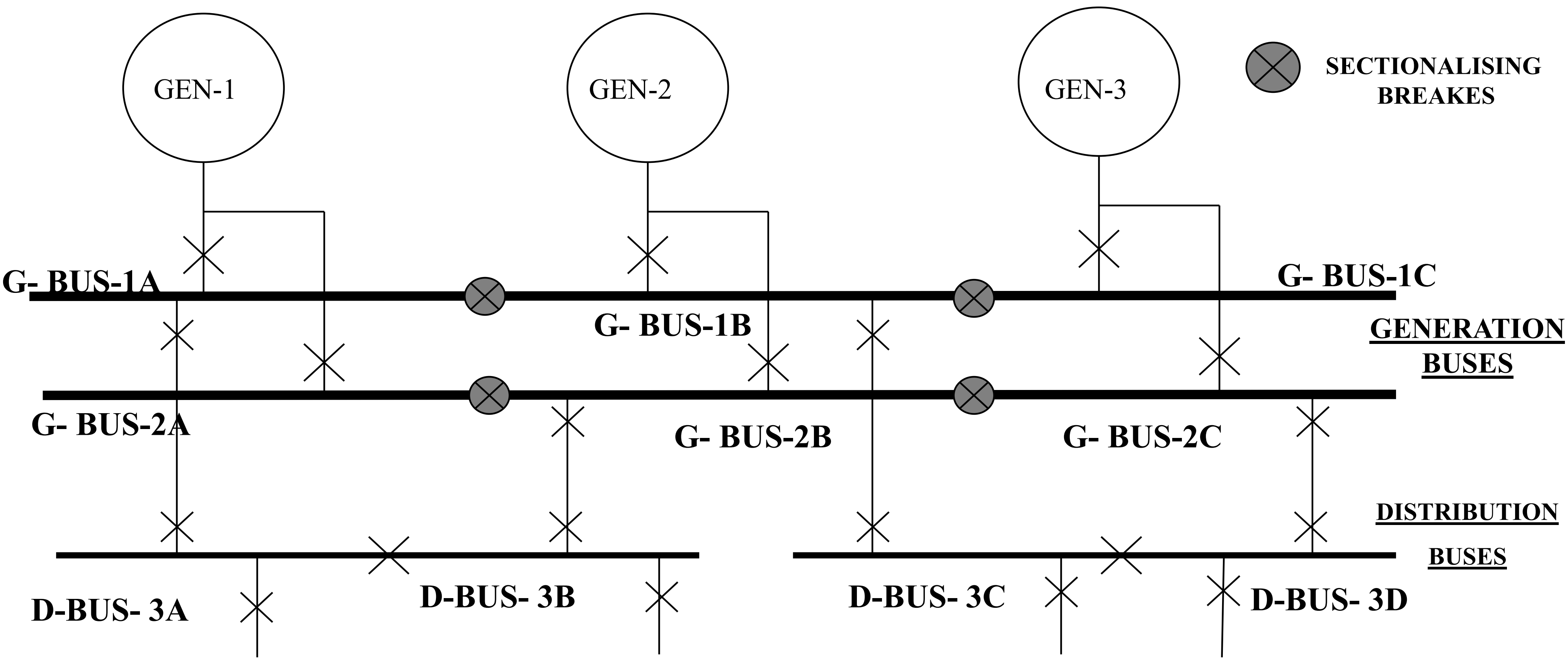
	requirements during HT fault/ HT motor starting due to inaccurate setting of the field current limiter (filed forcing mode). It is, therefore, desirable to ensure the proper settings of field forcing limiter in AVR for boosting the excitation during voltage dip condition upto 10 secs. Following Typical settings, as recommended by BHEL, may be adopted to achieve the above: • Maximum ceiling value (160%) • Ceiling Time (10Sec) • Integral I2t (18.7 pu). In case of mismatch, the same is to be set right in consultation with BHEL
1.3.8	There have been instances that while resetting the AVR alarms, operator has inadvertently pressed the RESET button of the Processor Card in side AVR cubicle resulting into AVR tripping. To prevent such human errors, it is recommended to provide clear instructions regarding resetting procedure of DAVR alarms on the DAVR panel. To prevent accidental reset of DAVR modules due to human error from the reset button provided on the cards/ modules, suitable printed inscription/ sticker should be provided on such critical reset push buttons indicating " Do Not reset- Connected to trip. "
1.3.9	In order to ensure proper dynamic response of AVR / DAVR, It is desirable to perform step test (dynamic tests) of the AVR as per the instructions / procedure given by the OEM during machine M&I.
1.3.10	In order to facilitate AVR trouble shooting, it is recommended to maintain record of AVR test point values documented at various loads conditions e.g. 25%, 50%, 75% & 100% as a ready reference.
1.3.11	In order to prevent tripping of AVR on AVR PT fuse failure, it is to ensure that the scheme for "AVR changeover from Auto to manual mode on PT fuse failure" is in place. The recommendation is to be verified particularly for old type of AVRs.
1.3.12	Provision of separate emergency channel to take care of excitation requirement in case of operation of stage-3 fault – to be firmed up with BHEL – EDN (Refer Schematic Drawing No. 1C.3)
1.3.13	With the increased installations of Variable Speed Drives & other thyristorised devices in our power system, the harmonic contents in the power system is significantly increasing which may adversely affect the performance of DAVR's. BHEL EDN has opined that this may even lead to the tripping of DAVR if the harmonic content increases. It has been recommended by BHEL to use harmonic suppression filters in the PT

	input circuits to take care the harmonics in the power supply. Though no such incidence have reported from units, in view of the above as a long-term reliability measure, harmonic filters may be provided in the DAVR's in consultation with the OEM.
1.3.15	PSS function is effective in case of grid connected systems only and is used for dampening the power angle fluctuations of individual machines during power swing thus helping it to stabilize faster after any transient condition.
1.4.1	It is recommended to have window type CT's in Generator bus (phase & neutral side up to switchgear to avoid any possibility of CT insulation failure due to heating.
1.4.2	It is been experienced that a choke of tube light fitting installed in the PT / LA cubicle got burnt and its smoke caused tracking inside the PT cubicle which resulted in the flashover in the 11 kV section of the generator. In order to prevent such trippings of HT sections due to the flashover of non-essential equipments e.g. light fittings etc. installed inside the LA / PT/ NGR panel / HT cubicles or in the close vicinity, it is recommended to remove such equipments from these locations.
1.4.3	Equipotential wire of the window type CT's installed in generator bus duct are to be examined for its dressing & extra length of the wire needs to be cut to avoid possibility of flashover with the adjacent buses of the other phases)
1.4.4	In order to prevent flashover at generator terminal, PT cubicle, bus ducts, cable box etc, proper tightness & inspection is necessary during every shutdown. Contact Resistance Measurement should be adopted to ensure the tightness. Practice of temperature monitoring of bulk load circuit breakers, joints etc also to be ensured.
1.5.1	To instantaneously clear the faults in the generator/generator cables/generator circuit breaker/ generation bus and also to minimize the consequential damage, it is essential to provide differential protection scheme for the complete Generator including Bus Duct ,HT cables & generator breaker. The scheme shall have overlapping protection zone with the bus differential scheme at switchgear level. (Refer Schematic Drawing No. 1C.4)
1.5.2	In order to prevent spurious tripping of generator on differential protection due to CT saturation or any other reason, it is desirable to periodically measure the spill current of the differential scheme. It is, therefore, recommended to use numerical relays in the Generator protection with 3- phase online monitoring of spill current.

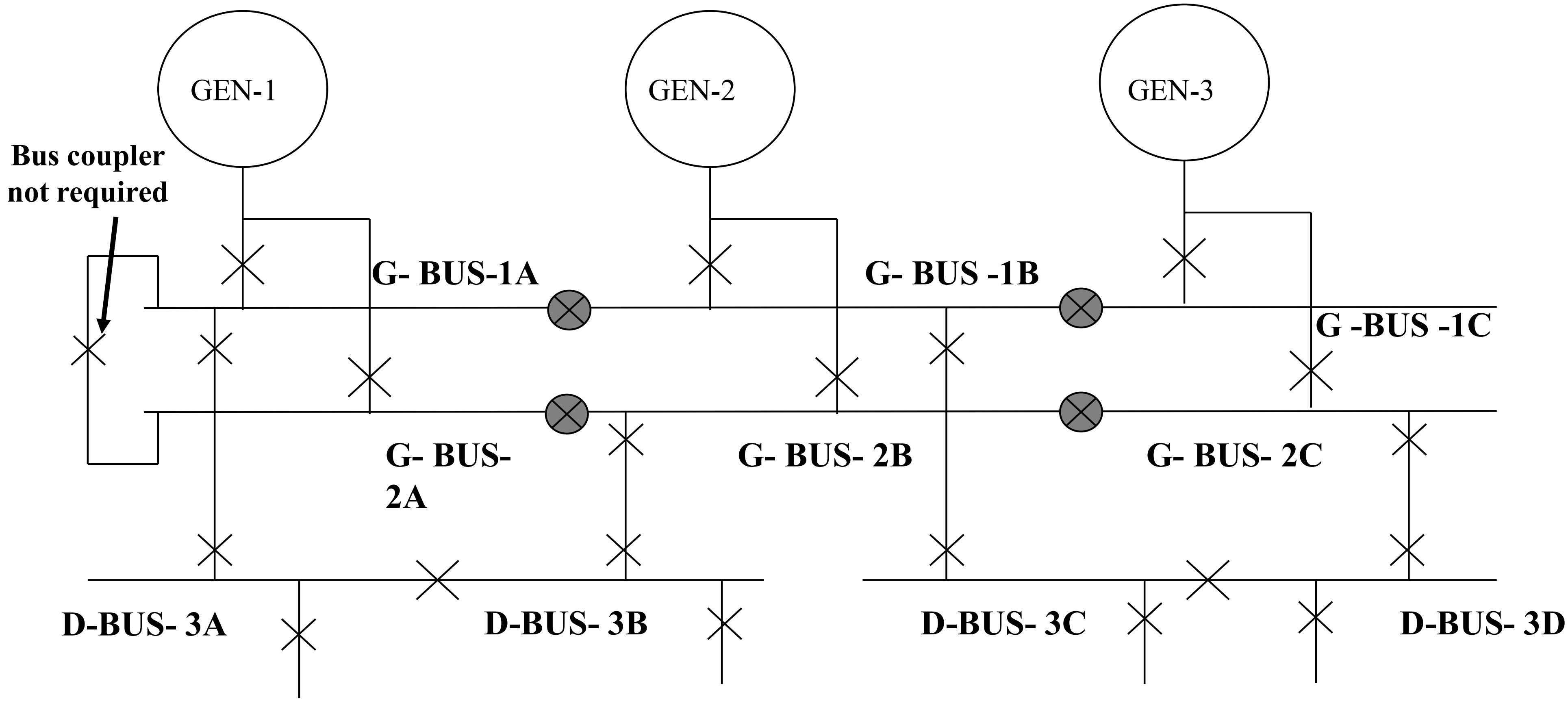
1.5.3	In case differential scheme is provided separately for Generator & outgoing cables, the HV cable differential protection shall be connected to the Unit Master trip Relay (86U). This is to avoid the damage to generator by continuously feeding fault in the cable zone for longer duration with the residual voltage at FSNL (Full speed no Load).
1.5.4	It is desirable to provide separate back up over current and earth fault protections for individual generator breaker to have better coordination. The setting of breaker end relay shall be one step lower to the generator backup over current & earth fault relay. (Refer Schematic Drawing No. 1C.5)
1.5.5	There have been instances where generator has tripped on under voltage protection on faults in distribution network. The under voltage protection is generally provided to safe guard the equipment (Motors/ transformers etc) in the distribution system. Distribution networks in our refineries are provided with U/V trip scheme right from Primary HT distribution bus up to PCC level. Therefore, units may look into the decision of providing under voltage tripping on generators. Some of the units (Mathura) are not having U/V trip of generators under the recommendation of TCE and have not experienced any trouble during system disturbances on this account. IEEE Std 242- 1986 also does not include U/V (27) protection in the standard list of protection for Medium & Large industrial generators. However, IEEE (Cl.11.4.7) recommends that if it is provided as backup-to-backup protections, a time delay of at least 15-20 sec. should be provided to give opportunity to all other relays to operate. (Refer Annexure 1D.1) Moreover, the protections provided on the generators/ AVR are adequately provided to ensure the generator operation with in its capability region and 51V (CDV) protection also takes care of the generator in case of sustained under voltages / faults. In case, units decide to retain the U/V tripping on generators then the voltage and time delay should be judiciously reviewed by units based on the under voltage coordination with downstream incomers and maximum time allowed for the re-acceleration of motors. If units decide not to provide u/v tripping on the generators, the U/V trip scheme in the distribution network to be re-strengthened by proper time grading. An 80% U/V alarm may be provided on the generator for the purpose of monitoring.
1.5.6	In case of Rotor Earth Fault protection based on the insulation resistance measurement method, there have been instances of spurious tripping of generator on account of intermittent leakage currents at brush / slip rings due to deposition of carbon / lube oil. To prevent such

	tripping, it is desirable to provide a 5-10 second delay in the Rotor Earth fault protection. It is also recommended by the OEM to keep the slip ring area pressurized / continuous blowing through air in case of accumulation of dust/ oil.
1.5.7	The control supply to Generator Controls, Relay Panel and Generation Bus shall be DC with redundant. Provision shall be made for monitoring the health of the control supply to each switchgear panel
1.5.8	Wherever numerical type generator protection relay is installed, in view of the reliability & safety of machine, it is recommended to install two such relays in parallel mode in order to avoid emergency shutdown requirement in case of fault in single numerical relay condition.



