphtha purging SOV, Flame scanner JB etc., which are located in the turbine compartment their cables need to be relocated at safe zone.

(m) For multiple GT installation, separate earth-pit-network shall be used for individual GT. Effort should also be made for physical separation of the Mark –IV / Mark – V panels to maintain the integrity of the separate earth-pit networks so that the problem of one unit shall not affect in other units.

(n) Following audio-visual alarms are desirable in the DCS to enhance safety and monitoring of the running GT:
- Failure of any Fire Detectors,
- Fire alarm of Gas Turbine,
- Vibration alarm of Bently System for Load Gear Box of GT.
- Communication-failure of <I>-Station (Console). This alarm is essentially required where the Mark-V panel is installed in the rack room (un-manned location) and away from the control room. In case <I>-Station communication fails, no change in the I-station will be visible, and the <I>-Station will show the last graphics display with the last values of all the parameters. This may create an unsafe condition

(o) Provision by means of a long neck funnel (located away from the level switch) shall be made to prevent actuation of the "LOW LEVEL SWITCH" of the Hi-tech tank during re-filling operation of Hi-tech solution in the tank while GT is running on naphtha.

(p) Heat shield shall be provided to protect the exhaust thermocouple junction box to protect the cables and the sensors

(thermocouples) in case of leakage from exhaust plenum bellow.

(q) The logic (Mark-V) shall be modified to avoid tripping of Gas Turbine on low lube oil pressure protection of warren pump, when GT is running on Gas fuel. An alarm should be provided at low lube oil pressure of the warren pump.

(r) Facility shall be provided to start jacket-cooling fans (88-TK1 & 2) of GT from their respective control room.

(s) A temperature indication and high temperature alarm for monitoring the atomising air temperature after the cooler shall be provided in the control room.

(t) A temperature indication and high temperature alarm for monitoring the GT leg cooling system shall be provided in the control room.

(u) Following additional monitoring facilities with alarm may be provided in the control room (DCS / Mark-V console):

- Differential pressure across the Inlet Air filter,
- Liquid fuel DP across the HP filter,
- Bypass stack temperature (additional point).
- Atomising air temperature after the air cooler.
- Leg-cooler temperature (for Frame-VI machines)

(v) UPS supply shall be provided for GT damper control system.

(w) Swage lock / Parker make fittings may be used for all tubing connections of Gas Turbine.

5.8 Power Station Auxiliaries

(a) Processing plant power stations which produce process steam and electricity must be provided with highly reliable station auxiliaries.

(b) The critical auxiliaries shall be spared and each shall be supplied from an independent sources devoted solely to providing auxiliaries. The sparing philosophy shall be minimum

2 operating (including steam/DC drive)+ 1 Standby + 1 maintenance spare.

(c) Critical auxiliaries for air, fuel, and water supplies at power plant shall have at least one steam driven / DC driven equipment along with AC drives. Similar philosophy shall be adopted for auxillaries of critical process equipment (like MAB, compressors etc)

(d) The number of pumps in operation shall be such that in the event of failure of one running pump the pressure must be automatically maintained.

(e) In case DM Plant operation is on DCS/ PLC, the ON/OFF control of DM Transfer pump should also be available in Hard-Wired Mode. This will ensure DM water service to boilers in case of troubles in DCS/ PLC at DM Plant. Similar practice shall also be adopted for other auxillary systems at TPS (viz. FO, CW, Air compressors etc) where similar situation may arise and may lead to trouble in TPS operation.

(f) Additionally, hard wired alarm for running low pressure / running pump trip should also be available, to initiate corrective manual intervention in case of PLC trouble in any sub system.

(g) The system shall be designed to facilitate maintenance/ removal of pumps/ attend leakages without interruption of operations.

(h) FO system for boilers shall have two headers with interconnection facility to facilitate emergency maintenance jobs without shut down of the FO system

(i) The pipeline network / headers/ heating equipment shall be such that leakage / outage of a particular section shall not affect the power plant operation.

(j) Critical AC Drives (LT) should have a reliable re-acceleration scheme for ensuring reliability during voltage dips.

(k) The critical AC drives should also have a reliable auto-changeover scheme. The auto-changeover shall be activated both by pressure interlock as well as contactor/ breaker interlock. The low-pressure signal for auto-changeover shall be taken from a system of redundant low-pressure switches.

(l) The control supply for auto change over scheme should be either DC or UPS.

(m) Power distribution to the all the installed pumps/ compressors and their auxillary drives shall be such that they are fed from different switchgears which are finally connected to different sections of HT primary and generation bus.

(n) Availability of alarms, annunciation, indications on the following to be ensured in local as well as in the Power Plant control room

- Status of Auto-mode selection of standby pump.
- Low Pressure alarm.
- Auto-changeover alarm.
- Status of equipment running.
- Alarm on tripping of running equipment

6. Power Supply Sources

6.1 General

The power supply system shall be designed to provide safe and economical operation. The safety aspects should cover both plant and personnel. Economic considerations shall cover capital and running costs and an assessment of the reliability and consequent availability of the system.

6.2 Rating and Diversity Factors

Electrical equipment shall be rated to carry continuously the maximum load associated with peak design production with an additional 10% contingency. The ambient conditions at which this rating applies shall be defined in equipment specifications, and unless otherwise approved by IOCL, shall not be less than 45^{o}C air temperature at an altitude not exceeding 1000m ASL.

Assessment of maximum load requirements of an installation shall allow for diversity between various loads, drives or plants. The diversity factors used shall consider the likelihood of loads, drives, production or process trains coincidentally requiring peak demands and shall be based on similar installations wherever possible. The use of diversity factors shall result in "After Diversity Maximum Demands" (ADMD) being used for design purposes.

6.3 Power Import from a Public Utility

Where the principal source of electrical power is selected to be from a public utility, the supply should be via duplicate feeders. An

exception to this may be permitted for economic reasons where low power loads are to be supplied from overhead lines and where a single feeder may be employed, provided that on-site standby generating equipment is available to meet the total load. Critical loads should always be provided for by on-site standby generating equipment, which should only operate in the event of main supply failure.

6.4 On-site Generation with no Public Utility Connection or with Public Utility Connection as a emergency back up.

Where a site is offshore, or remote from a public utility network, or has a surplus of fuel or process energy, on-site generation will normally be selected as the principal source of power. The number and types of on-site generating sets shall depend on :

- The fuel source
- The nature of the process energy
- The process steam or other heat requirements, if any
- The relationship between electric power requirements and the energy sources on any given site.

Unless otherwise agreed by IOCL, a minimum of 3 generating sets shall be provided on sites where there is no alternative electricity supply. The following criteria shall be satisfied:

- There shall be sufficient generation to meet the "After Diversity Maximum Demand" (ADMD), when the largest single source of supply is out of service at peak demand times due to maintenance or any other reason.
- Generation shall be able to cater for the load requiring a supply after automatic load shedding (if provided) when the largest single source of supply is out of service and the second largest single source is coincidentally shut down due to unforeseen circumstances.

6.5 Primary Substation

(a) Generator circuits other than local emergency generators and public utility power intakes shall be connected together at a common primary substation on generation bus. Primary substation shall have separate generation and distribution bus (in double bus arrangements. In certain cases,

however, generators and public utility power intakes may be located at different points throughout the site, in which case there may be a number of primary substations, which shall be interconnected on the site.

(b) The switchgear for primary substations shall comply with following in addition to project specifications.

- Operational flexibility to permit loads and power supplies to be effectively connected under scheduled and unscheduled outages of circuits and busbar sections.
- Minimal switchgear per circuit and simple control and protection
- Unscheduled loss of bus bar sections shall not shutdown the system beyond the level designed and provided for.
- Scheduled maintenance of bus bars shall be possible without system shutdowns beyond those designed and provided for.
- The switchgear shall be indoor metal clad type

(c) Double bus-bar arrangements shall be provided in installations where outdoor air insulated bus bars are supplied or where regular bus bar maintenance is considered necessary for environmental or pollution reasons. They may also be supplied, subject to approval by IOCL, where the operational flexibility available from being able to connect incoming power circuits and outgoing load circuits in a variety of ways is considered to be particularly advantageous.

(d) Where the power supply is obtained from a public utility via equipment such as transformers or feeders, the bus bars shall be sectionalised to prevent total power system shutdown in the event of unscheduled outage of any bus bar section. Coincidental maintenance of a public utility intake transformer shall not be considered.

(e) Primary substations shall be located in areas classified as 'non-hazardous'. The selected location within the site shall take account of the ability to distribute power to the on site loads without unnecessary high distribution equipment costs, shall be adjacent to the generation or public utility intake and shall be suitable for future expansion. Care should taken that primary sub station in not in the close vicinity of humidity and coal dust etc.

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7. Load shedding scheme

A sudden loss of generation in captive power plant may lead to collapse of the total system if demand is more than the generation and if corrective actions are not taken immediately for electrical system / steam generation. It may not be practicable to take corrective measures to prevent the total collapse with manual intervention and therefore automatic load shedding scheme is essential for power system operating in islanding mode. Following key aspects for ensuring effectiveness of the load shedding scheme are to be adhered to

(a) For new projects / New plants/ major augmentation of electrical system the Power & Steam load shedding scheme shall be engineered and executed during project stage. The scheme recommended by project consultant should be thoroughly reviewed and cleared by IOCL.

(b) The Power and Steam Load Shedding Schemes shall actuate "Automatically" and shall always be kept in "Auto" mode. Automatic Scheme will be designed / reengineered in manner that gap between load demand and generation is only shedded. The priority and selection loads to be shed during load shedding should jointly be decided by a multidisciplinary group of IOCL consisting of P&U and Process

(c) Provision of Manual load shedding form TPS control room may additionally be provided for non-critical load / units as a backup for manual intervention.

(d) Load shedding scheme shall be adequate to take care of the simultaneous tripping of the largest power and steam generation sets.

(e) After actuation of all the steps of load shedding scheme, the amount of load available in the system (i.e. remaining plant load left out on the system after actuation of complete load shedding), shall be less than the capacity of smallest machine.

(f) The load shedding should take place in such away that the system voltage and the frequency remain within limits throughout the process of load shedding.

(g) The load-shedding scheme shall have predefined order for the various steps to be shed during a particular type of emergency.

(h) Command from two redundant outputs / relays shall be used to trip a particular step of load shedding scheme.

(i) Scheme shall be provided with reliable & redundant control supply with suitable change over so that scheme shall remain operational in case of failure of one control supply.

(j) Load shedding scheme shall be designed in such a way that it shall automatically take care of climatic impact, any variation in machine response from designed values during emergency etc. System Disturbances / transient phenomenon shall not cause nuisance tripping of the scheme.

(k) Critical loads like UPS, battery chargers, critical process units and critical process equipment shall not be covered under the load shedding scheme.

(l) For improved reliability, it is desirable that the logic / ECS based schemes should be backed up by under frequency-based load shedding schemes for units not running in parallel with the Grid.

In case of under frequency based load-shedding schemes following points to be taken care

- *Loading resistance in PT secondary shall be available during system transients / disturbance at the locations where PT secondary voltage has been used for frequency sensing.*
- *It is recommended to block Frequency Based load shedding during under voltage conditions.*

(m) Self-reset contact and hand reset flag type relays shall be used for actuating load shedding to achieve faster normalization of the system.