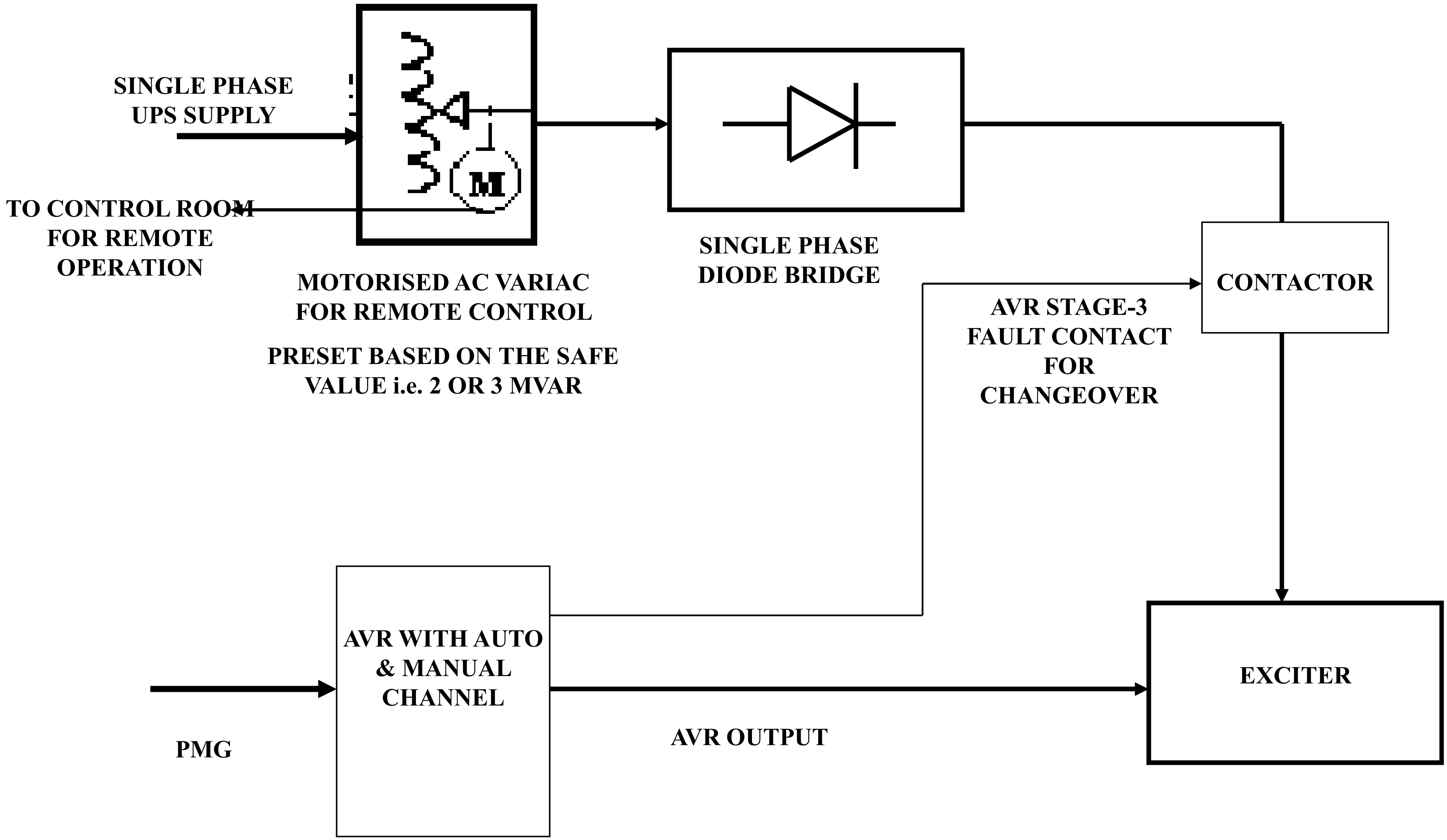
GENERATION & DISTRIBUTION SYSTEM WITH GEN. BUS SECTIONALIZING

DRG. NO. 1C.1



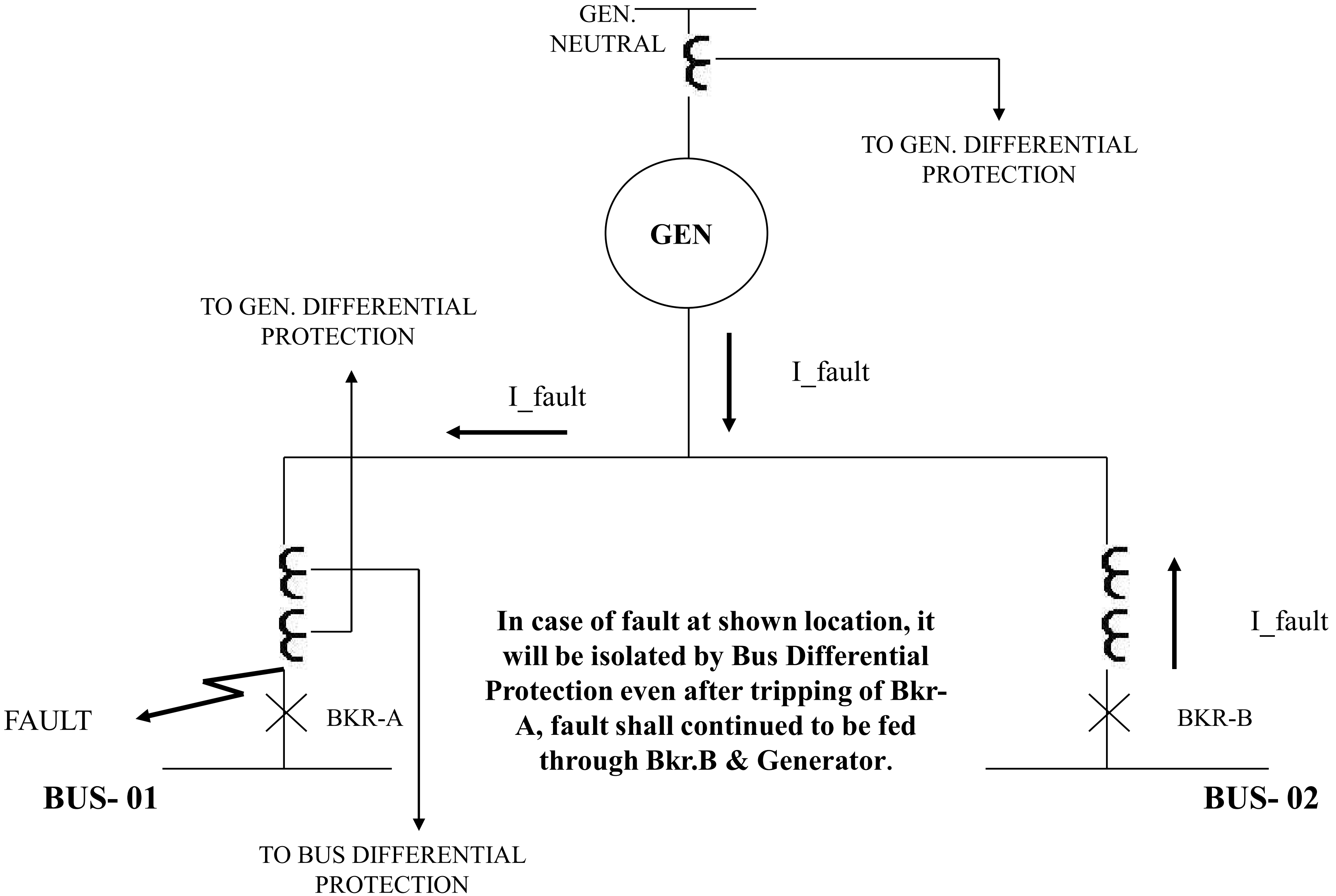
GENERATION & DISTRIBUTION SYSTEM WITH GEN. BUS SECTIONALIZING

DRG. NO. 1C.2



EMERGENCY CHANNEL FOR AVR / DAVR

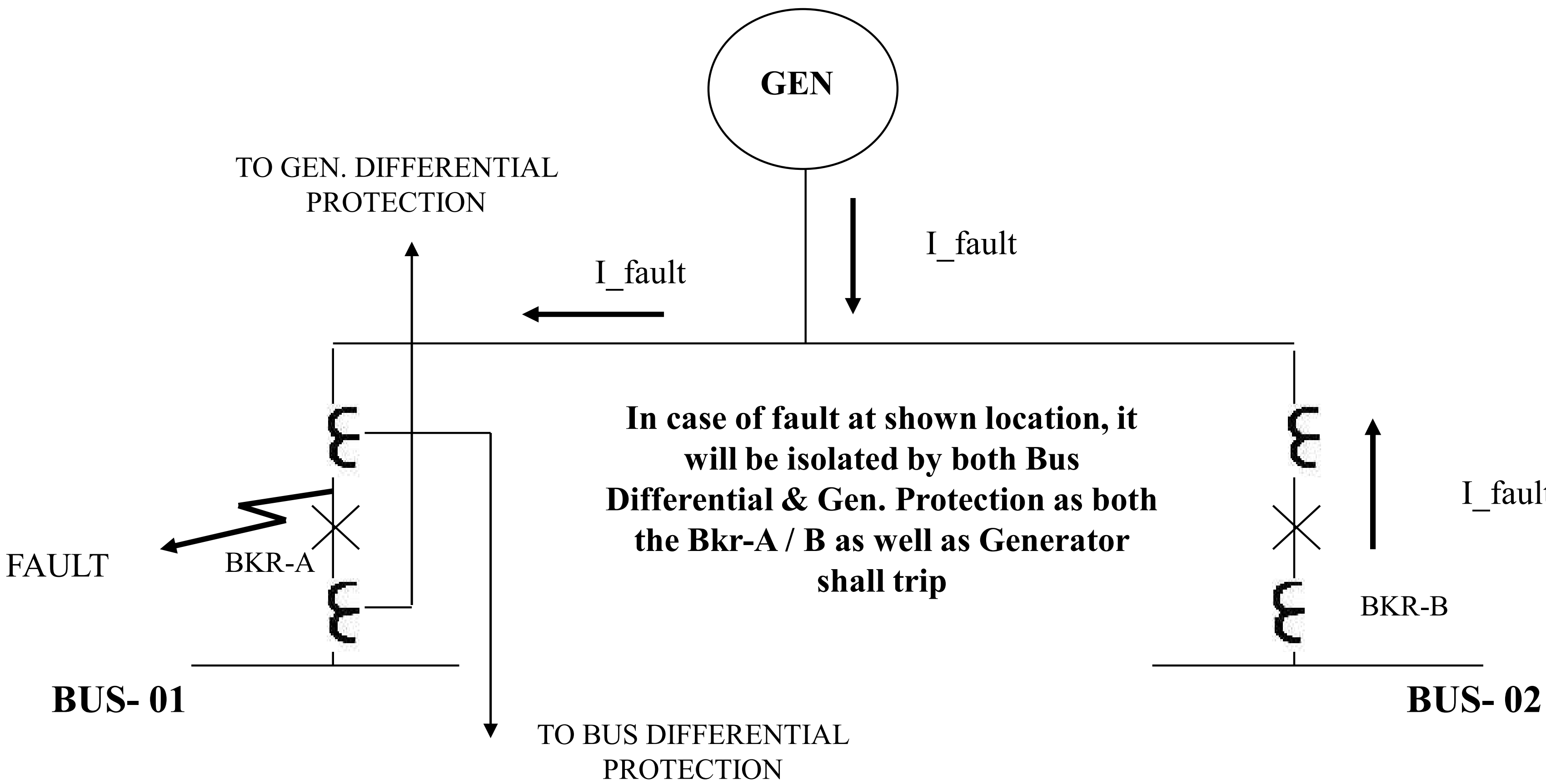
DRG. NO. 1C.3A



In case of fault at shown location, it will be isolated by Bus Differential Protection even after tripping of Bkr-A, fault shall continued to be fed through Bkr.B & Generator.

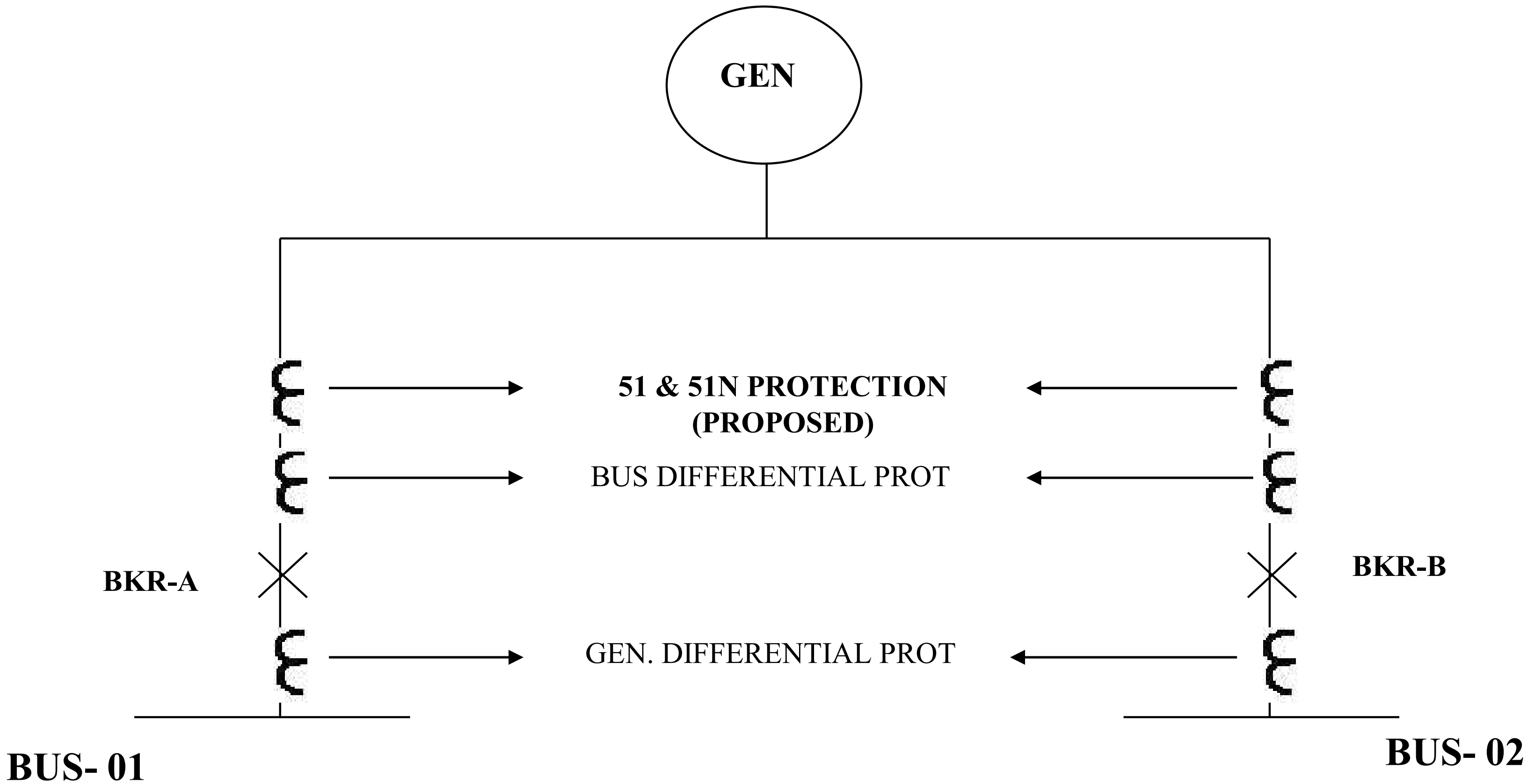
GENERATOR DIFFERENTIAL PROTECTION SCHEME (EXISTING)

DRG. NO. 1C.4A



GENERATOR DIFFERENTIAL PROTECTION SCHEME (PROPOSED)

DRG. NO. 1C.4B



GENERATOR PROTECTION WITH DIFFERENTIAL AND BACKUP O/C ,E/F SCHEME (PROPOSED)

DRG. NO. 1C.5

Check List 1E.1

Chapter -1 GENERATORS AND GENERATOR AUXILIARY SYSTEM

Area/ Location:- (to be filled)

Note:- Gaps in the existing system and actions to be taken are to be indicated by ***BOLD ITALICS in RED COLOUR***

S.No.	Recomm. Ref.		**Generator No. /Area / Sub Station** →		TG-1	TG-2												
			Switch Board No. → ↓ **Reliability check point**															
1	1.1.1		Ensure that direct turbine trip command from Mark - V to generator master relay (86) is available	**Yes / No**														
2	1.1.2		**Measures taken to prevent machine tripping by using master relay "NO" contact or by providing warning.**	**Yes / No**														
3	1.1.3		**Provision of cover over the mechnical closing push button on the generator brekaer fron plate.**	**Disabled / Enabled**														
4	1.1.4		**Provision of two Emergency push buttons in series or protective cover.**	**Yes / No**														
5	1.1.5		Ensure suitable interlock exists for preventing accidental opening of generator field breaker in service condition.	**Yes / No**														
6	1.1.6		Provision of check synch. relay contact in series with auto synchronizer, if applicable.	**Yes / No**														
7	1.1.7		Provision of series contact of 80 deg & 100 deg. for Generator High temp. trip or implementation of 2-o-o-3 logic.	**Yes / No**														
8	1.1.8		Reliable UPS AC or DC supply for generator fire alarm panel	**UPS / DC / Other**														
9	1.1.9		Control of generator space heater from breaker contacts or confirmation regarding availability of space heater "ON" alarm at manned location.	**Available / Not Available**														
10	1.1.10	New project	Ensure healthiness of coupling bolt & bush for newly commissioned machines with overhang type PMG, if applicabe.	**None / Not done**														
11	1.1.11		Use of stroboscope gun to check exciter diode haelthiness, if applicable.	**In use/ Not in use**														
12	1.1.12		Provision of separate trip commands upto generator breakers from TNC switch & generator master relays.	**Yes / No**														
13	1.1.13		Provision of humidity sensors in air cooler ducts	**Yes / No**														
14	1.1.14	New project	Direct Air cooled generators shall be preferred for new projects	**Yes / No**														
15	1.1.15		Provision of RF based Wireless Temperature monitoring with alarm in Generator terminals and generator bus incomers	**Yes / No**														
16	1.1.16		Provision of online PD monitoring in generators	**Yes / No**														
17	1.2.1	New project	Separate Generation Bus and Distribution bus configuration.	**Yes / No**														
18	1.2.2		**Keeping the Bus coupler between the two generation buses in "Off" condition, if exists for double bus configuration**	**Yes / No**														

S.No.	Recomm. Ref.		Generator No. /Area / Sub Station →		TG-1	TG-2												
			Switch Board No. → ↓ Reliability check point															
19	1.2.4		Single side earthing in case of single core cable for generator output.	**Done / Not done**														
20	1.2.4	New project	Proper trifoil with transposing in case of single core cable for generator output.	**Done / Not done**														
21	1.2.4	New project	Transposition of screen with armour (with proper insulation) of the single core cables	**Yes / No**														
22	1.2.5	New project	Provision of sectionalizing breakers	**Yes / No**														
23	1.2.6	New project	Consideration of GIS for generation bus	**Yes / No**														
24	1.3.1		**Confirm AVR performance is satisfactory during power system voltage dips.**	**Yes / No**														
25	1.3.2		Ensure that all the AVR limiters are in service	**Yes / No**														
26	1.3.2		Confirm that limiter settings have been made as per generator capability	**Yes / No**														
27	1.3.3		Verify the size of AVR output cable depending upon the distance between AVR & Exciter.	**Yes / No**														
28	1.3.4		Incorporation of a time delay of 2.5. To 3 sec in under voltage auto changeover scheme of DAVR.	**Yes / No**														
29	1.3.4		incorporation of 100ms time delay in AUTO to AUTO changeover of DAVR	**Yes / No**														
30	1.3.5		Ensure that Power supply failure alarm exists for AVR's.	**Yes / No**														
31	1.3.6		Provision of direct tripping of generator on AVR stage-3 faults.	**Available / Not Available**														
32	1.3.7		Confirm proper setting of field forcing limiter are done in AVR to boost excitation during faults.	**Done / Not done**														
33	1.3.8		Proper DAVR alarm reset procedure to be provided on the panel.	**Available / Not Available**														
34	1.3.8		Proper measures to prevent accidental reset of DAVR cards e.g. warning message etc.	**Done / Not done**														
35	1.3.9		Whether dynamic tests performed on AVR during M&I.	**Done / Not done**														
36	1.3.10		Maintain record of AVR test point values documented at various loads conditions e.g. 25%, 50%, 75% & 100%	**Available / Not Available**														
37	1.3.11		Ensure that the scheme for "AVR changeover from Auto to manual mode on PT fuse failure" is in line.	**Yes / No**														
38	1.3.12	New project	provision of dual auto channel with manual channel in DAVR	**Available / Not Available**														
39	1.3.13		Feasibility to use harmonic suppression filters in the PT input circuits	**Feasible / Not Feasible**														
40	1.3.14		Provision of Redundant power supply to PLC cards of DAVR	**Yes / No**														
41	1.3.15		Disabling of Power system stabiliser (PSS) function in DAVR	**Yes / No**														

S.No.	Recomm. Ref.		Generator No. /Area / Sub Station →		TG-1	TG-2												
			Switch Board No. → ↓ Reliability check point															
42	1.4.1	New project	Provision of window type CT's in the Generator bus duct.	**Yes / No**														
43	1.4.2		Remove non-essential equipments e.g. tube light etc. installed from the LA / PT/ NGR panel	**Done / Not done**														
44	1.4.3		Ensure length of equipotential wire of the window type CT's installed in generator bus duct is proper	**Done / Not done**														
45	1.5.1		Confirm differential protection scheme exists for the complete Generator including Bus Duct, HT cables & generator breaker.	**Available / Not Available**														
46	1.5.1		Confirm that differential scheme is having overlapping protection zone with the bus differential scheme at switchgear level.	**Yes / No**														
47	1.5.2		Provision of numerical type differential relay for generator protection or provision of perodic measurement of spill current.	**Available / Not Available**														
48	1.5.3		Confirm HV cable differential protection is connected to the Unit Master trip Relay (86U)	**Yes / No**														
49	1.5.4		Provision of separate back up over current protections for individual generator breaker	**Available / Not Available**														
50	1.5.4		Provision of separate back up earth fault protections for individual generator breaker	**Available / Not Available**														
51	1.5.5		Tripping of generator on under voltage.	**Not provided / Provided**														
52	1.5.5		Time and volage setting, if provided	**Setting**														
53	1.5.6		**Provision of continuous detection of Rotor Earth Fault. Time delay provided in alarm / tripping, if aplicable.**	**Yes / No**														
54	1.5.7		Redundant DC supply for Generator control & relay panel	**Available / Not Available**														
55	1.5.7		Provision of DC fail alarm at manned location.	**Available / Not Available**														
56	1.5.8		Whether numerical relay is provided for generator protection, if yes, confirm redundanc or provision of alarm in control room.	**Yes / No**														
57	1.5.9		The hardcopy of the relay logic and setting chart of generator numerical relays	**Available/Not available**														
58	1.5.10		The protection provided in generators for field failure plus under voltage should trip the generator instantaneously without any time delay	**Yes / No**														
59	1.5.11		Has scheme been provided as per 1.5.11	**Yes / No**														
60	1.5.12		Is stabilizin resistace of generator differential scheme in order	**Yes / No**														
61	1.5.13		Static excitation system, which derives power from generator terminal is to be avoided	**Yes / No**														

S.No.	Recomm. Ref.		Generator No. /Area / Sub Station →		TG-1	TG-2												
			Switch Board No. → ↓ Reliability check point															
62	1.5.14		monitor the generator field current and excitation field current at particular loads	**Yes / No**														
63	1.5.15		Practice of checking of generator Co2 system in place during shutdowns through simulation	**Yes / No**														
64	1.5.16	New projects	DVR dual auto channel with dual PLC to be considered for enhanced reliability	**Yes / No**														
65	1.5.17		Practice of Checking of end termination of generator cables	**Yes / No**														
66	1.5.18		Protection coordination of the generator voltage restrained/controlled over current protection (CDV) t with the over current protection of the outgoing feeders	**Checked/ Not Checked**														
			REMARKS															

Chapter-2

HT DISTRIBUTION SYSTEM *(Primary & Secondary)*

2A - <u>RECOMMENDATIONS</u>

Following actions are desirable for reliable and healthy HT Distribution System. Detailed explanation to these recommendations marked as (◄) has been enclosed at Section 2B of this chapter. For better focus and clarity the actionable points have been divided into following sub groups:

1. HT Generation / Distribution System –Configuration
2. Control Supplies
3. Protection Systems
   - (a) Relay Coordination
   - (b) Differential Protection
     - Bus Differential Protection
     - Cable Differential Protection
   - (c) Other Protections
4. Alarm and Annunciation

2.1 HT GENERATION / DISTRIBUTION SYSTEM –CONFIGURATION

2.1.1 Refineries to ensure that rated three phase short circuit fault level (KA / MVA) of the HT switchgear is higher than the actual fault level for the maximum operating machines configuration. (Refer Schematic Drawing No. – 2C.1, 2C.2 & 2C.3) ◄

***The system study / relay coordination needs revalidation with the new expansions / source augmentation as per IEC guidelines.** (New Facilities/ Projects)*

***2.1.2 It is desirable to have a separate generation bus and separate Distribution buses in the Primary Sub Station. The generation bus shall be with Double Bus configuration with out any bus coupler. In case the bus coupler exists between two generation buses, it should be kept off.** (New Facilities/ Projects)(not applicable to G)*

The distribution bus shall comprise of two sections with bus coupler. (Refer Schematic Drawing No. – 2C.4) ◄

2.1.3 It is *desirable* to have sectionalizing breakers in the generation bus between generators. (Refer Schematic Drawing No. – 2C.5) ◄ ***(New Facilities/ Projects)***

2.1.4 The *sectionalizing* breaker, wherever provided in the generation bus, shall normally remain in closed condition, unless otherwise situation demands. These breakers shall be provided ONLY with manual closing feature from Control room through synchronization scheme. ◄

2.1.5 In order to build in reliability in the system, it is desirable that primary as well as secondary distribution buses with bus couplers shall not be fed from the same generation bus or their adjacent sections. (Refer Schematic Drawing No. – 2C.5) ◄

2.1.6 Locations having more than one primary distribution sub station in close vicinity may consider a manual emergency tie connection in distribution buses of the two sub stations (of same fault level) for increased operational flexibility. (Refer Schematic Drawing No. – 2C.6). ◄

2.1.7 It is desirable to convert all outdoor bare / exposed HT electrical installations fed directly from the power plant into indoor systems except grid facilities.◄

2.1.8 Non-hygroscopic phase barriers should 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 should also to be provided with HT tapes/sleeves. ◄

2.1.9 It is to be ensured that all power cables are properly supported by clamps at the panel entry to avoid tension on cable lugs. ◄

2.1.10 String insulators with high creepage distances shall be used in terminal boxes, especially in transformers (new projects) ◄

2.1.11 50BF (Circuit breaker failure) scheme is to be provided in critical buses viz Generation & power plant distribution buses. ◄

2.2 CONTROL SUPPLIES

2.2.1 It is desirable that each HT bus section should be provided with dual DC control supply. Each bus section should be fed from separate DC feeder. The redundant DC control supply shall be designed for auto / manual changeover to the alternate backup DC supply as per the requirement. (Refer Schematic Drawing No. – 2C.7 & 2C.8) ◄

For the new projects, it is recommended to provide Diode based dual supply for the each panel as per the scheme 2C.8.