(n) All alarm / annunciation/ indications related to healthiness and operation of load shedding shall be made available in the power plant control room / nearly manned sub station.

(o) Alarm / Indication for load shedding operation may also be provided in the Process control room for immediate information.

8. Power Distribution Systems

8.1 General

(a) The distribution network shall be designed to carry continuously at least 110% of the 'After Diversity Maximum Demand' (ADMD) associated with peak design production at the maximum ambient conditions.

(b) The selected distribution arrangement shall have a degree of reliability consistent with the type of load being supplied, and

with the power supply design philosophy which provides for coincidental maintenance and unscheduled outage of the largest component of on-site generating plant or unscheduled outage of the largest feeder component of the power supply equipment.

8.2 Power Distribution System (HT &LT)

(a) HT distribution shall have a separate generation bus and separate Distribution buses in the Primary Sub Station.

(b) The distribution bus shall comprise of two sections with bus coupler having auto- manual change over

(c) The primary as well as secondary distribution buses with bus couplers shall not be fed from the same generation bus or their adjacent sections.

(d) There shall be no outdoor bare / exposed HT electrical installations fed directly from the power plant except grid facilities.

(e) Non-hygroscopic phase barriers shall be used between Phase to Phase and Phase to Earth in the breaker trolley and out going box of HV switchgears. Additionally, the exposed bus bars in the cable box shall also to be provided with HT tapes/sleeves.

(f) Each PCC shall be fed by two identical incomers and a bus coupler. Supply to transformer incomers should be sourced from different HT sections from the upstream. It is to be ensured that the HT supply to PCC incomers should not be fed from the same generation bus or their adjacent sections.

(g) Both transformers for PCCs should be of identical ratings and PCC bus shall suitable for continuous parallel operation with both transformers in service, unless there are limitations of bus fault level.

9. Automatic Bus Transfer Schemes

(a) All the HT incoming / distribution bus section (Primary and secondary) and PCCs with two incoming sources shall be provided with a bus coupler with continuous paralleling capability and with Auto- Manual changeover scheme in order to maintain the reliability of the plant.

(b) All Bus Couplers shall be provided through check synchronization facility for manual closing of breaker.

(c) The control supply for auto-changeover scheme shall be taken from reliable source e.g. DC, UPS with redundancy and auto change over feature.

(d) Master relay (86) contacts of both the incomers to be provided in the common path of the bus coupler closing circuit to block the operation in both the "Auto / Manual" scheme.

(e) The closing command to bus coupler breaker (i.e. to de-activate the auto change over scheme) shall be blocked after a suitable time gap on tripping of any of the incomer breaker. Blocking may be provided through a timer activated from the dead bus condition of the unhealthy bus.

(f) It is recommended to provide inter-tripping from upstream breaker contact between upstream & downstream breaker.

Provision of Inter tripping shall be provided mainly in the following breakers: -

- Incomer breakers at Generation & distribution buses
- HT & LT breakers of transformers
- Upstream & Downstream breakers of the radial feeder

(g) The bus coupler change over scheme shall have separate relays for monitoring the bus healthy and Un -healthy condition. It is preferable to have healthy bus relay setting at 80% and unhealthy Bus relay setting at 40% (or less).

(h) Breaker shall be provided at both the upstream & downstream ends of a distribution section to ensure operational reliability and effective bus transfer during upstream faults (faults out side the bus zone).

(i) It is to be ensured that downstream Bus coupler changeover scheme is not getting blocked on operation of cable differential protection. Cable differential protection should operate master trip relay of upstream breaker. The downstream breaker shall either be directly tripped or through a dedicated master relay for cable differential protection.

(j) In case of transformer protection, the trip command from REF protection shall not actuate the master trip relay of the LT breaker to enable auto changeover of the bus coupler.

(k) It is desirable to provide alarm in control room / manned location for the manual mode selection of the Bus Transfer Scheme.

(l) Momentary Paralleling Scheme For Bus Sections:

All the bus sections are to designed for continuous parallel operation. In case it not possible to have continuos paralleling due to limitation of switch gear fault level, Momentary Paralleling Scheme for Bus Sections may be adopted with prior approval of IOCL. Following points to be ensured in operating the momentary bus paralleling option (manual bus transfer mode) of the bus transfer schemes..

- In "Momentary Paralleling Mode" of bus transfer scheme, manual open command to the breaker shall be defeated.
- A suitable time delay (5 to 10 sec) is to be incorporated in the monetary paralleling mode of the scheme such that the tripping command to the intended breaker is initiated only after successful transfer operation.

(m) In order to ensure the healthiness of Bus coupler auto changeover scheme, a Bus coupler "Auto Circuit Supervision Scheme" shall be incorporated for all bus couplers. (On the similar concept of trip circuit supervision scheme.)

10. Power System Protection

10.1 Protection Philosophy

(a) Protective relay application philosophy shall divide the power system into zones and/or equipment types each having their own relays to determine the existence of faults and to instruct appropriate circuit switches to isolate the fault in the shortest possible time.

(b) The protective system shall be designed to consider the following main criteria :

i)	Reliability	Perform correctly when required and avoid unnecessary operation
ii)	Speed	Disconnect the fault in the shortest possible time

iii)	Selectivity	Ability to locate the fault and trip the minimum number of breakers to isolate only the faulty zone or equipment. Some relays are inherently selective as they only operate for faults within a zone. Others however operate for faults outside their primary zone and therefore need to be made selective by current, voltage &/or time delay co-ordination.
iv)	Economics	Maximum protection should be provided at minimum cost.
v)	Simplicity	Minimum equipment and circuitry should be provided to give the required protection.

(c) Overlapping of protected zones shall always be provided to ensure that no part of the power system is ever unprotected.

(d) At least one independent means of back up protection shall be provided to cater for failure of the primary protection system.

10.2 PROTECTION SYSTEMS

(A) Relay Co-ordination

The system study / relay co-ordination shall be done for grass root projects / revalidated with the new expansions / source augmentation as per IEC guidelines.

(B) Differential Protection

(a) The total electrical system 6.6 KV and above in refineries must be covered with Differential Protection to clear the faults without loss of time. It is not desirable at all to leave even a smallest length of HT system unprotected from this protection and therefore, cross over zones are also to be analysed critically.

(b) Use of ICTs for matching of CT ratios in Bus / cable Differential protection is not desirable for reliability of the scheme.

(c) All HT switch gears (11KV, 6.6.KV, or any other High voltage) must be provided with the Bus Differential Protection.

(d) All the CT's in the differential scheme should have similar characteristics e.g. Vk, secondary resistance, magnetizing current etc. to ensure uniform behavior.

(e) Separate Differential / REF CT's shall generally be used for this specific protection. In case the use of separate CT is not practicable then it is to be ensured that a dedicated core of the same CT is used for Differential/ REF application

(f) The sectionalising breakers provided in the Generation Bus shall be protected only by Bus Differential Protection with crossover zones between two adjacent buses.

(g) The Bus Differential scheme is to be so engineered that No portion of the HT switchgear is left out of the differential zone including the outgoing breakers.

(h) Differential scheme shall have cross over zones with bus coupler, Generator, Radial feeders incomers, transformer feeders etc

(i) Bus Bar Differential protection shall be based on proven & reliable high impedance scheme principle.

(j) It is desirable to use Numerical relays for differential protection with the spill current measurement display feature.

(k) Control supply to the differential relay shall be derived from a separate source with proper identification (not from the normal panel supply in which the relay is mounted).

(l) It is recommended to trip upstream breaker of the primary substation in case of tripping of incomer in downstream secondary switchgear on bus differential/ REF/ Cable Differential protection.

(m) Each breaker connected to the bus should trip on actuation of its Bus Differential Protection.

(C) Cable Differential Protection

(a) All HT radial feeders within Refinery shall have instantaneous pilot wire cable differential protection for instantaneous clearing of the fault.

(b) The feeders for which it is not possible to provided Feeder Differential Protection due to long cable lengths and non-critical

feeders must be provided with Instantaneous O/C and E/F protection in addition to IDMT protection.

(c) Cable differential protection shall have zone cross over with the upstream/ downstream bus differential protection.

(d) It is desirable to have same electrical specifications of CT's at both the ends w.r.t. ratio, resistance, knee point voltage, polarity for ensuring stability of the scheme.

(D) Other Protections

(a) It is desirable to install only window type CT's for both protection / metering in the critical HT switchgears. Only CT's with low ratio shall be of wound type construction if window type CT's are not available for that application. The PD value of the window type CTs shall be less than 20 pc.

(b) It is recommended not to take any control / CT wiring through the main HT bus chamber. In case it is not possible to reroute/ modify the wiring then proper dressing & clamping of the wiring is to be ensured.

(c) Transformer Differential Protection shall be provided for Transformers having HT voltage in primary and secondary side.

(d) .All the transformer feeders for PCC shall be provided with Instantaneous (high set) over current, three phase IDMT Over Current, and Earth Fault protection. The Earth fault protection shall be provided by CT connections in residual mode.

(e) In order to achieve complete isolation of fault, master relay operation of any downstream breaker should also trip the upstream breaker.

(f) The healthiness of "Trip Circuit" is to be ensured through a suitable "Trip Circuit Supervision scheme with continuous monitoring" in all the HT switchgear panels with alarm at manned locations.

(g) Numerical relays are normally using interrogation voltage feature (24v, 48 v) for interlocks / remote tripping. In such cases, it is desirable to use direct contact in place of contact through relay for critical interlocks. If dedicated contact is not feasible then It is recommended to use 220 or 110V interposing relays with energise to trip logic instead of using low voltage signals as binary inputs for inter-tripping interlock purpose particularly for intertripping of long distance breakers. It is also desirable to have shielded cable for low voltage applications.

(h) Watchdog timer alarm (Numerical relay faulty) to be wired up to control room / manned location.

(i) It is desirable to use Reed Switch type Bucholz Relays in place of Mercury Switch type relays in seismic prone area.

(j) It is desirable to provide clean & dedicated earthing for the numerical relays

(k) It is recommended to trip the breaker directly without using any intermediate numerical / auxiliary relay for ensuring reliability / integrity of tripping the circuit breaker in the event of numerical relay failure. The breaker service position contact should not be included in the tripping logic of breakers.

(l) All PCC Transformer should have REF protection

(m) All the transformer auxiliary protections (Bucholz, Oil temp. / Winding temp / Minimum oil gauge) shall be provided with alarms / tripping..

(n) In order to achieve complete isolation of fault, it is essential that master relay operation of any downstream PCC incomer breaker should also trip the upstream HT breaker

(o) In general numerical type relays shall be used, except for MCC fed LT motors where relays can be numerical/ conventional type.

(p) Protective relays shall be of the "semi flush" or "flush" mounting type with "draw-out" construction.

(E) LT Motor Protection

(a) For the LT motors having rating of 37 kW and above or fuse rating 160 Amp and above, it is desirable to provide an earth fault protection in addition to fuses to facilitate coordination with the upstream breakers.

(b) All process trip relays shall be self reset type contacts with hand reset flags or reset facility from PLC / DCS.

(F) Current Transformers (CTs) and Voltage Transformers (VTs)

(a) All CTs should have a 1 amp secondary rating unless otherwise approved by IOCL

(b) CTs for high impedance differential and/or restricted earth fault protection shall be exclusively used for that purpose.

(c) Separate CTs shall be used for protection and metering duties unless there is space constraint.

(d) VTs for protection shall be three phases for all directional and wattmetric type protection schemes.