2.2.2 ***The auxiliary power supply of the numerical relays should be drawn separately and not from a common control supply switch of the breaker panel.*** ✔

2.2.3 ***Control supply failure alarm shall be available at manned locations for prompt remedial action.***

2.2.4 ***Complete DC distribution system to be reviewed in totality to ensure proper fuse coordination between the upstream & downstream sections.*** ✔

2.2.5 ***The ratings of each fuse shall be marked on the panel above the fuse base. It is desirable to have complete DC system distribution diagram showing fuse ratings up to downstream end for each DCDB. This diagram should be displayed at a suitable location in the switchgear.*** ✔

2.2.6 ***Failure of the DC control supply should not trip any breaker / process equipment. The contacts used for providing interlocks in the breakers mainly for the tripping logics should not be taken from the multiplying contactors / auxillary relays.*** ✔

2.3 PROTECTION SYSTEMS

(A) Relay Co-ordination

2.3.1 ***Each refinery shall have updated relay coordination based on the consolidated system study carried out for the entire connected electrical system.***

The system study / relay coordination needs revalidation with the new expansions / source augmentation as per IEEE guidelines.

Differential Protection

2.3.2 ***The total electrical system 6.6 KV and above in refineries must be covered with Differential Protection (or Instantaneous Protection) to clear the faults with 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.*** ✔

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

<u>Bus Differential Protection</u>

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

2.3.5 It is recommended to check the suitability of all " PS " class CT's installed for differential scheme with respect to knee point voltage considering the existing maximum fault level or the design fault level of the switchgear.

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

2.3.7 Differential / REF CT's shall generally be used for this specific protection only. 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. (New Projects)

2.3.8 The CT's for the Bus differential scheme are to be prominently marked to differentiate with other CT's of the same panel.

2.3.9 The sectionalizing *breakers* provided in the Generation Bus should be protected **only** by Bus Differential Protection with crossover zones between two adjacent buses.

2.3.10 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. (Refer Schematic Drawing No. – 2C.9)

2.3.11 Differential scheme shall have cross over zones with bus coupler, Generator, Radial feeders incomers, transformer feeders etc. (Refer Schematic Drawing No. – 2C.10)

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

2.3.13 It is desirable to use Numerical relays for differential protection with the spill current measurement display feature or periodic spill current measurement practice to be adopted.

2.3.14 The calculation for stabilizing resistance value shall be done properly based on the maximum / designed fault current. The suitable resistance shall be used in both versions of relays i.e. electromagnetic as well as numerical.

2.3.15 Control supply to the differential relay should be derived from a separate source with proper identification (not

from the normal panel supply in which the relay is mounted).

2.3.16 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. (Refer Schematic Drawing No. – 2C.12)

2.3.17 It is recommended to trip each breaker connected to the bus on actuation of its Bus Differential Protection.

2.3.18 *CT* supervision shall be provided in bus differential protection.

<u>Cable Differential Protection</u>

2.3.19 **All HT radial feeders within Refinery shall have instantaneous cable differential protection with OFC pilot cable for instantaneous clearing of the fault.**

2.3.20 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.

2.3.21 Cable differential protection shall have zone cross over with the upstream/ downstream bus differential protection.

2.3.22 **It is to be ensured that the OFC pilot cable supervision scheme with alarm at manned location is provided for the cable differential protection.**

2.3.23 The knee point voltage of the CT's to be verified as per guidelines provided by relay manufacturer and using the refinery fault levels.

2.3.24 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.

2.3.25 The CT secondary connection configuration plays a very vital role in the stability of the cable differential scheme. The recommended connection configuration of the OEM for both ends shall be strictly followed. (Refer Schematic Drawing No. – 2C.13A & B)

2.3.26 In view of absence of spill current /voltage monitoring feature in the cable differential relay, it is desirable to monitor the spill voltage across the relay-operating coil at least once, preferably at the time of commissioning the scheme. A suggested scheme to achieve above is enclose as Annexure - 2D.2, for reference)

2.3.27 Soft link of OFC based Cable differential relay shall be used for Inter-tripping of incomer breakers & upstream breakers to avoid spurious tripping due to control cable failures wherever OFC based Cable differential relays are provided.

(B) Other Protections

2.3.28 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. It is to be ensured while procurement that the PD value of the CT's shall be less than 20 pc.

2.3.29 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.

2.3.30 It is desirable to have Transformer Differential Protection for Transformers having HT voltage in primary and secondary side.

2.3.31 In case of transformers feeding to PCCs, the HT breaker of transformer must be provided with Instantaneous (High Set) Over current protection.

2.3.32 In order to achieve complete isolation of fault, master relay operation of any downstream breaker should also trip the upstream breaker. (Refer Schematic Drawing No. – 2C.12)

2.3.33 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. At locations, where such scheme is provided thru' a Push Button, should be modified with continuous monitoring type of scheme.

2.3.34 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.

2.3.35 It is recommended to replace obsolete electro-mechanical relays, in phased manner, with latest numerical relays in all critical feeders to prevent spurious tripping/ relay mal-operation, drift etc.

2.3.36 Watchdog timer alarm (Numerical relay faulty) to be wired up to control room / manned location.

2.3.37 It is desirable to use Reed Switch type Bucholz Relays in place of Mercury Switch type relays in seismic prone area.

2.3.38 It is desirable to provide clean & dedicated earthing for the numerical relays in line with OEM recommendations.

2.3.39 It is recommended to develop a standard document/ data sheet (with enabling / disabling status application wise) as ready reference for a particular make & model specific numerical relay to prevent any unwanted human errors.

2.3.40 **It is recommended to trip the breaker directly on Emergency PB trip, LCS stop etc. (other than the protections in numerical relay) without using any intermediate numerical / auxiliary relay for ensuring reliability / integrity of tripping the circuit breaker in the event of numerical relay failure.**

2.3.41 The breaker service position contact should not be included in the tripping logic of breakers.

2.3.42 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. Refineries to review the LBB protection scheme / applicability at their end.

2.3.43 The control fuse ratings of protection schemes like CDV / bus bar differential scheme/under voltage scheme etc. to be reviewed and correct rating of the fuse to be ensured as per design requirement. Control supply failure alarm should be available at manned location as per earlier clause 2.2.3.

2.3.44 In view of the failures experienced in ABB make PQ8 master trip relay it is recommended to provide VAJH type of the tripping relays.

2.3.45 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%.

2.3.46 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.

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

2.3.48 In order to capture the data of MW, MVAR, Voltage, and Frequency during transient conditions of faults/ disturbance (which is normally not possible from ECS) it is recommended to provide chartless recorders / Numerical disturbance recorder (NDR) for each generator and in the generation bus.

2.3.49 For ensuring reliability of generator breakers and for 33KV circuit breakers double trip coil to be provided. (New Projects)

2.3.50 HT switchgear at TPS i.e. generation bus and distribution bus shall be rated for short circuit current of preferably 3 second duration for better protection coordination. The short circuit current rating of HT cables from TPS to downstream sub-station shall also be rated for 1 Second. (New Projects)

2.3.51 All outgoing HT feeders from TPS are to be provided with cable differential protection for instantaneous fault clearance. Differential / instantaneous protection requirement shall not be compromised. For long feeders like township etc. where such type of provision is not available, back up instantaneous over current protection to be provided.

2.3.52 It is recommended to provide a minimum time gradation of about 0.15 to 0.2 sec. between bus coupler and incomer to avoid simultaneous tripping of incomer and bus coupler under fault conditions.

2.3.53 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. (New Projects)

2.3.54 Stabilising resistance shall be provided in instantaneous earth fault protection of transformer feeders.

2.3.55 **All transformer feeders shall be provided with CBCT for sensitive Earth Fault protection. Residual E/F connection not be used.(new projects/New procurements).**

2.4 Alarm and annunciation

2.4.1 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) should be extended to the power plant control room, in addition to Generator related alarms.

2.5 Reliability Enhancement Practices

2.5.1 Monitoring of the temperature through Infrared IR windows in HT switchgear is to be provided in a phase manner according to the priority of location like generation bus, incomer breakers / outgoing feeders for radial systems having high loads etc.

2.5.2 Integrity of the protection system of HT switchgears should be ensured annually / with unit shutdown or earliest opportunity not exceeding two years by primary injection. The check list given in Annexure-I(a), I(b), I(c) for HT feeder / transformer / motor testing to be followed during feeder testing.

2.5.3 At present for any modification/ changes in protection settings & schemes etc. in electrical system approvals are obtained within the department without any formal Management of Change (MOC). It is recommended that structured MOC be carried out for electrical system for modifications, changes in relay settings. Some of the critical protections and interlocks which are to be given high priority are Instantaneous over current & earth fault relay settings, differential protection, inter tripping, transformer protections etc. Approval shall be as per the existing norms for MOC.

2.5.4 Bypass of interlocks / protections shall not be permitted under any circumstances. Immediate action for checking / rectification shall be taken up after taking the necessary shutdown.

2.5.5 Services through external agencies / in-house expertise for on line partial discharge of HT switchgears to be explored on trial basis and based on its effectiveness, suitable procurement of on line PD detection equipment to be initiated.

2.5.6 Sample testing of current transformer (CT) healthiness of old switchgears (more than 20 Years) to be done w.r.t partial discharge (PD). For CT's having PD values greater than 50 pico coloumbs, suitable replacement action to be initiated.

2.5.7 A survey for ensuring integrity of the cable end terminations in the HT system to be carried out for ensuring proper end termination workmanship as per OEM guidelines. During the survey, physical verification for any signs of tracking, cracks, heating is to be done. As failures in end termination have taken place due to improper workmanship / supervision, it is recommended that a second level of random checking of end terminations carried out during new projects / maintenance to be ensured.

2.5.8 For ensuring the reliability of circuit breakers / HT switchgear panels specially with respect to the circuit breaker mechanism, insulation condition, vacuum bottle healthiness, insulating barriers integrity etc. it is desirable to get the switchgears overhauled through OEM during unit shutdown. During PM, motor feeders are to be checked annually (in-house).

2.5.9 Proper installation of numerical relays in the HT panels to be ensured and all fastening screws to be in position to prevent the draw out portion of the relays coming out from its operating position during breaker operation / panel door operation.

2.5.10 Flashovers in BHEL metal enclosed switchgears have been observed. As a precautionary measure anti tracking paint to be applied on the insulating barriers and sufficient clearance between the breaker arm insulation and the safety shutter to be ensured.

2.5.11 For new Projects, availability of IR(Infra Red) windows in all HT switchgears shall be a part of the standard specifications. In existing switchgears IR windows for monitoring of panel inside temperature to be installed in phases i.e. incomer/ bulk current feeders.

2.5.12 Adequacy of instantaneous fault clearance in HT system with regard to primary bus differential, instantaneous over current / earth fault shall be reviewed annually. The updated document shall be available in Testing Department and surprise audit to be carried out by Senior Officers.

2.5.13 For ensuring proper sealing of panels, neoprene gaskets should be replaced every 4 years.

2.5.14 Control schemes for incomer, bus coupler, feeder incorporating the critical reliability aspects have been prepared as a standard scheme / philosophy. The same shall be utilized while finalizing engineering drawings, new procurements etc.

2.5.15 Earth fault setting:

i. The pick-up setting of the earth fault protection shall be set to at least less than 30% of the minimum expected fault current.
ii. The minimum expected fault current shall be calculated based on the earth fault limiting current with only one grounding source.
iii. In places where required pick-up setting for the residually connected earth fault protection calculated based on the above criteria is working out to less than 10% of the CT primary rating (of 5P CT), it is suggested to use CBCT based earth fault protection to ensure accuracy.
iv. For co-ordination purpose the maximum expected earth fault current shall be used.