11. Under Voltage Management

(a) All Bus incomer breakers up to the PCC level shall be provided with the "Under Voltage Tripping Scheme".

(b) Upstream (primary side) feeders for Transformer & PCC outgoing breaker to MCC shall not be provided with U/V tripping.

(c) The complete under voltage tripping scheme provided for the distribution system at various voltage levels shall be time graded.

Under voltage protection co-ordination of power distribution shall preferably be such that the time delay at the highest voltage level is minimum and the time delay at subsequent lower voltage levels is suitably increased in steps.

(d) Under Voltage tripping of the incomer breakers shall not be given through the master relay.

(e) The under voltage tripping shall be initiated from the line side PT of the incomer breaker and should not be from bus PT.

(f) To achieve reliability in the scheme and to prevent its mal-operation, under voltage condition of at least two phases shall be used for tripping to the extent possible.

(g) In case numerical relays are in use, either "AND" mode is to be selected (If the feature is available) otherwise contacts derived from two phases shall be used as the same numerical relay is used for all the three phases.

(h) Under voltage scheme is to be so engineered that;

- *The incomer breaker should not trip in case the other incomer is also experiencing under voltage simultaneously.*
- *The incomer breaker should also not trip in case the other incomer breaker is OFF*

(i) It is desirable to block under voltage trip scheme to prevent mal-operation of the scheme due to incomer PT fuse failure condition.

(j) In order to achieve faster restoration of the system after total power failure, under voltage tripping relay contact multiplication (if required) should be provided through self reset relays.

12. Power System Control

(a) Sufficient instrumentation metering, control switches and alarms shall be provided at each location to enable safe control and monitoring to be accomplished.

(b) It is desirable that each HT bus section should be provided with dual redundant DC control supply. The redundant DC control supply shall be designed for auto / manual changeover to the alternate backup DC supply or Diode based dual supply shall be provided for the each panel

(c) The auxiliary power supply of the numerical relays shall be drawn separately and not from a common control supply switch of the breaker panel.

(d) Control supply failure alarm shall be available at manned locations for prompt remedial action.

(e) Failure of the DC control supply shall not trip any breaker / process equipment. The contacts used for providing interlocks in the breakers mainly for the tripping logics shall not be taken from the multiplying contactors / auxillary relays.

(f) The control supply to protection relays shall be separate from the breaker control supply in the switchgear feeders where Numerical relays are used

(g) The control supply to MCCs shall only be AC. In view of the reliability of the plant it is desirable to have control supply derived from the individual modules in MCC.

13. Re -acceleration & Auto change over of LT Motors

(a) Re-acceleration scheme shall be provided for the selected extremely critical motors in the refinery..

(b) The control supply to re- acceleration scheme should preferably be DC / UPS.

(c) In case UPS / DC control supply is not used, re-acceleration scheme shall be provided with stay put / latched contact from a timer / PLC / DCS. In such case, it is to be ensured that the

contact gets de-energized in case motor field stop / trip command is generated.

(d) It is recommended to provide only PLC / DCS based re-acceleration schemes

(e) The critical AC drives should have a reliable auto-changeover scheme in addition to the re-acceleration scheme. The auto-changeover shall be activated both by pressure interlock (Process Interlock) as well as contactor/ breaker interlock. The low-pressure signal for auto-changeover shall be taken from a system of redundant low-pressure switches.

(f) To the extent possible, the control supply for auto-change over scheme should be either DC or UPS.

14. Alarms and Annunciation

(a) SCADA type systems shall be used.

(b) Each generator alarm panel shall have an alarm window associated with each separate alarm condition

(c) All the critical alarms of power plant sub station (viz, Incomer/ Bus Coupler Trip / Critical PCC Status /Control Supply Status / UPS Status/ Battery Chargers Status/ Status Of Load Shedding etc) shall be extended to the power plant control room, in addition to Generator related alarms.

(d) All the critical alarms in unmanned sub stations (viz. tripping of incomers, bus coupler change over, control supply status, UPS trouble, charger trouble, critical VSD trouble and tripping of any other very critical equipment) shall be extended to nearest manned substation / location for initiating quick action by electrical personnel.

15. Power System Studies

15.1 General

(a) The power system design aspects of new installations and extensions to existing plants shall be studied using computer programs to aid analysis where necessary.

(b) The analysis shall be used :

- To define equipment parameters before purchasing

- Select control and protective relay settings
- Ascertain the system reaction to normal and abnormal operating conditions

(c) Stability studies shall be carried out for steady state, transient, dynamic and induction motor stability analysis and also taking into consideration the health and aging of the existing power system and its equipment.

15.2 Conventional Studies

15.2.1 These shall include

a) Load flow analysis – to check voltage profiles and circuit loading conditions under steady state conditions.

b) Short circuit studies – to analyse fault currents that might flow under a variety of symmetrical, asymmetrical and unbalanced fault conditions. These shall be used for switchgear specification and control and protective relay application and setting purposes.

c) Stability studies – to analyse the transient and dynamic performance of power systems after large load changes and fault disturbances. These should be used to check :

- The ability of the system to stay in synchronism
- Induction motor stability after start
- Reacceleration and restart schemes
- The need and effectiveness of under frequency load shedding schemes

They should also be used to consider the technical merit of :

- Auto changeover scheme
- Parallel or open operation, or radial feeders
- Operation of fault limiting devices
- Insertion of switched reactors or capacitors, etc.

15.2.2 Relay co-ordination studies:-

(A) Protection Relay Settings

(a) Relay setting philosophy shall divide the system into zones covering generators, busbars, transformers, motors and feeders. These shall be adequately protected with the minimum time of system disconnection in the event of a fault.

(b) The choice of protective devices and their settings shall be dictated by the ability to protect without preventing normal operation of the system, and to ensure co-ordination is obtained with other devices that are in the same chain under consideration.

(B) Relay Setting Studies

(a) Short circuit studies shall be conducted on the system to be protected in order to obtain the necessary data to select the most appropriate relay ranges and to set the relays most effectively.

(b) These studies shall be carried out to determine current flows for three phase, phase to phase and earth faults at all busbars & extremities of the power system.

(c) For relays operating in less than 0.2 seconds, the current flows shall be determined by using either subtransient reactance values or calculated reactance values appropriate to the first half cycle of the fault which will be 10 m.secs for 50Hz systems and 8.3 m.secs for 60 Hz systems. These are generally known as fault make currents.

(d) For relays operating in 0.2 seconds and above, the current flows shall be determined by using either transient reactance values or calculated reactance values appropriate to actual circuit break contact parting times plus 10 m.secs. These are generally known as fault break currents. In most cases computer aided studies are unnecessary for earth fault current flows as earth faults are limited either by neutral earthing equipment or, virtually identical to those obtained from three phase studies on solidly earthed systems.

(e) Relay setting and application short circuit studies may adopt a simple approach to motor contributions. In this event induction motor contributions based on locked rotor reactances shall only be used for relays that operate in less than 0.2 seconds and

may be ignored for all slower acting relays. Synchronous motor contributions shall be considered for both types of relays.

(f) When analysing the results of phase to phase and earth fault studies the effect of delta/star transformer connections on fault currents shall be taken into account when determining "upstream" relay settings. Phase to phase faults on the secondary side of such transformers would be 0.866 of the equivalent phase fault current, but on the primary side the line currents would be half the referred phase fault current in two lines and equal to the referred phase fault current in the third line. Phase to earth fault currents on the secondary side of such transformers which are solidly earthed, would be equal to the equivalent phase fault current but on the primary side the line currents would be 0.577 of the referred phase fault current in two lines and zero in the third line.

(g) Short circuit studies for relays shall be carried out both under maximum and minimum generation/load. Studies shall also be done with certain pre-selected distribution system outages to ensure satisfactory relay operation. The latter requirement is particularly appropriate on ring fed systems where the first breaker to clear generally leaves the fault fed via a longer or higher impedance route.

(h) Differential relays shall be set in accordance with manufacturers' recommendations, bearing in mind the through fault stability requirements, and the effect of power transformer tap changers where these are within the differential zone.

15.2.3 The above studies shall be carried out with terms of reference approved by IOCL as early as possible within a project. The software programs and computer capability shall also be approved by IOCL. Models for generators, automatic voltage regulators, governors, motors, transformers, cables and loads shall be sufficiently detailed and proven to give confidence in the results of the studies. In certain circumstances, the actual study work may be carried out by IOCL to ensure that a permanent data file, which can be modified as changes occur, is available throughout the life of the installation.

15.2.4 Steady state stability studies shall be limited to systems which may be operated at leading power factors. In all cases however, inspection of generator operating charts to ascertain that they are always likely to be operated within their prescribed stability limit shall be carried out.

15.2.5 Transient stability studies, using first swing criteria for the first second after a disturbance, shall be carried out on systems which include :

- Dissimilar on-site generators
- On-site generators operating in parallel with a public utility
- Synchronous motors

These studies shall be used to determine whether synchronous machines are liable to fall out of synchronism after the most severe single disturbance. Generally this shall be a three phase fault applied at the generator busbars for a fault duration determined by the protecting switchgear, which when cleared results in disconnection of the largest single fault contributor from the system.

15.2.6 With transient stability studies the steady state operating condition before the fault is applied shall be one in which the spinning reserve of generation is kept at a minimum due to assumed maintenance of the largest on-site generator. The primary object shall be to obtain the maximum acceptable fault clearing time, but secondary objectives such as the best location of system open bus section points, and the relationship between impedance earthing to stability should also be ascertained from these studies.

15.2.7 Dynamic and induction motor stability studies shall be carried out to investigate the performance of the system after a major disturbance for the period from 1 second after the fault to the time when steady state equilibrium is reached. They shall all require AVR and governor modelling as these items assist the return to steady state and will react positively in the time scales likely to be considered. Loss of frequency, loss of voltage and loss of induction motors shall be checked with these studies.

15.2.8 Stability studies shall be carried out to consider the loss of the largest power supply component under an earth fault or a mechanical trip condition as these circumstances do not normally result in motor loads being tripped by a.c. contactors dropping off under low voltage, and may therefore result in the greatest post fault generation deficiency. Where the frequency drop is predicted to exceed 6%, underfrequency load shedding schemes shall be considered. In such cases, stability studies shall be used to define the minimum number and magnitude of the various stages of load shedding that will be necessary to keep the frequency loss within acceptable limits.

15.2.9 Induction motor stability studies shall be carried out to cover the ability to start, reaccelerate or restart motor loads without their stalling or

tripping under overload. Re-acceleration studies shall determine whether motors reaccelerate after the disturbances described in 9.2.7 have cleared. Where motor restart schemes are required, induction motor stability studies shall be used to define the maximum number and magnitude of the various stages of re-start that will be possible after clearance of faults as described in 9.2.4, without causing further undue voltage disturbance.

15.3 Special Studies

Harmonic penetration studies may be necessary to analyse the magnitude and location of harmonic distortions within the power system. These studies shall be required whenever rectification equipment represents a significant proportion of the total rating of a system at any one voltage level or where there is concern about harmonic levels being excessive.

16. HT Motors

16.1 HT Motor Switch gear Configuration

(a) Emergency Stop Button of HT motors should directly trip the breaker without routing the command thru' DCS/ PLC or a parallel direct command to be provided in addition to the command thru DCS / PLC.