2.5.16 **Aux Contactors in critical feeders (I/C, B/C, HT Motor Soft starter etc) which remain energized in normal condition, shall be replaced every 4-5 years**

2.5.17 **Condition monitoring of critical electrical equipments through Partial discharge monitoring, thermography, DGA, Furan Analysis etc. shall be strengthened through RCM/SAP.**

In order to facilitate full implementation of above recommendations by identifying GAPs and preparing action plan, a check list has been developed for reference and is given at Section 2E of this chapter.

New Point Annexure-I(a)

Ref. Pt.2.5.2 of Ch.2

CHECKLIST FOR HT FEEDER TESTING (Incomers , Line PTs , Bus PTs)

Feeder Tag: Unit:

	CHECK POINT	DONE / NOT DONE	***REMARKS***
	Common points		
1	**Tightness checking for TB's**		
2	**Checking of CT terminals and link positions (at TB)**		
3	**CT terminal checking (At CT end)**		
4	**Circuit breaker plug connections tightness checking**		
5	**Visual inspection of relay modules, contacts, casing, etc.**		
6	**Cleaning of relay panel**		
7	**Cleaning of relays/auxiliary relays**		
8	**O/C protection relay checking by primary injection**		
9	**Primary injection for Earth fault**		
10	**Checking of auxiliary relays /timers**		
11	**Check tripping of breaker from relay**		
12	**Checking of panel indication lamps**		
13	**Analog meters calibration check**		
14	**Fuse checking & providing control fuse sticker**		
15	**Provide differential CT sticker**		
16	**Separation of control supply for Numerical relay**		
17	**Voltage relay testing (Pick up & drop down)**		
18	**Auto changeover checking**		**During section shutdown / normalisation**
19	**Line PT checking**		
20	**Bus PT checking**		
21	**All protection relay settings verified**		
22	**All under voltage relay settings verified**		
23	**Fill up relay test sheet**		

Signed

Countersigned

Random Checking by Higher Official / Manager

New Point Annexure-I(b)
Ref. Pt.2.5.2 of Ch.2

CHECKLIST FOR HT TRANSFORMER FEEDER TESTING

Feeder Tag: Unit:

	CHECK POINT	DONE / NOT DONE	*REMARKS*
	Common points		
1	Tightness checking for TB's		
2	Checking of CT terminals and link positions (at TB)		
3	CT terminal checking (At CT end)		
4	Circuit breaker plug connections tightness checking		
5	Visual inspection of relay modules, contacts, casing, etc.		
6	Cleaning of relay panel		
7	Cleaning of relays/auxiliary relays		
8	O/C protection relay checking by primary injection		
9	Primary injection for Earth fault		
10	Checking of auxiliary relays /timers		
11	Check tripping of breaker from relay		
12	Checking of panel indication lamps		
13	Analog meters calibration check		
14	Fuse checking & providing control fuse sticker		
15	Differential CT sticker provided (Yes/No)		
16	Whether control supply for Numerical relay separate from panel control supply ? (Yes/No)		
17	Checking of intertripping		
18	Checking of transformer protections like Buchholz,OTI, etc. by actual simulation from field (for trans. feeder)		
19	Whether settings are as recommended		
20	Relay test report filled		

Signed

Countersigned

Random Checking by Higher Official / Manager

New Point Annexure-I(c)
Ref. Pt.2.5.2 of Ch.2

CHECKLIST FOR BREAKER FED MOTOR FEEDER TESTING

ELECTRICAL TESTING SECTION

Date:

KW		Prot. CTR		Brkr. TYPE		Control Fuse Ratings:	
AMPS		E/F CTR		Brkr. Amps Rating:		Prot. Relay Make & Model	

Sl.No.	CHECK POINT	DONE / NOT DONE	REMARKS
1.	**Thorough Cleaning of control cubicle.**		
2.	**Wiring tightness checking at each termination.**		
3.	**Physical checking of power cable termination & support insulators**		
4.	**Note protection relay settings and compare with original settings for any deviation.**		
5.	**Check operation of Thermal overload.**	**____Amps Primary current applied in __ PH & Thermal Prot. Operated in ___ sec**	
6.	**Check operation of earth fault prot.**	**____Amps Primary current applied & E/F Prot. Operated in ___ Sec.**	
7.	**Check operation of negative Ph. Seq. prot**	**____Amps Primary current applied in __ PH & Thermal Prot. Operated in ___ Sec.**	
8.	**Check master trip relay is operating in each case. Close the breaker in TEST position & check the breaker tripping**		

	in at least one operation.		
9.	Check the healthiness of trip circuit supervision scheme.		
10.	Breakers Plug connections are tight & fitting okay		
11.	Check all indications are healthy.		
12.	Check healthiness of Analogue meters.		

Signed

Countersigned

Random Checking by Higher Official / Manager

Chapter-2

HT DISTRIBUTION SYSTEM *(Primary & Secondary)*

2B - EXPLANATION TO RECOMMENDATIONS

Reference	Explanation
2.1.1	This is to take care of the adequacy of the switchgear in sustaining the fault current. This may be ensured for all switchgears including secondary distribution, which are at generation voltages level. (Refer Schematic Drawing No. – 2C.1) The same to be ensured every time a new machine is added to the system. In case the new fault level of exceeds the rated fault level of the existing switchgear, adequate fault limiting transformers may be used. (Refer Schematic Drawing No. – 2C.2) For secondary voltage level (6.6KV etc), the fault level of the switchgear (i.e. after transformer) is largely governed by the impendence of the transformer. However, fault level adequacy of the secondary level switchgear to be ensured for sustained parallel operation of incoming transformers of both the sections. (Refer Schematic Drawing No. – 2C.3)
2.1.2	In the system configurations having single & common Generation cum distribution bus systems, (Refer Schematic Drawing No. – 2C.4) any fault in the bus section shall lead to the outage of complete bus resulting into Total Power Failure. To achieve higher reliability & operational flexibility in the system, it is desirable to have a separate generation bus and separate Distribution buses in the Primary Sub Station. Refer Schematic Drawing No. – 2C.4) This is to ensure continuous supply to distribution network in case of outage of any the generation bus on fault. It is will also provide improved protection coordination for isolation of fault without effecting running generators.
2.1.3	The philosophy is to have one integral generation Bus with sectionalized isolation devices in-between for better fault management and operational flexibility. Sectionalizing breakers in the generation bus between each generator will minimize the possibility of outage of complete generation bus on bus faults. This configuration will also facilitate the running maintenance and operational flexibility. (Refer Schematic Drawing No. – 2C.5) This may be adopted if the retrofit in the generation bus is feasible in the existing systems. However, it should be followed in new installations.

2.1.4	In case the sectionalizing breaker is provided the Auto changeover facility, it will lead to very complicated auto changeover logics with more than two incomers and two bus couplers and may affect the system reliability.
2.1.5	The distribution buses in the primary sub-station shall be fed from the main generation buses. It is to be to ensured that outage of any of the generation bus shall not affect the complete distribution system i.e. the simultaneous outage of both the distribution bus sections should not occur. (Refer Schematic Drawing No. – 2C.5)
2.1.6	This configuration shall provide operational flexibility during non-availability of an incomer of either of the distribution bus and will still ensure power supply from twin sources. (Refer Schematic Drawing No. – 2C.6) Units may review incorporating the above tie connection based on system requirement and desired operational flexibity in the distribution network.
2.1.7	The exposed outdoor HT installations are vulnerable to frequent flashover due to monkey / peacock etc. Any fault shall result in sever voltage dip in the system and thereby effecting unit operation.
2.1.8	There have been many instances of flashover resulting into plant interruption due to rodent fault in the exposed portion of Breaker trolley/ out going cable box. Though all out efforts to be made to prevent entry of rodents on the panel, it will additionally help in eliminating Phase to phase faults and minimizing the extent of damage in case of ground faults due to rodents.
2.1.9	It has been experienced that flashovers have taken place due to continuous tension on the cable lugs or cable sheath/ insulation damage from the extruded portions due to improper lying.
2.1.10	String insulators provide increased protection from surface tracking phenomenon due to higher creepage distances and hence are more reliable.
2.1.11	Circuit breaker failure protection at generation bus & distribution bus should be provided to prevent collapse of the system during non-tripping of any circuit breaker in the generation bus or distribution on faults.
2.2.1	The DC control supply of Bus sections shall be provided with redundancy to meet the exigency of failure of the primary control supply. It is recommended to provide either following modes of control supply scheme related to redundancy. • Standard contactor based control supply scheme changeover scheme with through AC supply. (Refer Schematic Drawing No. –

	2C.7) • Parallel control supply scheme with proper rating blocking diodes where one supply shall remain in service at a time. (Refer Schematic Drawing No. – 2C.8)
2.2.2	Numerical relays loose his history with the failure of its power supply normally drawn from the control supply of the breaker panel.
2.2.4	This shall help in maintaining reliable control supply without unwarranted failure due to wrong fuse coordination.
2.2.5	Labeling of fuse rating shall help the operator in providing correct fuse rating during replacements. The use of overall DC diagram with fuse ratings will mainly help in; • Source identification • Overall fuse coordination for entire DC system in a sub station • Verification of fuse rating, in case of doubt by operator. • Fuse inventory management.
2.2.6	This is to ensure that even a momentary interruption in the switchgear DC control supply shall not lead to tripping of the circuit breakers, Not even from the multiplier contactor mounted in side the breaker. Only directly wired hard contacts shall be used in the tripping circuit.
2.3.2	It is required that entire HT system should be protected enough to the faults instantaneously. This may be achieved by a suitable differential protection (either by Generator Differential, Bus Differential, Transformer Differential or by Cable differential protection). In case of transformers feeding to PCCs, the HT breaker of transformer must be provided with Instantaneous (High Set) Over current protection. Cross-over zones shall be provided to ensure that even the smallest part of the switchgear is not left unprotected by differential protection. This may result in overdoing the protection, it is very much desirable to have such measures for improved system reliability.
2.3.3	Use of ICTs, to compensate for non-matching CT ratios in Differential schemes, may lead to mal operation of scheme on account of spill currents generated due to probable mismatch in CT characteristics.
2.3.4	It is imperative to clear the faults in HT Switchgears in the least possible time through a high-speed zone protection system (viz. Bus Differential Protection) in view of the following: • To minimize damage of electrical equipment at fault location • To minimize impact on the operation of process units due to sustained voltage dip in the system (even one second time delay in clearing the fault may result shutdown of all units operation).

	In case it is not possible to provide Bus Differential in the HT switchgear due to technical constraints, the Incomer breaker of such switchgears ***MUST*** be provided with instantaneous O/C and E/F protections.
2. 3.5	Interruptions have been experienced due to mal-operation of protection scheme as knee point voltage in "PS" class CT's was lower than the desired value during through fault conditions. Due to low knee point voltage, CT's may experience saturation during high current flow condition thus the current transformation through CT shall become erratic leading to mal-operation of differential scheme. (The sample procedure for calculating knee point voltage is attached as Annexure - 2D.1, for reference)
2. 3.6	Mismatch in CT characteristics may generate spill over currents in the circuit particularly during the through fault conditions and may lead to the mal-operation of the differential protection.
2. 3.7	Use of dedicated CT for Differential/ Ref protection, will help in performing the testing of individual panel with out disturbing the Bus differential scheme. In case the use of separate CT is inevitable, it is to be ensured that a dedicated core of the CT is used for DIFFERENTIAL/ REF application. If same CT –core is used for metering and other protection • The burden of the CT may increase, if not originally designed for such applications • Due to series wiring of the current signal from CT, the differential wiring will also get involved in the other applications resulting into complex wiring network. This may result in mal-operation of differential due to its vulnerability of circuit problems. • While testing of nay other application, the differential protection may mal-operate, if adequate precautions are not taken.
2.3.8	During the shutdown of the panel, while testing the other protections, the person performing the test may easily distinguish between the various types of CTs and thereby avoid the current injection / testing of CT's provided specifically provided for bus differential protection thereby mal-operation of the scheme by human error may be prevented.
2. 3.9	No other standard protection shall be provided in the sectionalizing breakers as these breakers are considered as the part of the bus section. Also due to possibility of bi-directional current flow, relay coordination shall be very difficult and may lead to spurious tripping.
2.3.11	Overlapping of protected zones shall be provided to ensure that even the smallest part of the switchgear is not left unprotected by differential protection. (Refer Schematic Drawing No. – 2C.10)
2.3.12	The Bus Differential Scheme shall be based on standard current balance

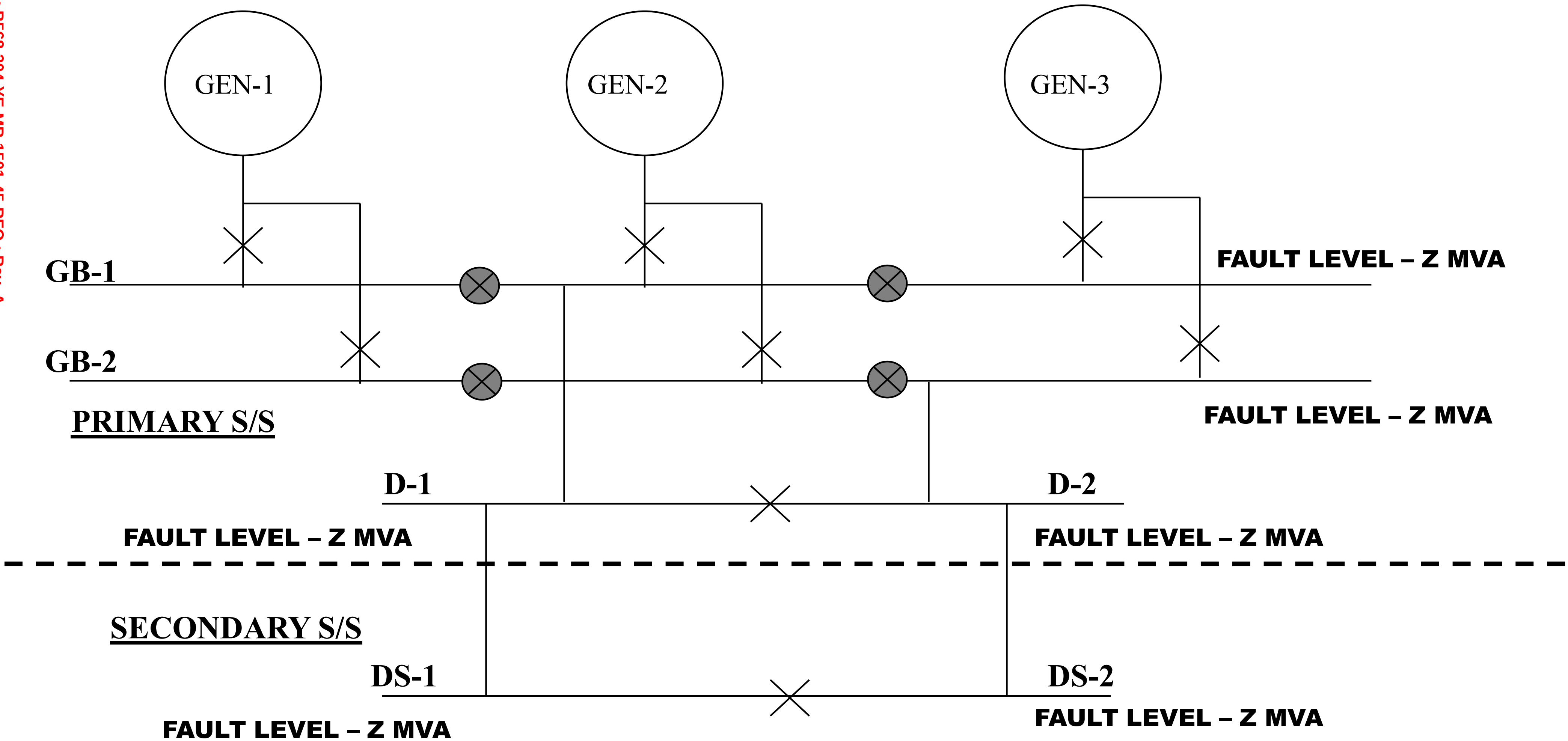
	method between all the feeders of particular switchgear and shall basically constitute of dedicated Class PS CT's in each feeder along with Stabilizing resistances, Metrosil (Voltage limiting variastor) & instantaneous differential relay (87) etc. ***Bus differential schemes based on other principles e.g. reverse blocking; interlocking type etc. shall be discouraged.***
2.3.13	• Numerical relay have a feature of online monitoring of spill current in all the three phases. Display & alarming of spill current shall help in timely remedial action due to saturation, wrong connection etc. thereby avoiding spurious operation of the scheme. **Scheme with numerical relays are working satisfactorily at several locations and are very helpful in preventing mal tripping with regular monitoring**. However, if desired, initially these numerical type differential relays may be installed in series with the existing electromagnetic relays for monitoring spill currents and other disturbances without connecting to the trip circuit for boosting confidence. • In case of availability of High set instantaneous O/C and E/F feature in the relays of incomers and bus couplers, contact of High set tripping from the relays of Incomer and bus coupler may also be provided in series of the 87 –Differential relay trip command. This will help in further strengthening the reliability of the differential protection to operate only on actual bus faults and not on CT related problem and through faults. Refer Schematic Drawing No. – 2C.11
2.3.14	Proper stabilizing resistance prevents mal-operation of the scheme during through fault condition or during CT saturation, The sizing of the stabilizing resistance shall be based on the relay burden, CT secondary resistance, wiring resistance, and designed fault level of the switchboard. Calculations should be based on the rated fault level of the board to prevent replacement of resistance at the time of adding commissioning of new generator. However, Stabilizing Resistance is not required for schemes provided with *Biased Differential Protection Schemes*. (The sample procedure for calculating stabilizing resistance is attached as Annexure - 2D.1, for reference)
2.3.15	Normally power supply to differential scheme is derived from the control supply of the panel in which the differential relay is mounted. Care is to be taken that the control supply to differential scheme/ relay should remain intact when the individual panel supply is switched off while giving the shutdown of panel. Otherwise the differential protection shall be shall get inadvertently bypassed.
2.3.16	Refer Schematic Drawing No. – 2C.12. If a fault takes place in the

	portion between the CT and the breaker, the bus differential scheme shall operate to trip the breakers of the switchgear, still the fault shall be continued to be fed from the upstream side. The upstream breaker shall trip on over current or earth fault protection with a time delay as per the setting. The delay in fault clearance may jeopardize the whole system. To eliminate such situation, the tripping may be provided from the downstream master relay contact to the upstream breaker. This shall ensure in complete isolation of the fault under all circumstances, and to prevent chances of fault feeding even after the operation of differential scheme.
2.3.17	At some of the locations, tripping of only Incomer & Bus Coupler is done on actuation of bus differential protection. It is proposed to trip each breaker connected to the switchgear on actuation of differential protection. This shall enable fast auto changeover of bus coupler scheme at downstream S/S and also possibility of back feeding from the downstream s/s can be completely avoided.
2.3.21	Overlapping of protected zones shall be provided to ensure that even the smallest part of the switchgear is not left unprotected by differential protection. This may result in overdoing the protection, it is very much desirable to have such measures for improved system reliability.
2.3.22	The OFC pilot cable used in the cable differential scheme is the communication link between the differential relays provided at the two ends of the cable for matching the sending end as well as the receiving end currents. The cable differential protection will not work if the OFC pilot cable is unhealthy. Therefore, there is a need of continuously supervising the health of OFC & relay.
2.3.23	Interruptions have been experienced due to mal-operation of protection scheme as knee point voltage in "PS" class CT's was lower than the desired value during through fault conditions. Due to low knee point voltage, CT's may experience saturation during high current flow condition thus the current transformation through CT shall become erratic leading to mal-operation of differential scheme. (The sample procedure for calculating knee point voltage is attached as Annexure - 2D.1, for reference)
2.3.24	It may be possible that the switchgears at Upstream and down stream ends of the feeder cable are of different make or not procured together. This may result into the mismatch in the CT specification resulting into mal-operation of the cable differential protection.
2.3.25	There have been experience of undesirable operation of HORM-4 relay due to inadequate installation process. In case of stability problem in Alstom make HORM-4 relay, the recommended orientation of CT installation (P1 & P2) and corresponding CT secondary connections are to made as per manufacturer commissioning catalogue (Refer

	Schematic Drawing No. – 2C.13A &B). It is recommended to ensure star point formation for CT's as follows: - • In case P1 of CT is towards cable side & P2 towards bus side – S1 terminal of CT shall make star point • In case P2 of CT is towards cable side & P1 towards bus side – S2 terminal of CT shall make star point Star point formation is to be seen for both end panels and it is to be noted that connections are independent of other end CT connection. Star point is to be formed keeping the primary CT connections of that particular end into consideration).
2.3.26	In order to ensure stability of HORM-4 relays, the spill voltage across the relay-operating coil is to be monitored with relay in service condition, at least during the first charging of the feeder. Since it is not possible to measure the voltage directly from the relay, alternate arrangements have to be made using a test relay to monitor the spill voltage. A scheme suggesting the same is enclosed as Annexure - 2D.2, for reference. The test relay can be safely inserted one by one in the feeders to measure the spill voltage. It is recommended to check the spill voltages in the existing schemes once to ensure the stability of the cable differential protection.
2.3.27	To avoid inter tripping of incomer breakers & upstream breakers due to control cable failures, inter tripping is to be provided with Soft link of OFC based Cable differential relay using digital inputs.
2.3.28	There have been instances of power interruptions and TPF on account of CT failure in the Generation / distribution systems having BAR Type (wound Type) CTS. The heat due to improper connection of CT with the Bus bar may lead to failure of CTs. To prevent such failure it is recommended to use window type CTs for all critical HT switchgears and bus applications. In window type CTs, due to absence of power connections / contacts, the inherent problem related with the contact heating in wound type CT's of high current rating can be avoided. In case it is not feasible to replace the CTs in all HT switchgears, efforts to be made to replace the CTs at least in the Generation system and particularly those locations where CT failures due to heating are observed.
2.3.29	This shall help in avoiding flashover in main bus chamber. Adhesive type sticking clamps should not be used for this purpose, as the same gets detached from the surface after some time and causes short circuits in the HT bus chamber. The CT wiring in the CT/ Cable chamber should be properly dressed in the trays to avoid any possibility of flashover with the main bus bars.

2.3.32	Refer Schematic Drawing No. – 2C.12. If a fault takes place in the portion between the CT and the breaker, the bus differential scheme shall operate to trip the breakers of the switchgear, still the fault shall be continued to be fed from the upstream side. The upstream breaker shall trip on over current or earth fault protection with a time delay as per the setting. The delay in fault clearance may jeopardize the whole system. To eliminate such situation, the tripping may be provided from the downstream master relay contact to the upstream breaker. This shall ensure in complete isolation of the fault under all circumstances, and to prevent chances of fault feeding even after the operation of differential scheme.
2.3.33	The supervision shall be done for both “On” & “Off” condition of the breaker. It is to be ensured that the longest loop in the trip circuit is taken care while finalizing the scheme to ensure correctness of the loop as the scheme monitors the healthiness of both coil & trip circuit.
2.3.34	Due to low voltage of binary signal (24V, 48 V) used in numerical relays, spurious operation of numerical relays program for inter-tripping interlock protection has been observed due to interference from nearby power cables/ capacitive effect. It is, therefore, recommended to use interposing relays instead of using low voltage signals as binary inputs.
2.3.36	Watchdog is a diagnostic feature in numerical relays which monitors the healthiness of the relay by generating alarm on the relay panel in case the relay becomes faulty. It is not practicable for operator to continuously monitor the status on every relay. It is therefore recommended to extend this alarm at a suitable manned location, either individually or in the form of group alarm.
2.3.37	It is desirable to use in place of Mercury Switch type relays in seismic prone area. There have been instances that transformer have tripped on Bucholz protection due to mal-operation of mercury switch in the relay during earthquakes. To improve the operational reliability of the secondary distribution system Reed Switch type Bucholz Relays should be used. Mark –10 Bucholz Relay of L&T (P&B) is one of such relay available in the market. The catalogue for the relay is enclosed as Annexure - 2D.3, for reference
2.3.38	This is based on the experiences of mal-operation of numerical relays and also on vendor recommendation. This can be done by making a common and dedicated earthing grid for numerical relays.
2.3.39	This is essential for numerical relays to disable all unwanted settings as it can result in undesired trippings. This shall also ensure uniformity in the selection of features & settings. A sample sheet is enclosed as Annexure 2D.4 (for Alstom make MICOM relay). The sheet for all other