(b) The critical *single* synchronous motors provided without PMG's for excitation and getting tripped during power system under voltages, it is desirable to provide reliable excitation power supply to the exciter panels either from dedicated three phases or single phase UPS or any other reliable source, as feasible. In case scheme is provided through UPS, only proven UPS systems to be considered.

(c) To ensure the proper functioning of space heaters in HT motors, it is desirable to have an ammeter in the panel for monitoring the space heater current

16.2 Protection and control

(a) In case Numerical relays *are* provided for Motor feeders, the control supply to protection relays shall be separate from the

breaker control supply in the switchgear panel *to avoid problem of data loss*.

(b) Critical contacts used for providing process interlocks shall be direct hard contacts and these shall not be taken from the multiplying contactors / auxiliary relays

(c) The Earth fault protection for motors should have "Instantaneous Tripping". A suitable stabilizing resistance is also to be used to prevent mal-operation on account of spill currents.

(d) All process trip relays shall have self reset Contacts and Hand reset Flag or reset facility from control room through PLC/ DCS.

(e) In case of numerical relay applications it is recommended to directly trip the breaker without using any intermediate numerical / auxiliary relay/ PLC intervention etc. for ensuring reliability / integrity of tripping the circuit breaker in the event of numerical relay failure.

(f) The breaker service position contact shall not be included in the tripping logic of breakers.

16.3 Auto start of HT motors

(a) The critical motors of power plants shall have a reliable auto-changeover / Auto-start scheme. The auto-changeover shall be activated both by pressure interlock as well as contactor/ breaker interlock (The low-pressure signal for auto-changeover is desirable from redundant low-pressure switches,

(b) The control supply for auto-change over scheme shall be provided from a reliable source.

16.4 Under Voltage Trip Scheme for HT motors

(a) All HT motors shall be provided with a Time Graded (e.g.0.5,1.0, 2.0, 3.0 Sec etc) under-voltage trip scheme to ensure recovery of the system after voltage dips and to safe guard the health of motors.

(b) The setting of under voltage relays shall not be less than 75% for tripping of HT motors.

(c) The voltage input to under voltage relay shall be derived from the Bus PT of the switchgear section from which the motors are connected.

(d) Voltages of at least two phases shall be used for under voltage tripping of the motors.

(e) Blocking of under voltage tripping scheme of motors to be provided in case of fuse failure, by using Fuse Failure relays

(f) Contact multiplication of under voltage relay, if required, for the purpose of tripping of various HT motors, shall be provided through self reset type relays / auxiliary relays.

(g) Under voltage command for trip motors shall be direct to breaker and not through the motor feeder Master Trip Relay.

17. DC systems

(a) Each HT sub station complex shall have a separate dedicated DC system.

(b) Each DC System shall be provided with two battery banks and Dual Float cum Boost Charger (100% each). The output of which shall be connected to two DC bus sections with coupler switch and finally connected to each section of a dual DCDB.

(c) The battery charger supply shall be taken from the switch fuse units / MCB's and not from contactor based modules. The incoming power supply sources of the battery charger system shall not fall on the same primary Generation / distribution source at 11 kV level.

(d) The battery charger shall have a provision to come into service automatically after the system is recovered from voltage dips or restoration of power supply in the event of plant interruptions.

(e) The DC distribution system shall have dual DCDB with a coupler switch.

(f) Provision shall be made to monitor the DC leakage current in the system with a milliamp meter at DCDB / control room or in ECS

(g) Following alarms shall be provided in the control room / manned locations.

- DC ground fault alarm
- Boost charging alarm of the chargers
- Battery Charger fail alarm
- Alarm for filter capacitor bank fuse monitoring to take care of ripple content.

(h) DC systems commonly feeding to both Instrumentation system and emergency light should be separated by having separate DC systems for each. However, in view of the space constraints and economic considerations the DC emergency light system can be combined with the 220V DC system meant for feeding electrical controls (where, unlike instrumentation systems, momentary dip in DC voltage does not affect the plant operation) by suitability increasing the capacity of the battery bank and using a dedicated sub DCDB for lighting which in turn can be fed from the main DCDB of 220 V system.

18. UPS

(a) There shall be dedicated UPS system for each process unit (associated units).

(b) UPS system shall be Parallel redundant types with each UPS capable of feeding 100% plant load. The UPS shall have Dual ACDB..

(c) Separate battery banks shall be installed for each UPS section

(d) Incoming power supply sources to the UPS system (UPS-1 / UPS-2 / Bypass) shall not fall on the same primary Generation / distribution source at 11 kV level. It is preferable to provide the bypass incoming supply form a different substation/ PCC.

(e) All the input supplies to the UPS shall be provided from SFU's & not from the contactor controlled modules.

(f) All UPS alarms shall be extended to the manned location / control room..

(g) UPS systems shall be placed in only dust free air-conditioned atmosphere.

(h) The power supply to auxiliary equipments e.g. tube light, fans, space heater etc. shall not be a UPS supply and shall be taken form the normal plant supply

19. VSDs

(a) Use of VSDs shall be avoided in case there is single equipment used for a particular service and tripping of which may result in tripping of process unit

(b) In case it is not possible to do away with VSDs, It is recommended to run two motors with VSDs in parallel, at 50% load on each, for critical applications. It is to be ensured that suitable damper / isolation arrangement exists between the parallel running drives to prevent reverse rotation in idle condition.

(c) In case of existing single critical drive operation, the feasibility of providing redundant VSD's in hot standby mode may be explored, provided change over delay are within the process tolerances

(d) The drive panels of VSDs shall be installed in dust free and air-conditioned environment with humidity control in order to protect the electronic components / PCB's of drives panels from dust & heat.

(e) Critical cards which are essential for the successful operation of the VSD be provided with redundancy with diagnostic feature and a provision for online replacement of defective card

(f) The critical power supply units (Cards) installed inside the drive panel shall be redundant.

(g) The drive enclosure shall have IP-42 class ingress protection for fan cooled type enclosure & IP-52 for self ventilated enclosure. Additional precautions to be taken to minimize the dust entry if the above-mentioned class is not provided for the panels.

(h) The interlocks/ logics in VSDs shall be PLC based..

(i) Drives must be provided with "Power Off Ride Through feature" to maintain drive operation during voltage dips and power changeovers.

(j) The auxiliary / Control supply of the drive panel shall be provided from reliable source e.g. UPS / DC source depending upon the requirement.(wherever control supply is not derived internally)

(k) Only reputed make of relays with PTR for similar application shall be used for process interlock tripping.

(l) Reliability in providing the critical "drive run signal" to the PLC is to be ensured & following measures are to be taken: -

- Both Drive run and Drive fault signal shall be independently given to PLC for monitoring the status and better diagnostics purpose.
- In order to prevent spurious tripping due to momentary loss of drive run signal (due to loose contact etc), feasibility of providing interlocks with the process parameters e.g. Furnace draft etc may be explored & implemented.
- Analog 4-20 mA signals shall be provided through screened control cable.

(m) The necessary latching (holding of command) of start command shall be done at the drive panel end & only pulse type command shall be generated from the PLC / DCS to take care the possibility of tripping of drive due to momentary missing of contact due to any cable termination / contact looseness problems.

(n) The earthing requirement for the VSD's as per OEM shall be strictly adhered to during execution

(o) HT motors with VSD applications shall have insulated bearing.

(p) Only screened type signal cables are desirable in VSD applications.

(q) Normally, the drive shall be self-cooled (without ventilating fans). However, in case ventilating system with fans is necessary, redundant ventilating fans must be provided with 100% capacity,

(r) The cards provided in VSDs should be capable to function well in the environment VSDs are installed in substations, where possibility of dust & moisture cannot be completely ruled out.

(s) For effective troubleshooting, provision shall be made to have trending of VSD parameters & alarm logging through a dedicated PC/ DCS.

(t) Separate control cable shall be used for different voltage level of control supplies.

20. Distributed Control System (DCS)

20.1 General

The DCS shall primarily drive the instrumentation required for : - Processing all plant input and output signals; providing fault tolerant basic regulatory control of process variables; and managing a comprehensive, prioritised alarm capability. It shall able to accommodate the major portion of advanced controls, and shall act as the platform for plant operating data to be made available to process control and refinery information computers. It shall also be capable of monitoring, via serial link, other independent instrument systems, such as ESD, compressor surge control, gas detection systems, machinery condition monitoring equipment, etc. Typically, DCS systems shall be designed with at least 25% spare capacity upon project completion.

20.2 Redundancy and Reliability

The DCS shall be designed with sufficient redundancy such that no single component failure shall affect plant operability or safety (this includes operator interfaces such as VDU's and keyboards). This means that full redundancy must be provided for all control loops and monitor only points, that are critical to safe plant operation. Redundancy includes everything from the power supply feeders into the control cabinets and I/O boards.

Electronic systems shall be provided with multiple electric power feeders and an uninterruptible power supply providing a minimum of thirty minutes of continuous operation after power failure. Uninterruptable power supplies shall be made fully redundant. This includes battery banks, chargers, inverters and static bypass switches.

All redundant communications cables etc., shall be routed separately so that in the event of physical damage to one cable, its redundant back up cable will not be affected. The use of fibre optic cabling external to the

Control Room should be considered, to minimise Radio Frequency and Electro-Magnetic interference.

20.3 Operator Interface

Every effort should be made to minimise the number of "windows" that the operator has into the process. Preferably the DCS will be the only window. The use of hardwired annunciators should be minimised, although some critical alarms, such as DCS failure or UPS failure are typically tied into an annunciator.

An operating console containing at least three VDU's shall be provided for each control operator. The actual number of VDU's shall be determined by the number of screens required to control the process safely, and by the requirements for redundancy.

Each console shall be independent in its function and serve one or more process units, providing a single window for the operator to view his process.

21. Instrument Power Supplies

This section describes IOCL general requirements for electrical power supplies for Instrumentation and control systems. This includes power supplies for field instrumentation, control panels, distributed control systems, telemetry systems, supervisory computer systems, emergency shutdown systems and fire and gas detection systems.

21.1 General Requirements

(a) Instrument power supplies shall be designed such that the security of power supply is consistent with the integrity required by the connected loads, and does not exceed this requirement.

(b) Power supplies shall be designed such that they meet the requirements of the connected loads in terms of:

- Voltage
- Voltage stability
- Frequency
- Rate of change of frequency
- R.F. content
- Maximum interrupt time
- Harmonic content
- Power factor

(c) Power supply capacities shall be rated to take account of switching surges and the effects of harmonics and transient loads.

(d) Power supply capacities shall be rated to take account of any anticipated future expansion requirements.

(e) The design philosophy for instrument power supplies shall be subject to approval by IOCL.

21.2 Security of Supply

(a) Instrument power supplies shall be classified according to the required integrity of the connected loads as Class A, B or C.

The basis of this classification is that loss of supply will cause:

i) Class –A

A shutdown of the whole or major part of a plant or process, a failure to shutdown under emergency conditions, loss of monitoring facilities on critical items of equipment, loss of fire and gas alarm annunciation, or loss of alarm annunciation on any other system specified by IOCL.

ii) Class-B

An acceptable temporary loss of control, degradation of normal monitoring or control where alternative methods are available, or loss of other alarm annunciation facilities.

This classification can apply to a supervisory computer system where back up panel instrumentation exists or control room operation where local plant control panels exist. The operation of a plant from hand wheels can not normally be considered as an acceptable foprm of back u control.

iii) Class-C

No significant impairment of the ability of the operator to control and monitor the plant.