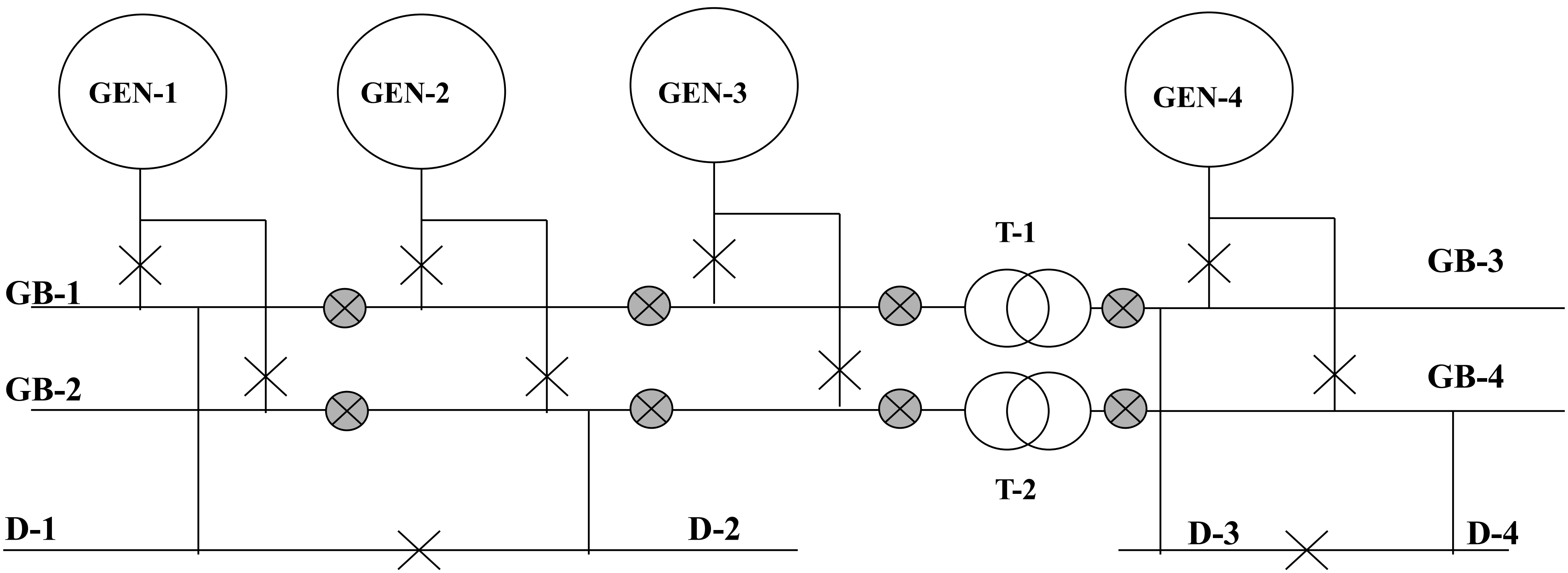
	make / model of relays shall be developed by users on similar lines.
2.3.40	In case of numerical relay applications, all the Trip/ Stop commands(including emergency trip from field) are routed through the numerical relay. In the event of faulty numerical relay it will not be possible to trip the breaker in emergency situations and during faults. Therefore, it is recommended to route all the trip/ Stop commands (including TNC switch) to directly trip the breaker without using any intermediate numerical / auxiliary relay for ensuring reliability and safety. In case the modification in this regard is cumbersome, an additional command to trip breaker directly be incorporated by using spare contact of PB / TNC switch.
2.3.41	It is not desirable to prevent the tripping of any breaker in case of emergency in field and fault conditions. There have been instances that the motor did not trip during fault or when stopped from field due to problem in the Breaker service position limit switch contact or its wiring resulting into greater degree of damage either to equipment or to process. Some of the OEMs/ switchgear supplier say that this situation should be taken care by the backup (ie. Upstream breaker) in case of fault in the running equipment. This may not be true for conditions which result in partial increase in motor current like over load , bearing failure, rotor rubbing due to bearing seizure or emergency requirements from field to stop the motor. Hence it is desirable to remove the service contact interlock from the tripping logic of all the equipments including motors.
2.3.54	The phase CTs are generally connected in residual mode for deriving the earth fault current or else CBCT is used for earth fault protection. In residual connections suitable stabilizing resistance is to be provided in the circuit to prevent relay mal-operation during high inrush currents. By installation of stabilizing resistance, sensitivity of the relay is affected to some extent but spurious operation of earth fault protection can be completely eliminated. The current setting of earth fault protection is so low that loss of some sensitivity does not make much impact on the pickup of the relay. Moreover, use of stabilizing resistance is a standard technique which is used in all-current balance schemes e.g. differential protection, REF,50N etc. Hence use of the same in E/F protection will provide an opportunity to further reduce the current setting up to 10%.
2.3.55	Residual connected earth fault schemes require stabilising resistance for stability with some loss of sensitivity. CBCT allow sensitive Earth Fault protection.



FAULT LEVEL OF GB-1,GB-2,D1,D2,DS1,DS2 SHOULD BE SAME AND SHOULD BE BASED ON COMBIND FAULT LEVEL OF ALL THE MACHINES CONNECTED TO THE GB-1 & GB-2

PRIMARY & SECONDARY SUBSTATION FAULT LEVEL ADEQUACY

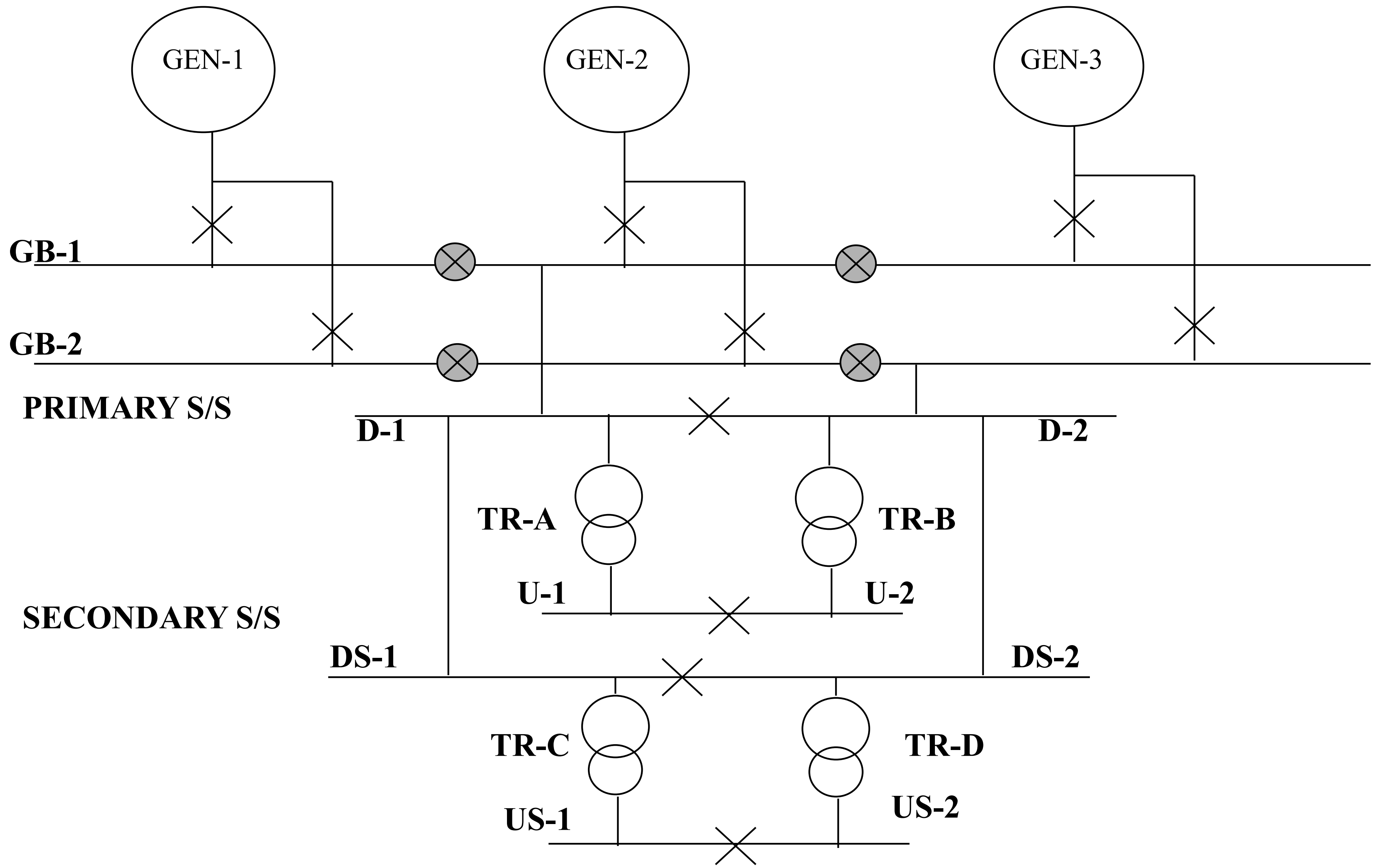
DRG. NO. 2C.1



- With the hookup of Gen-4, if the combined fault level is within the rated fault level of Gen. Buses G1 / G2 then new Generator can be directly hooked up to the Bus.(T1 & T2 are not required)
- In case the combined fault level exceeds the rated level of Gen. Buses G1 / G2, then a suitable fault level device e.g. transformer (T1 & T2) should be used for interconnection of new generator with the existing system.

INTEGRATION OF NEW MACHINE AT PRIMARY SUBSTATION

DRG. NO. 2C.2



SECONDARY SYSTEM FAULT LEVEL ADEQUACY

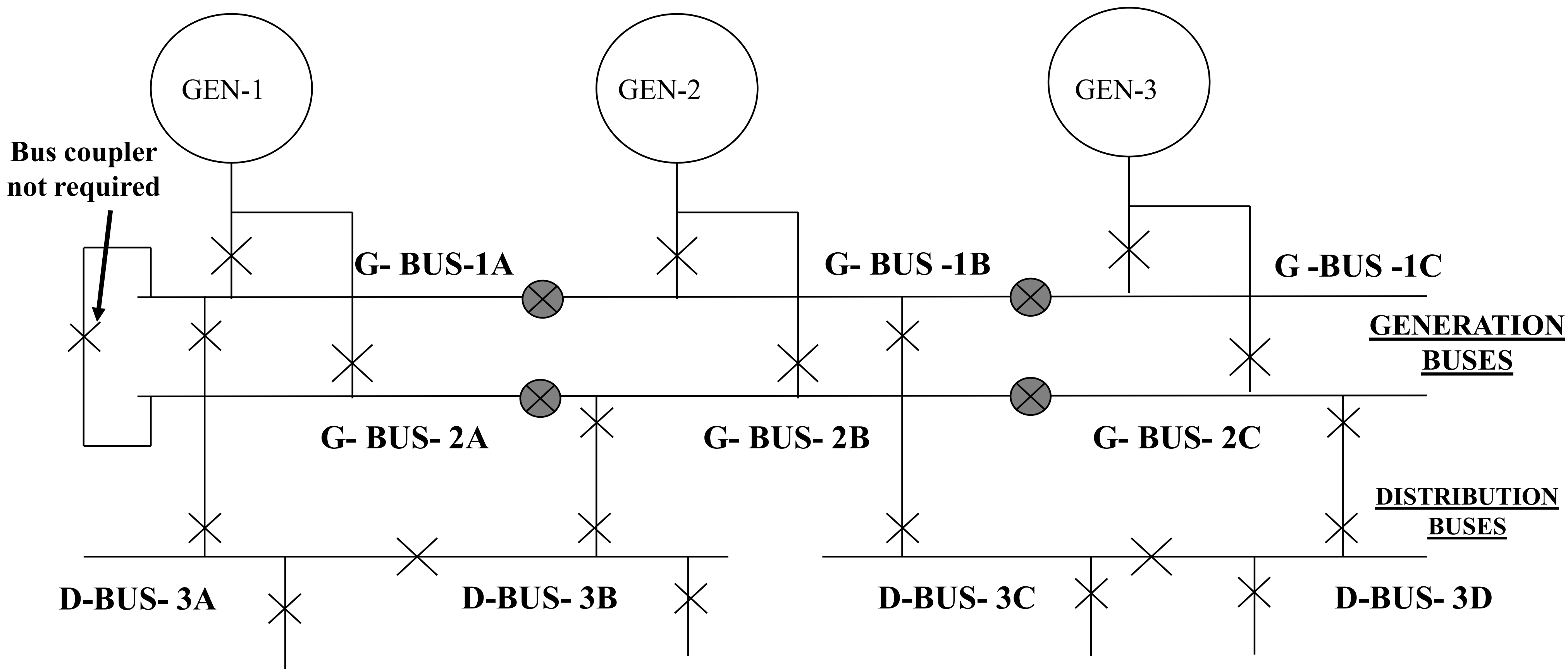
DRG. NO. 2C.3A

NOTE :-

- Fault level of GB-1, GB-2, D1,D2, DS-1,DS-2 shall be same
- Fault level of U1 & U2 shall be dependent on the impedance transformers TR-A & TR-B considering parallel operation of both the transformers.
- Similar shall be the case for US-1 & US-2, which shall be dependent on the parallel operation of the transformers TR-C & TR-D.