(b) Classification of the power supplies shall be subject to approval by IOCL.

21.3 Design Requirements

Instrument power supplies shall fulfil the following requirements :

i) Class A

Supplies shall automatically maintain a continuously uninterrupted electricity supply within the required tolerances upon failure or deterioration of the primary source, or any other item of power conversion equipment, for a period of one hour (1 hr) or as otherwise specified by IOCL. They shall be separate and independent from other supplies except the primary a.c. source.

ii) Class B

Supplies shall automatically maintain continuity of electricity supply within the required tolerances for a period of one hour (1 hr), or as specified by IOCL. The changeover time between normal and standby circuits shall not be greater than 10 m/sec or as otherwise specified by IOCL.

iii) Class C

Supplies have no requirement for a standby source of supply.

21.4 Distribution and Protection

(a) Protective devices shall be time and current graded to maintain discrimination

(b) Cartridge type fuses should be used throughout the power supply system. Protective circuit breakers may be used only in final sub circuits provided it can be demonstrated that discrimination will be maintained with the other protective devices.

(c) Two separate AC distribution boards (Dual ACDB), fed from parallel redundant UPS shall be used for instrumentation power distribution system for the improved reliability of instrumentation system.

(d) A separate switched and fused sub circuit shall be provided for each functional loop. Redundant equipment shall be separately switched and fused.

(e) Each sub circuit shall be clearly labelled with a unique identifier.

(f) The UPS supply shall not be used for the utility supplies like cooling fans, lighting power sockets in the consoles / panels / cabinets / Local Control Panels, etc. A separate non-UPS supply shall be used for the same.

(g) The distribution shall be designed such that failure of a single sub circuit does not cause an unacceptable loss of control or loss of data display to the plant operator.

(h) Integral Power Supplies

(i) All the cooling fans in the cabinets / panels / consoles etc. shall be in operation to avoid failure of cards due to high temperature. "Fan failure" alarm shall be ensured and must be attended on priority.

(j) Where dual power supplies are installed to increase availability indication shall be provided to show failure of a single supply.

(k) Minimum two numbers of Bulk Power Supplies (BPS) shall be configured for powering all critical instrumentation systems..

(l) Power supplies shall be clearly labelled with a unique identifier.

21.5 Monitoring and Alarm Systems

(a) Sufficient information shall be provided either remotely or local to the power supply equipment to enable rapid identification of fault conditions or confirmation of healthy status.

(b) Alarms shall be provided to indicate at a manned control point any fault condition on a major unit in a power supply system. This may take the form of a common alarm requiring examination of the local indication to diagnose a fault condition.

(c) Remote signaling of alarm conditions shall be classified into the categories :

- Emergency Trip
- Urgent Alarm
- Information

22. Operations & Maintenance

All control and recording of variables pertinent to safe, economic and reliable operation shall be located in the Central Control Room. An extensive radio and paging facility shall be provided for operator to operator and inter control room communications, particularly for outside operators, who will perform local outside operations tasks.

Where an outside operator's attention to equipment and systems is required on more than a periodic basis, or required for local take over during start-up, shut-down or gross upsets, local instrumentation shall be provided to the extent necessary to accomplish his job safely and reliably.

The overall operations start up sequence shall be determined early enough in the Front End Engineering, to ensure that the design, and Process Hazard Analysis (HAZOP) studies, recognise this sequence. In addition, this knowledge will aid construction planning, ensuring the most efficient commissioning and start up of the completed facilities.

Care shall be exercised in piping design to ensure that frequently operated valves, control valves, orifice plates, D/P cells, and other items which require regular maintenance are accessible from grade where possible.

Special attention shall be given to standardisation and interchangeability of equipment and spares.

23. REFERENCE TO CLAUSES WHERE IOCL's APPROVAL IS REQUIRED

Clause No.	Subject
5.3	Steam balance using process waste heat boilers and nos. of Steam Generators
6.2	Ambient conditions
6.4	Nos. of power generating sets
6.5 (c)	Changes in the bus bar arrangement
7(a,b)	Power and Steam Load shedding (Approval of design and selection of loads)
9(l)	Adopting momentary paralleling scheme is switchgears
10.2 F(a)	CT ratings
15 (2.3)	Approval for software programme for system study
21.1(e)	Design philosophy for instrumentation power supplies
21.2 (c)	Approval on classification of instrument power supplies

IOCL's SPECIFIC REQUIREMENTS

FOR INSTRUMENTATION SYSTEM

IOCL's SPECIFIC REQUIREMENTS FOR INSTRUMENTATION SYSTEM

CONTENTS

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IOCL's SPECIFIC REQUIREMENTS FOR RELIABLE INSTRUMENTATION SYSTEM

1 Scope

This document highlights some of the specific requirement of IOCL, which are to be adopted by the contractor/ agency in interpreting minimum requirement for the Instrumentation Systems, along with other project specifications, before detailed design/ engineering is taken up.

The guidelines deal mostly with front-end engineering design, which does not necessarily provide complete design basis. As such, the focus is on what is to be produced as an end result and not on how this is to be achieved. It is, therefore, a communication document to obviate interface difficulties. The requirements outlined hereunder are to ensure a reliable instrumentation system. However, the statutory requirements/ regulations for the instrumentation system need to be complied with during the engineering and execution.

The scope covered is typical for a Grass Root Refinery Project. The guidelines shall also be applicable for Instrumentation systems of new refinery projects(Grass root), New plants and extensions / modifications in the Instrumentation systems of existing refineries/plants.

2 Control / Deviations

The IOCL specific requirements laid down herein below are to be strictly followed for all the new jobs as mentioned above. Any project specific deviation to the laid down requirement shall be with the prior approval of the Head of the Project at HQ or Unit Head depending upon the type of project. The reason for deviations along with its merits / demerits should be clearly spelled out while seeking the approval for any such deviation.

3 IOCL Design Concepts

The objective in designing new and revamped plant is to achieve performance comparable with, or exceeding that of, leading refineries in the region. The design shall be based on the most cost effective and commercially proven technology, applying the most appropriate philosophy and methodology to each individual project situation. In this respect, the contractor/ agency will be expected to expand upon, and improve where possible, the design approach indicated in this document, and other project specifications.

4 Control Room Instrumentation

(a) The emergency shut down system shall be implemented in a dedicated PLC and the regulatory control / monitoring in the controller sub-system of DCS only.

(b) The transfer of data between the logic solver (PLC) and the controller sub-systems through soft link (that is, transfer of data between PLC and DCS controller and vis-à-vis) should only be used for monitoring purpose and not for control and trip, unless recommended by licensors / statutory bodies like TUV etc. with proper technical justifications.

(c) Input signal voting (2-O-O-3) shall be configured for all the tripping interlocks.

(d) All the inputs and outputs related to a trip circuit shall be configured in the SOE with comprehensive description.

(e) Emergency shutdown push buttons for all the electrical drives shall be connected directly to the MCC and not through PLC.

(f) Two separate AC distribution boards (Dual ACDB), fed from parallel redundant UPS are desirable for instrumentation power distribution system for the improved reliability of instrumentation system. (Refer Schematic- A).

(g) The UPS supply shall not be used for the utility supplies like cooling fans, lighting power sockets in the consoles / panels / cabinets / Local Control Panels, etc. A separate non-UPS supply shall be used for the same.

(h) A summery (common) alarm of all critical UPS alarms shall necessarily be provided in the DCS and hardware annunciation in the control room or any manned location.

(i) Only copper cables and tin-plated copper lugs shall be considered for Instrumentation power distribution system i.e. from ACDB/ DCDB to down stream distribution systems.

(j) UPS Battery back up should be available for a minimum period of 60 min, at full load condition. The same to be ensured during capacity discharge test of the battery bank during pre-commissioning activity.

(k) Protection coordination with respect to the fuse/MCB ratings from the supply source ACDB / DCDB to the downstream distribution panels shall be thoroughly studied by the system designer / OEM and documented as a part of the system documentation, and be implemented accordingly.

(l) Elimination of unwanted fuses & use of proper fuses in power distribution to be ensured.

(m) Power supply to all critical devices like, PLC, DCS, operator console etc. shall be drawn through individual feeders and not by "looping in" or "looping out" from a common source (Refer Schematic- C).

(n) The DC power supply source, for instrumentation emergency shut down system shall be segregated from emergency lighting system.

(o) Minimum two numbers of Bulk Power Supplies (BPS) shall be configured for powering all critical instrumentation systems. (Refer Schematic- A & B).

(p) Use of multiple set of BPS (Bulk Power Supply) of smaller capacity in place of single set of higher capacity per unit shall be considered.

(q) A set of redundant-BPS shall be fed from two separate AC feeders. Power looping in and looping out shall be avoided / eliminated. (Refer Schematic- A & B).

(r) The loading of individual BPS should be such that the failure of single BPS shall not result in loading of the other operating / redundant BPS beyond 70% of their individual rated capacity).

(s) "BPS failure" alarm shall be provided in hardware annunciation system and in DCS with highest priority.

(t) Auxiliary power supply to the individual flame scanners / Igniters of any boiler to be sourced from separate locations, to avoid total shut down of the boiler.

(u) Unit wise segregation of power supply distribution to facilitate necessary maintenance during individual unit shut down to be ensured.

(v) Proper segregation of data bus / prefab cables & power cables below false floor shall be ensured.

(w) In consultation with process (PJ) and instrumentation (PJ) the number of process alarms shall be optimized.

(x) The identified Process alarms shall be judiciously prioritized (emergency / high / low etc.) on the basis their criticality.

(y) To avoid confusions related to electrical interfaces, it is recommended to build additional graphics in the system to show the status of the critical commands and flow of critical process logics. For example, if the start command of a compressor is generated from the output card of the system (DCS / PLC), the spare contact of the respective output relay shall be configured in a separate input point to facilitate to monitor the status of the command in the graphics.

(z) PLC consoles shall be considered in the new systems to understand the status of the "Logic flow" of the respective systems.

(aa) The air conditioning system of a control room shall be designed in such a way that can maintain steadily thorough out the year a control room temperature of 22~24 Deg C.

(bb) The control room air conditioning system shall have two AHU, supply and return air ducts dedicated separately for the console room, and the rack room.

(cc) Facility shall be provided for on-line monitoring of control room environmental parameters (like temperature, humidity, copper-silver corrosion etc.) with trending facility in DCS.

(dd) A common "Fan failure" alarm for all the cabinets, console-cooling fans shall be configured in DCS with high priority, to facilitate immediate maintenance attention.

(ee) All the left over cable entry-holes of the control room must be sealed and the spare cable gland holes of the control room cabinets / Panels must be plugged properly, before handing over a plant. This is required to prevent the entry of the rodents.

(ff) Rack rooms shall have false flooring to facilitating cable entry to the panels, but in the console rooms where very few cables are entering cable trenches in the console rooms may be used.

(gg) In case of UPS supply (110V ac) is used for SOV, a common isolation transformer (1:1) shall be used for powering the Solenoid operated valves, to arrest any "ground fault" generated in the field devices (SOV).

(hh) Provision` shall be made for on-line monitoring with trend and alarm, of the level of voltage (110VDC), where 110 VDC supply is used for SOV. This is to ensure that the voltage is not exceeding the recommended coil voltage of SOV.

5 Field instrumentation

(a) For emergency shut down system, all the input signals shall be of analog type (taken from transmitters rather than from switches), except for those signals where the OEM does not recommend it.

(b) Considering the criticality of this device (SOV), it is recommended to procure SOV from manufactures having PTR in refineries.

(c) It is recommended to procure I/P converter from manufactures having PTR in refineries.

(d) Dedicated orifice-tapings shall be used for each transmitter, for the installation of multiple transmitters from a common orifice.

(e) Closed-couple installation shall be considered for high viscous services, or hydrocarbons contain water for flow / pressure transmitters.

(f) The size (NB) of Impulse line shall be ¾" for corrosive / congealing and high-pressure service to avoid frequent choking.

(g) Temperature transmitters shall be used for measurement of all the temperature parameters, except for the purpose of data acquisition system (DAS).

6 Gas Turbines

(a) The OFF-SKID pressure control valve of GT on liquid fuel service, which maintains the upstream pressure of the GT SKID, should be installed on the return line for better control and to avoid stagnation of oil in the line for a long period. (Refer Schematic- I).

(b) Pressure tapping of this OFF-SKID control valve (for GT) shall be taken from the downstream of the LP duplex filters. (Refer Schematic- I).

(c) For the Gas turbines, where DM water-cooling system is used for the Atomizing Air cooler, a separate service water line shall be laid up to the atomizing air cooler, with draining facility, to avoid interruption of GT in case of failure of the dedicated DM water pumps.

(d) The ON-SKID instruments of GT, like naphtha purging SOV, Flame scanner JB etc., are located in the turbine compartment. Failure of instrumentation cables insulation has tripped the machine in the past. To avoid such tripping these cables need to be relocated at safe zone.

(e) Necessary modification in the logic (Mark-V) is desirable to avoid tripping of Gas Turbine on low lube oil pressure protection of warren pump, when GT is running on Gas fuel. Instead, an alarm should be provided at low lube oil pressure of the warren pump, when the GT is running on Gas fuel only. However, for liquid fuel firing existing logic remains.

(f) Separate isolation valves shall be considered for all the tripping devices like the three numbers of pressure transmitters installed for measuring the GT-compressor discharge pressure and all the three pressure switches for measuring the GT-Exhaust pressure etc.

(g) The <I>-station (GT console) networking is recommended for implementation in multi-GT operation to facilitate in operating a GT when its respective <I>-Station (console) of that machine has failed (not available). (Refer Schematic- G & H).

(h) Dedicated PLC & DCS controller sub-system shall be considered for each GT BOP, to avoid tripping of multiple machines (GT / HRSG) due to single PLC failure. This will also facilitate to carry out maintenance work of these DCS / PLC during the shut down of their respective GT / HRSG.

(i) Provision of duplex HP filter shall be considered for the GT operating with liquid fuel, to avoid stoppage of the machine (GT) for filter replacement.

(j) An additional facility shall be provided to start jacket-cooling fans (88-TK1 & 2) of GT from their respective control room. This will facilitate better emergency handling.

(k) A temperature indication and high temperature alarm for monitoring the atomizing air temperature after the cooler to be provided in the control room.

(l) A temperature indication and high temperature alarm for monitoring the GT leg cooling system to be provided in the control room.

(m) For a Gas Turbine control system, where the Speedtronics (Mark-V) panels are installed in the rack room / Unmanned locations, an audio-visual alarms shall be provided in the GT operating control room for "Communication-failure of <I>-Station (Console)". (This alarm is essentially required where the Mark-V panel is installed in the rack room (un-manned location) and away from the control room, because if, the <I>-Station communication fails, no change in the I-station will be visible, and the <I>-Station will show the last graphics display with the last values of all the parameters. This will create an unsafe condition of the running gas turbine).

(n) Swage lock / Parker make fittings (or equivalent) shall be used for all tubing connections of Gas Turbine.

(o) Size of instrumentation cable terminating in the MARK – V panel shall be 1.5 mm Sq (analog outputs) / 0.5 mm Sq (analog inputs) and 2.5 mm Sq. for (DI / DO). This is required for better termination and ease of maintenance.

7 Distributed Control System (DCS)

7.1 General

The DCS shall primarily drive the instrumentation required for : - Processing all plant input and output signals; providing fault tolerant basic regulatory control of process variables; and managing a comprehensive, prioritised alarm capability. It shall able to accommodate the major portion of advanced controls, and shall act as the platform for plant operating data to be made available to process control and refinery information computers. It shall also be capable of monitoring, via serial link, other independent instrument systems, such as ESD, compressor surge control, gas detection systems, machinery condition monitoring equipment, etc. Typically, DCS systems shall be designed with at least 25% spare capacity upon project completion.

7.2 Redundancy and Reliability

The DCS shall be designed with sufficient redundancy such that no single component failure shall affect plant operability or safety (this includes operator interfaces such as VDU's and keyboards). This means that full redundancy must be provided for all control loops and monitor only points, that are critical to safe plant operation. Redundancy includes everything from the power supply feeders into the control cabinets and I/O boards.

Electronic systems shall be provided with multiple electric power feeders and an uninterruptible power supply providing a minimum of thirty minutes of continuous operation after power failure. Uninterruptable power supplies shall be made fully redundant. This includes battery banks, chargers, inverters and static bypass switches.

All redundant communications cables etc., shall be routed separately so that in the event of physical damage to one cable, its redundant back up cable will not be affected. The use of fibre optic cabling external to the Control Room should be considered, to minimise Radio Frequency and Electro-Magnetic interference.

7.3 Operator Interface

Every effort should be made to minimise the number of "windows" that the operator has into the process. Preferably the DCS will be the only window. The use of hardwired annunciators should be minimised, although some critical alarms, such as DCS failure or UPS failure are typically tied into an annunciator.

An operating console containing at least three VDU's shall be provided for each control operator. The actual number of VDU's shall be determined by the number of screens required to control the process safely, and by the requirements for redundancy.

Each console shall be independent in its function and serve one or more process units, providing a single window for the operator to view his process.

8 Instrument Power Supplies

This section describes IOCL general requirements for power supplies for Instrumentation and control systems. This includes power supplies for field instrumentation, control panels, distributed control systems, telemetry systems, supervisory computer systems, emergency shutdown systems and fire and gas detection systems.

8.1 General Requirements

(a) Instrument power supplies shall be designed such that the security of power supply is consistent with the integrity required by the connected loads, and does not exceed this requirement.

(b) Power supplies shall be designed such that they meet the requirements of the connected loads in terms of:

- Voltage
- Voltage stability
- Frequency
- Rate of change of frequency
- R.F. content
- Maximum interrupt time
- Harmonic content
- Power factor

(c) Power supply capacities shall be rated to take account of switching surges and the effects of harmonics and transient loads.

(d) Power supply capacities shall be rated to take account of any anticipated future expansion requirements.

(e) The design philosophy for instrument power supplies shall be subject to approval by IOCL.

8.2 Security of Supply

(a) Instrument power supplies shall be classified according to the required integrity of the connected loads as Class A, B or C.

The basis of this classification is that loss of supply will cause:

i) Class –A

A shutdown of the whole or major part of a plant or process, a failure to shutdown under emergency conditions, loss of monitoring facilities on critical items of equipment, loss of fire and gas alarm annunciation, or loss

of alarm annunciation on any other system specified by IOCL.

ii) Class-B

An acceptable temporary loss of control, degradation of normal monitoring or control where alternative methods are available, or loss of other alarm annunciation facilities.

This classification can apply to a supervisory computer system where back up panel instrumentation exists or control room operation where local plant control panels exist. The operation of a plant from hand wheels can not normally be considered as an acceptable foprm of back u control.

iii) Class-C

No significant impairment of the ability of the operator to control and monitor the plant.

(b) Classification of the power supplies shall be subject to approval by IOCL.

8.3 Design Requirements

Instrument power supplies shall fulfil the following requirements :

i) Class A

Supplies shall automatically maintain a continuously uninterrupted electricity supply within the required tolerances upon failure or deterioration of the primary source, or any other item of power conversion equipment, for a period of one hour (1 hr) or as otherwise specified by IOCL. They shall be separate and independent from other supplies except the primary a.c. source.

ii) Class B

Supplies shall automatically maintain continuity of electricity supply within the required tolerances for a period of one hour (1 hr), or as specified by IOCL. The changeover time between normal and standby circuits shall not be greater than 10 m/sec or as otherwise specified by IOCL.

iii) Class C

Supplies have no requirement for a standby source of supply.

8.4 Distribution and Protection

(a) Protective devices shall be time and current graded to maintain discrimination

(b) Cartridge type fuses should be used throughout the power supply system. Protective circuit breakers may be used only in final sub circuits provided it can be demonstrated that discrimination will be maintained with the other protective devices.

(c) Two separate AC distribution boards (Dual ACDB), fed from parallel redundant UPS shall be used for instrumentation power distribution system for the improved reliability of instrumentation system.

(d) A separate switched and fused sub circuit shall be provided for each functional loop. Redundant equipment shall be separately switched and fused.

(e) Each sub circuit shall be clearly labelled with a unique identifier.

(f) The UPS supply shall not be used for the utility supplies like cooling fans, lighting power sockets in the consoles / panels / cabinets / Local Control Panels, etc. A separate non-UPS supply shall be used for the same.

(g) The distribution shall be designed such that failure of a single sub circuit does not cause an unacceptable loss of control or loss of data display to the plant operator.

(h) Integral Power Supplies

(i) All the cooling fans in the cabinets / panels / consoles etc. shall be in operation to avoid failure of cards due to high temperature. "Fan failure" alarm shall be ensured and must be attended on priority.

(j) Where dual power supplies are installed to increase availability indication shall be provided to show failure of a single supply.

(k) Minimum two numbers of Bulk Power Supplies (BPS) shall be configured for powering all critical instrumentation systems..

(l) Power supplies shall be clearly labelled with a unique identifier.

8.5 Monitoring and Alarm Systems

(a) Sufficient information shall be provided either remotely or local to the power supply equipment to enable rapid identification of fault conditions or confirmation of healthy status.

(b) Alarms shall be provided to indicate at a manned control point any fault condition on a major unit in a power supply system. This may take the form of a common alarm requiring examination of the local indication to diagnose a fault condition.

(c) Remote signaling of alarm conditions shall be classified into the categories :

- Emergency Trip
- Urgent Alarm
- Information

9. Miscellaneous points

(a) A Separate earth-pit networks is desirable for various instrumentation sub-systems like DCS / PLC earth, cable-screen earth, chassis earth, power earth etc. so that the problem in one system is not affecting the other system.

(b) Unit wise dedicated of earth-pit network is desirable for the Mark –IV / V systems, air compressor control systems etc. for higher reliability and ease of shut down maintenance of these earth-pit networks. (Refer Schematic- D, E & F)

(c) Earth-pit head must be covered properly, and clearly visible identification tags shall be in place and be documented properly.

(d) The earthing cables from the earth-pit to the respective systems shall be insulated and use of bare cable / strips shall be strictly avoided. Such cable shall be laid away from power cables etc.

(e) All the instruments and Local Control Panel (LCP) shall conform to hazardous area classification. Air purged type panels should be avoided

(f) Root valves for all high-pressure (> =60 Kg/Cm2) applications shall be of double isolation type.

(g) Proximity switches shall be considered in place of limit switches for all the places.

(h) Smart positioners shall be considered for all critical control valves. These positioners should preferably be manufactured by the manufacturer of the respective control valves. The control

valve position feed back shall be configured in the DCS with trend recording.

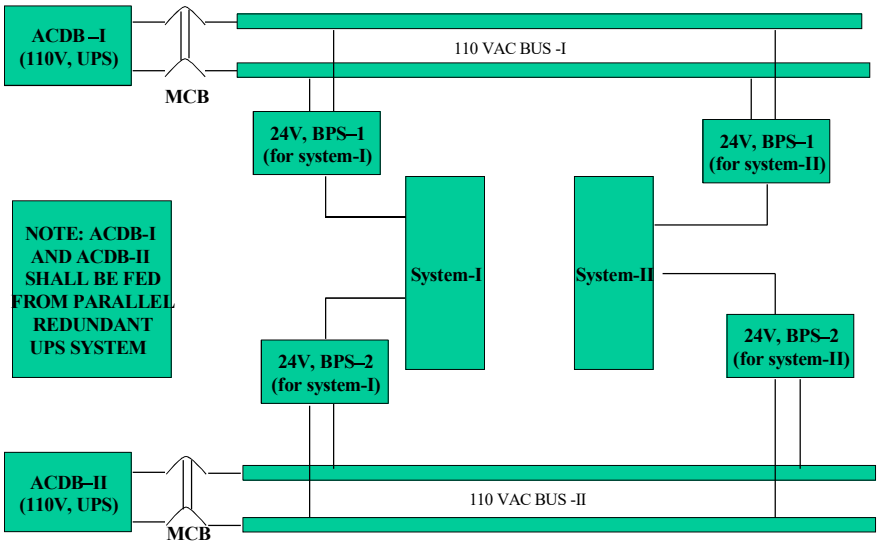
(i) For all the control / block and bleed valves connected to flare shall be of leakage class V or better.

(j) For the shelter analyzers, provision for monitoring the shelter temperature with high temperature alarm in the control room to be provided.

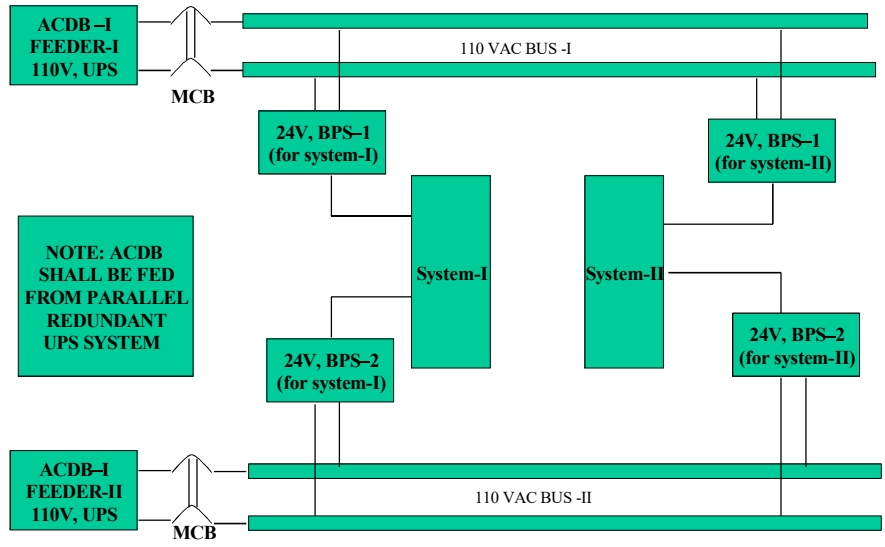
(k) "Parallel-redundant" philosophy for the critical PRDS / gas pressure control valves to Gas Turbines etc. is to be considered for improved reliability / availability.

Enclosed schematics are as follows: -

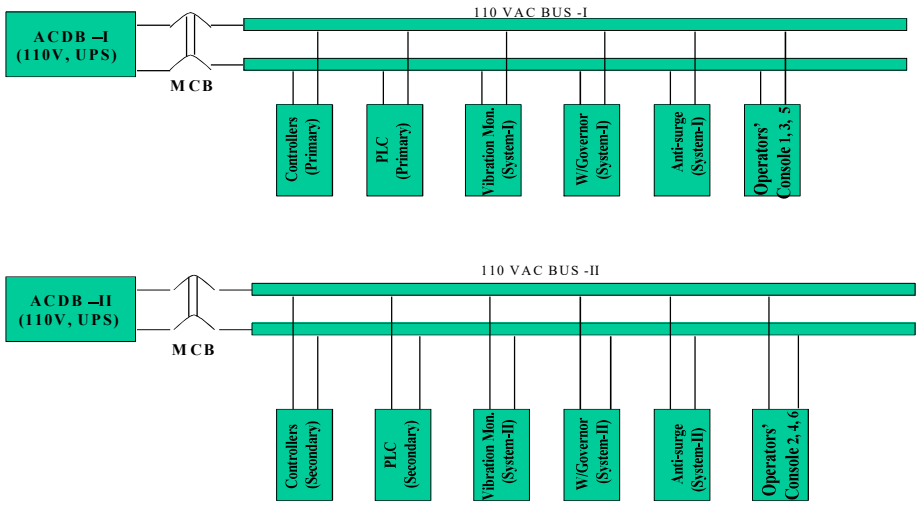
a) Schematic - A
b) Schematic - B
c) Schematic - C
d) Schematic - D
e) Schematic - E
f) Schematic - F
g) Schematic - G
h) Schematic - H
i) Schematic – I



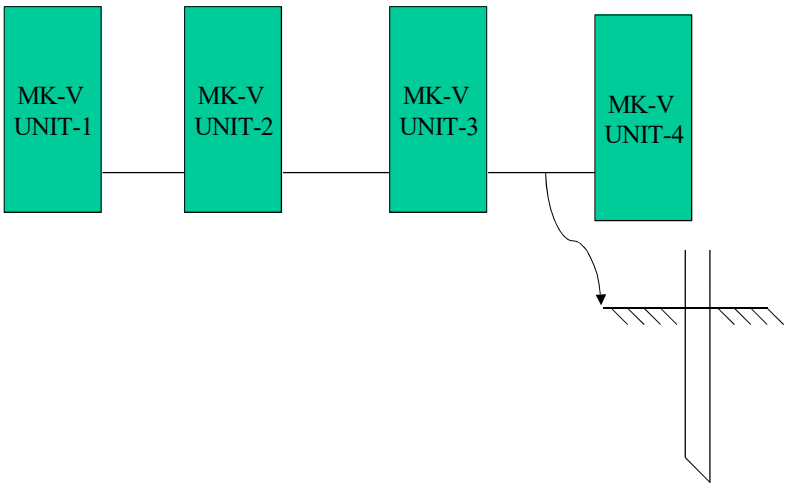
BPS (24VDC) distribution (typical) system (Scheme –A)



BPS (24VDC) distribution (typical) system (Scheme – B)

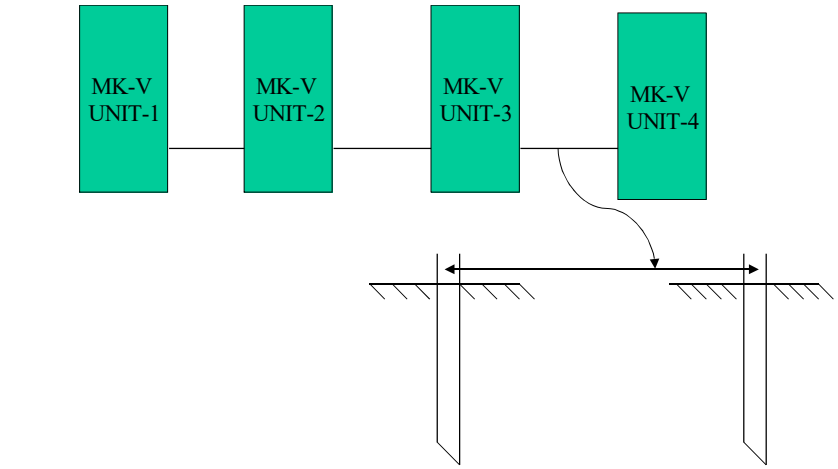


AC distribution (typical) system (Scheme – C)



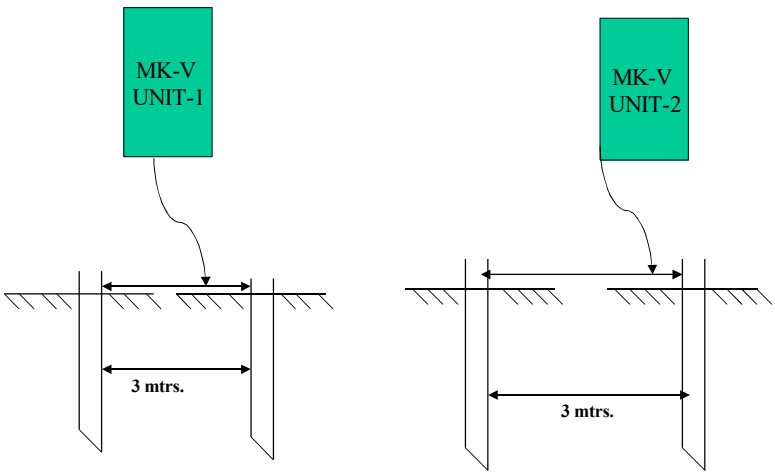
MULTIPLE UNITS WITH SINGLE EARTH-PIT *(NOT RECOMMENDED)*

Schematic- D



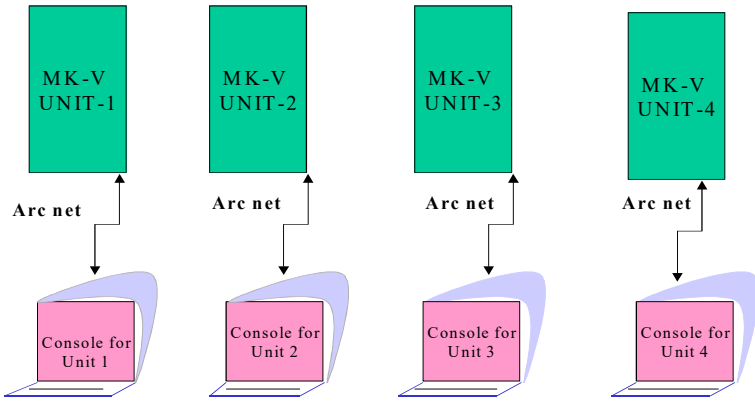
MULTIPLE UNITS CONNECTED WITH EARTHING NETWORK ***(NOT RECOMMENDED)***

Schematic- E



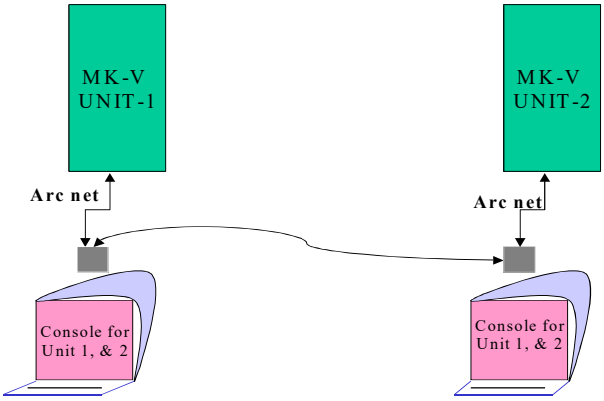
PROPOSED EARTH-PIT NETWORK ***(RECOMMENDED)***

Schematic- F



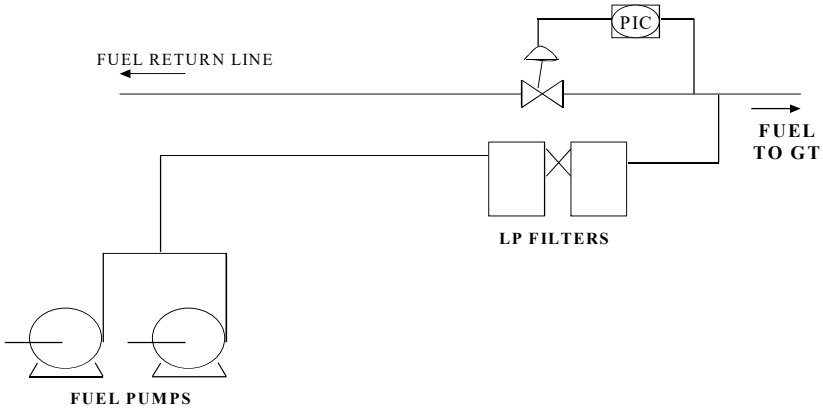
TYPICAL (EXISTING) CONFIGURATION

Schematic- G



TYPICAL RECOMMENDED CONFIGURATION

Schematic- H



GT LIQUID FUEL FORWARDING PUMP

Schematic- I

CYBER SECURITY GUIDELINES FOR CONTROL SYSTEMS 2021

M&I Department
Refineries Head Quarters
Indian Oil Corporation Limited
New Delhi

FOREWORD

Cyber security guidelines for Control systems were issued by RHQ(M&I) in 2017. Vide Notification dated 7th December 2020 by MoPNG, Industrial Control Systems (ICS) of six refineries of IOCL viz. PDR, PR, JR, MR, HR and BR have been identified as Critical Information Infrastructure (CII). Accordingly, Cyber security guidelines have been suitably updated to add Emergency response procedure for Cyber crisis management, Cyber incidence reporting system, Backup restoration procedure and awareness training and auditing process. These guidelines were prepared by M&I jointly with committee member from MR & PR, RHQ IS and e-security team of COIS based on the valuable inputs provided by m/s QOS Technology.

In the past, Industrial networks were primarily isolated systems, running proprietary control protocols, using specialized hardware and software. Now due to various digital initiatives, like IIoT based remote monitoring and predictive analysis, these systems are being integrated with enterprise systems and other business applications. This increased level of integration provides significant business benefits; however, this also increases vulnerability to misuse and attack with malicious intent.

Due to the confidentiality of ICS data, unauthorized or damaging access to a process control system is extremely critical. Any loss of process data or control in ICS can create havoc, resulting not only loss of production but serious consequence like equipment and environmental damage along with the regulatory violation. Hence it has necessitated to take all measures to foil any such attempt by adhering to issued guidelines for Protection of ICS. The cyber security policy is an evolving task, which needs to be regularly updated in line with technological and security challenges. These guidelines cater to the whole spectrum of ICS users of IOCL Refineries.

26.03.2021

26th March, 2021
New Delhi

(V. K. Raizada)
ED (M&I)

ACKNOWLEDGEMENT

Due to the increased information exchange between Industrial Control System (ICS), and business process, communication technologies has evolved for integration of ICS systems with other IT systems. With this integration, there has been a perceptible increase in vulnerability of the ICS to the external elements such as viruses, worms and Trojans. As per MoPNG directives, IOCL Refineries ICS have been identified as Critical Information Infrastructure (CII), hence rules for "Information security practices and procedures for protected system" are applicable for these ICS.

For safe and secure refinery operations, ICS policy framework and guideline are required to be periodically updated for protection from such threats. Maintenance and Inspection (M&I) Department at Refineries HQ have undertaken the task of updating the cyber security Guideline to address the various gaps and design inconsistencies prevalent in the existing ICS networks and to develop a standardized framework for designing and execution of future ICS networks across all the refineries. This document was prepared by M&I jointly with member participants from Mathura & Panipat Refineries, RHQ IS and e-security team of COIS.

This policy framework shall assist and benefit all the Instrument Maintenance and Projects personnel along with OEMs of control systems to design ICS systems within the contours defined by this policy.

26TH March, 2021
New Delhi

(Surya Roychoudhury)
GM(M&I)

Restricted Circulation

CYBER SECURITY GUIDELINES FOR CONTROL SYSTEMS

M&I Department
Refineries Head Quarters
Indian Oil Corporation Limited
New Delhi

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INDEX

Chapter 1: Physical Security

1.1 Secure Areas:

To prevent unauthorized physical access, damage and interference to the organization's Industrial Automation and Control Systems (IACS)

1.1.1 Physical Security Perimeter.

- Critical or sensitive IACS should be housed in secured area/ control room, protected by defined security perimeters, with appropriate entry controls.
- Limited access to IACS should be allowed.
- Clear demarcation of physical areas on basis of physical access like the operator zone, engineering zones and hardware zones shall be ensured.
- Access authorization on clear basis of requirement to be developed for employees as well as contractors and visitors.
- Office area and IACS area should not be clubbed.
- Higher critical zones like Engineering and Panel rooms should have key lock facilities.
- All access management for physical access should be referred from chapter 2 of this document.

1.1.2 Securing critical areas.

1.1.2.1 Engineering Room /Panels

- Only authorized entry to Engineering Rooms, Marshalling, Panel room etc. to be ensured.
- All visitors, vendors, contract persons should be escorted. Unsupervised working in high critical zones and equipment's to be minimized and recorded.
- All Panels shall remain closed at all times with proper locks.
- CPU of all Engineering stations and servers shall be kept safe.
- All technical controls as highlighted in chapter 2, to be adhered to.

1.1.2.2 Console/ Operation Room

- Only authorised Operation personnel should have access to operating consoles.
- Access to unauthorized persons like helper, office boy, and drivers shall be prohibited to console rooms.

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- Carrying external storage media in the console room shall be strictly prohibited. Pictorial advisory should be displayed at control room entrance.
- All operators workstations should be kept in consoles & same should be locked. Consoles shall have compulsorily key lock facilities.
- Local printers and other work stations in this area which are not in continuous use shall be appropriately guarded from unauthorized use.
- All network control related configurations are defined in chapter 8 of this document has to be adhered to.
- All consoles and operator workstations need to follow the best practices defined in chapter 9 of this document.

1.1.3 Equipment Security

1.1.3.1 Controllers

- Controllers shall be installed in locked cabinets.
- Controller shall always remain in Run mode (Key) in normal working condition to avoid any programme changes (wherever applicable).
- All unused programming /communication ports on controller shall be explored for physical closing/locking.
- All Controllers communicating on TCP/IP or any IP based communications shall never be provided access directly (all communication on TCP/IP should follow the broad guidelines given in the best practices defined in chapter 9 of this document). All programming shall be performed through Secured Engineering Stations.

1.1.3.2 CPU of Operator Station (OS)/ Engineering Station (ES) and Servers

- All OS CPUs shall be kept in locked consoles. ES and Servers to be kept safe.
- External Media/Networking/ USB ports, if available shall be provided with external locking mechanism.

1.1.3.3 Network Switches and Networking Components

- All networking components should be mounted in closed and locked panels or lockable mounting cabinets.
- Unused spare ports should be explored for physical locking, or shall be disabled by programming.

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- All field mounted networking components should be properly guarded from unauthorized access.
- Clear warning tagging in field mounted network switches should be provided, e.g." Don't Touch Critical"

1.1.3.4 Firewall/ Routers

- All firewall and routers providing connections with external networks shall remain under locked conditions.
- These shall be accessed only by authorized person only on requirement basis under supervision of concerned engineer.
- Location of firewalls and routers shall be in higher critical zones like engineering or hardware zones, thereby maintaining a limited access.
- Feasibility of physical locking of spare ports shall be explored or shall be disabled by programming.

1.1.4 Working in secure Areas

1.1.4.1 Identification of Personnel

- Person working in secure area shall bear clear identifications for authorizations.
- List of authorised personnel (duly approved by not below GM Level) according to zones should be maintained. E.g. Console or operating zones, engineering zones etc.
- Awareness among personnel using a specific zone shall be given. Further all employees should be motivated to stop unauthorized access to critical zones.
- Unsupervised working in engineering / hardware zones by vendors, visitors should be prohibited. They shall always be escorted by authorized person while performing activities.

1.1.4.2 Cyber Security Toolbox Briefing

- All persons who are required to perform or utilize the IACS shall properly be briefed about the security measures.
- A time bound authorization to be provided for external agencies with proper toolbox briefing about IOCL IACS cyber security policy. The access to areas shall be limited in accordance to job requirement.
- The chapter 5 should be referred to for details on awareness while doing such briefings.

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1.1.4.3 Visual Markings and Sign Boards

- Visual Zone marking shall be provided in control rooms e.g. Engineering, operation, Hardware Zone.
- All critical equipment's shall bear visual indications.
- Do and Don'ts shall be placed in Control rooms indicating warnings on use of external storages, portable devices, mobiles, camera etc.

1.1.5 Cabling Security

- Communication cable carrying data or supporting information services shall be protected from interception.
- Communication cables shall be under ground or in conduits. These shall not be easily accessible to tapping.

1.1.6 Equipment Maintenance

- Equipment's shall be maintained as per laid down procedure to ensure its continued availability and integrity.
- New / repaired equipments shall be properly diagnosed before taking the same into network.
- Detailed records including dates and jobs performed during maintenance shall be maintained.
- Systems to be developed for periodic maintenance and checking of critical networking components that are being used for external connections by competent person /Expert/ OEM.
- Only Authorized Maintenance person should carry out repair and maintenance jobs.
- This section has to be read in conjunction with section 5 of chapter 7 (7.5) of this document.

1.1.7 Security of Equipment in Off-premises

- Equipment & media when taken off the premises shall be properly packaged, sealed & transported.
- While receiving the equipment, either new or after maintenance shall be visually inspected for package tempering.
- OEM or specialist shall be contacted for pre-checking of equipment before taking into the network.
- Vendor/ maintenance agency shall abide by IOCL IACS cyber security policy against misuse/ tempering of the components being sent for maintenance.

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1.1.8 Secure Disposals and Re-use of Equipment

- All items of equipment containing storage media shall be checked to ensure sensitive data & license before disposal.
- Information should be physically destroyed or overwritten to make it non retrievable.
- Re-use of equipments should be done with utmost care.
- All re-useable components shall be properly diagnosed before using them.
- All operating stations being reuse should be mandatorily formatted &genuine original licensed software to be reloaded.
- Wherever formatting is not possible OEM/vendor to be contacted to authenticate the healthiness of the component.
- All re-useable type equipments shall be stored at secured locations therefore mandating no unauthorised access & misuse.
- Records shall be maintained for all re-useable equipments indicating their past installations & performance. Further, reason for disposal to be categorically indicated.
- This section has to be read in conjunction with section 5 of chapter 7 (7.5) of this document.

1.1.9 Removal of Property

- Equipment, information or software should not be taken outside without prior authorisation.
- Employees, contractor & third party users who have authority to permit & remove assets should be clearly identified.
- Records shall be maintained of removal/return of equipments indicating reasons & date of movements.

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