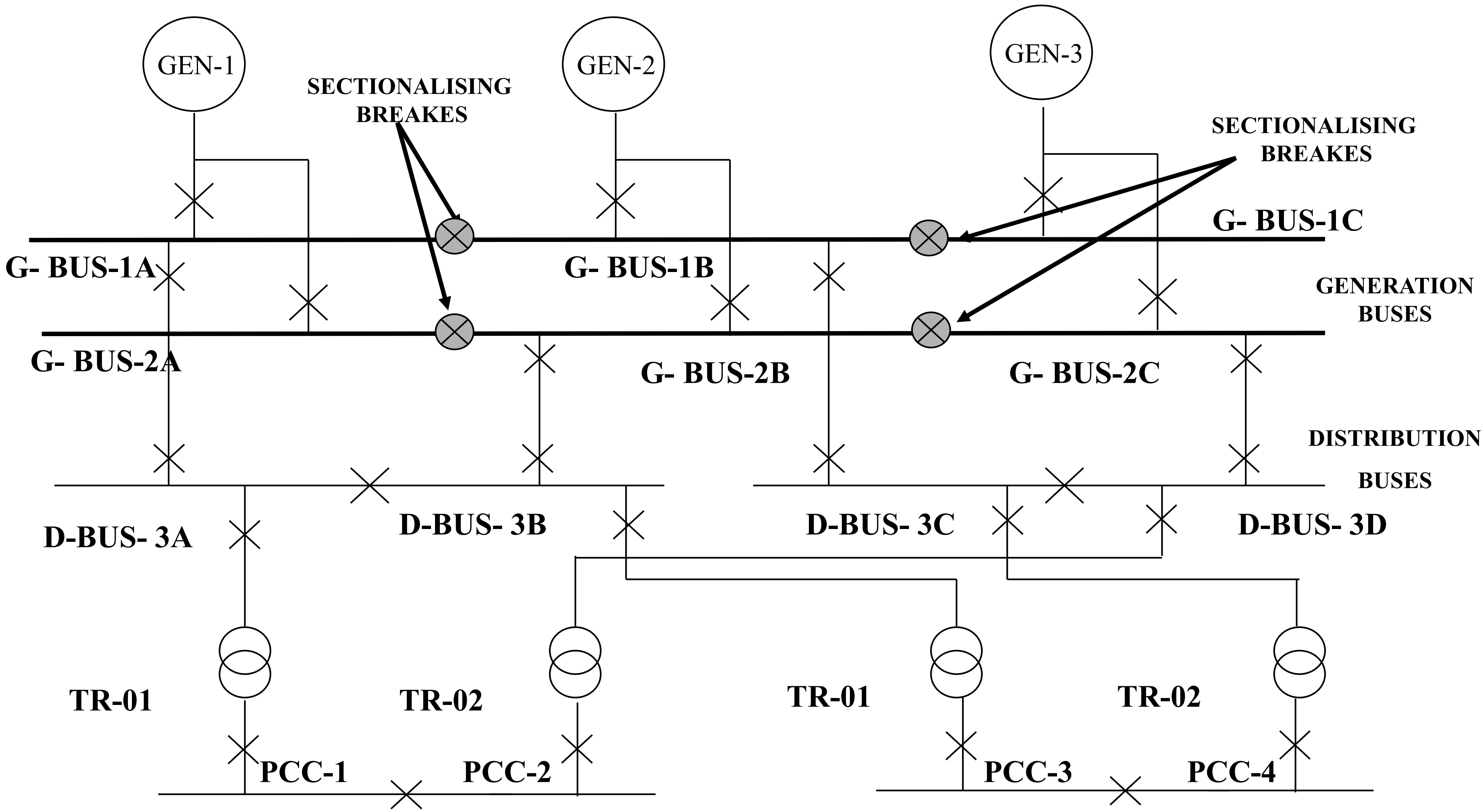
SECONDARY SYSTEM FAULT LEVEL ADEQUACY

DRG. NO. 2C.3B



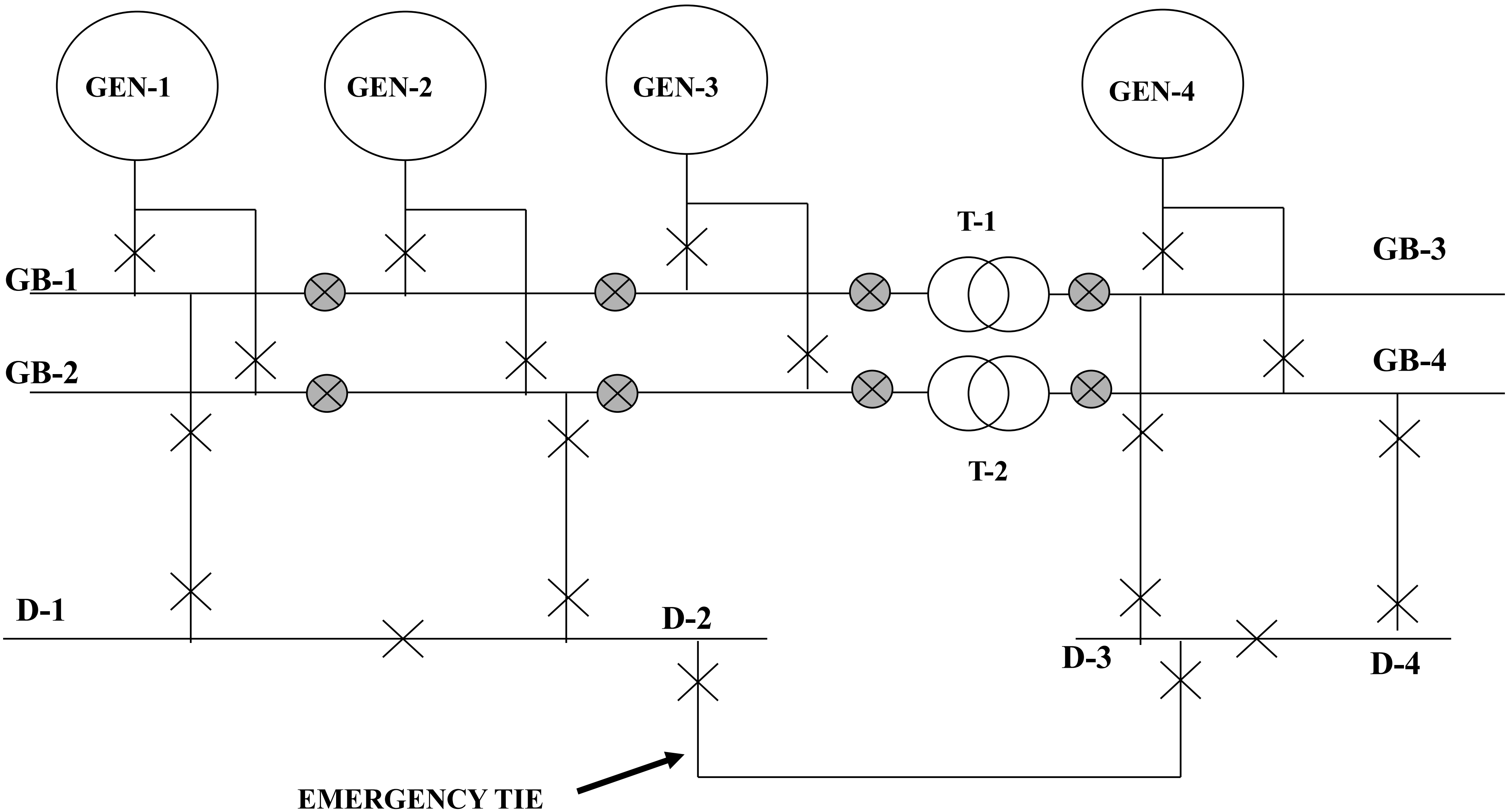
SEPARATE GENERATION & DISTRIBUTION BUS SYSTEM

DRG. NO. 2C.4



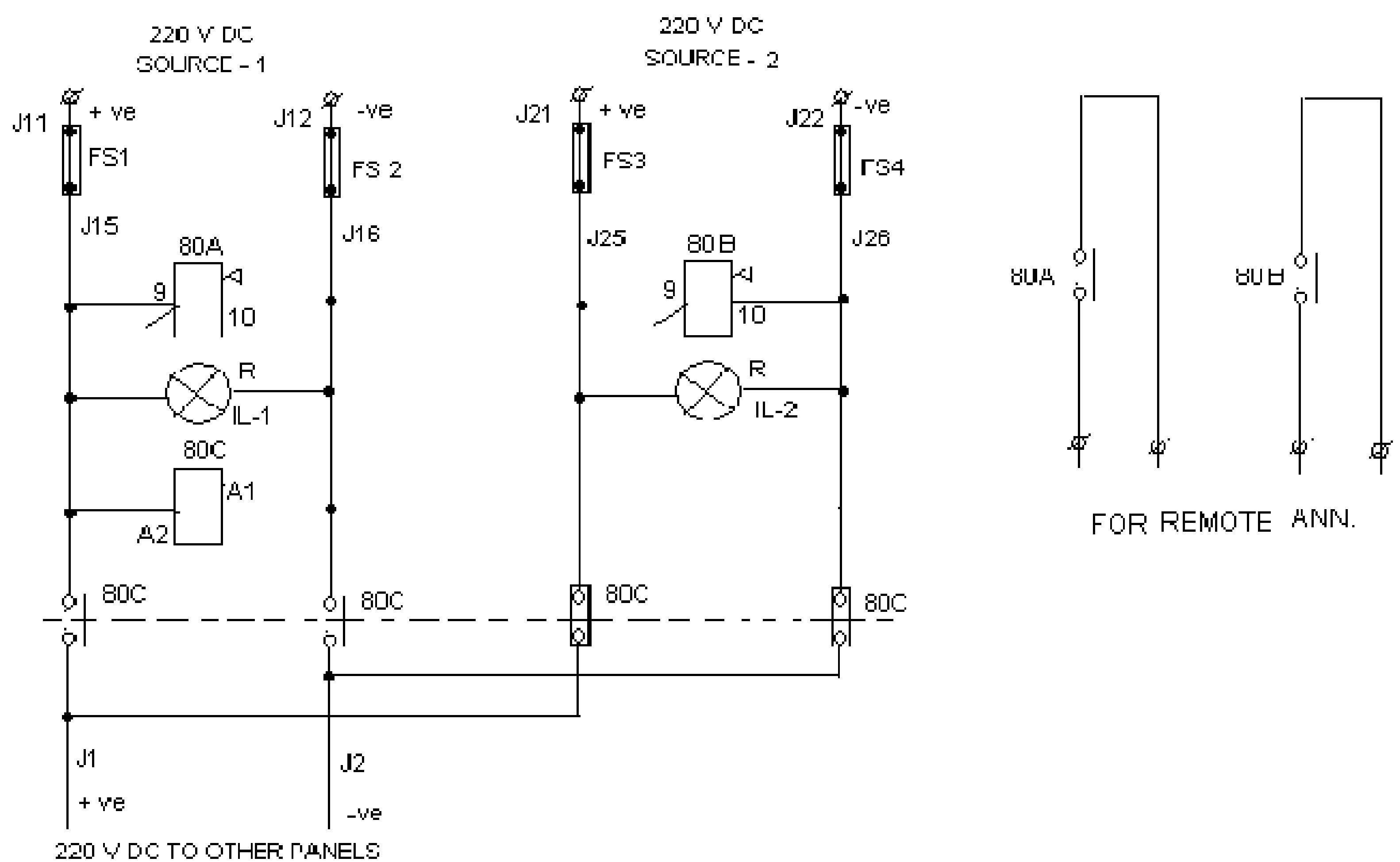
GENERATION & DISTRIBUTION SYSTEM WITH GEN. BUS SECTIONALIZING

DRG. NO. 2C.5



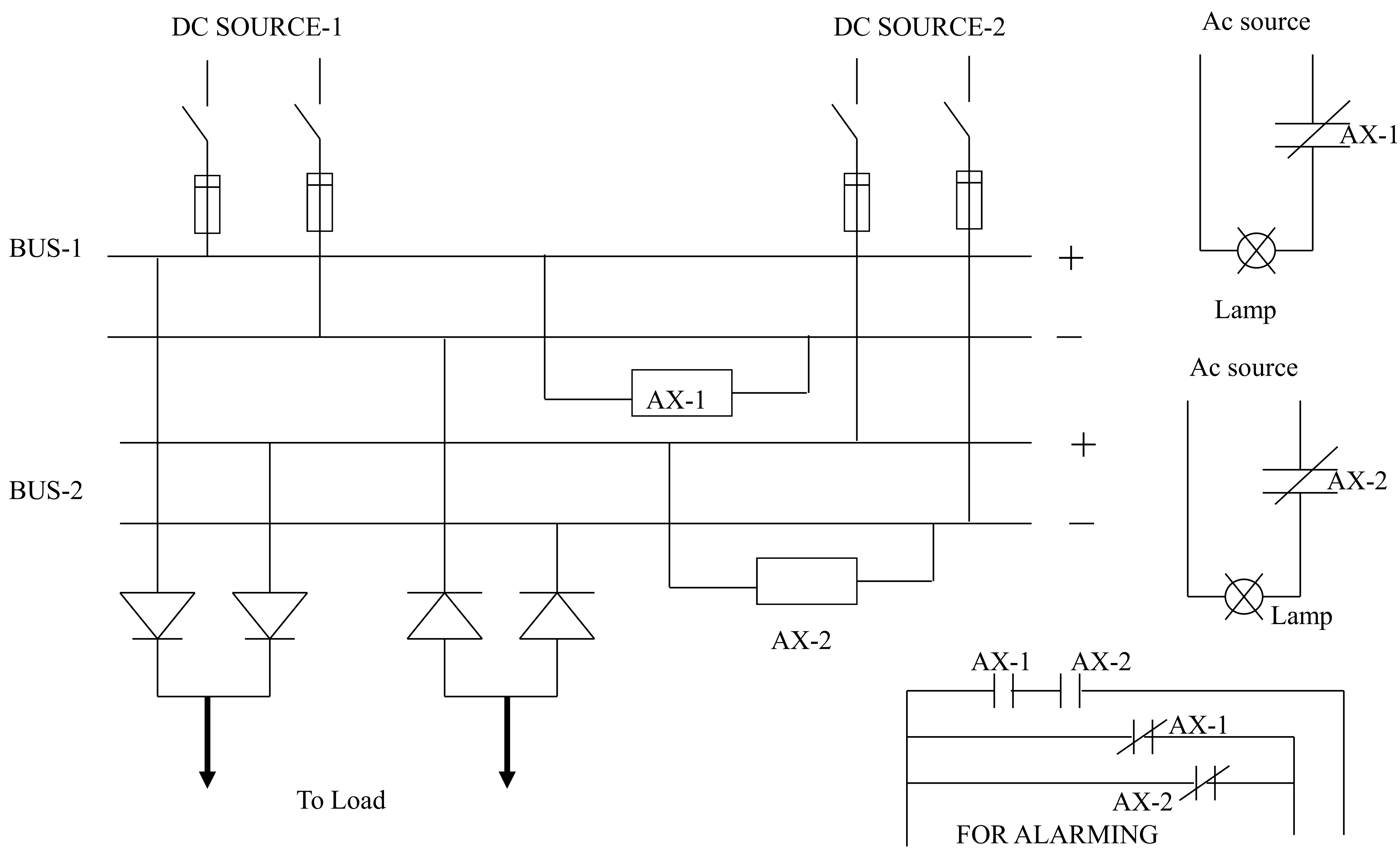
DISTRIBUTION SYSTEM WITH EMERGENCY TIES

DRG. NO. 2C.6



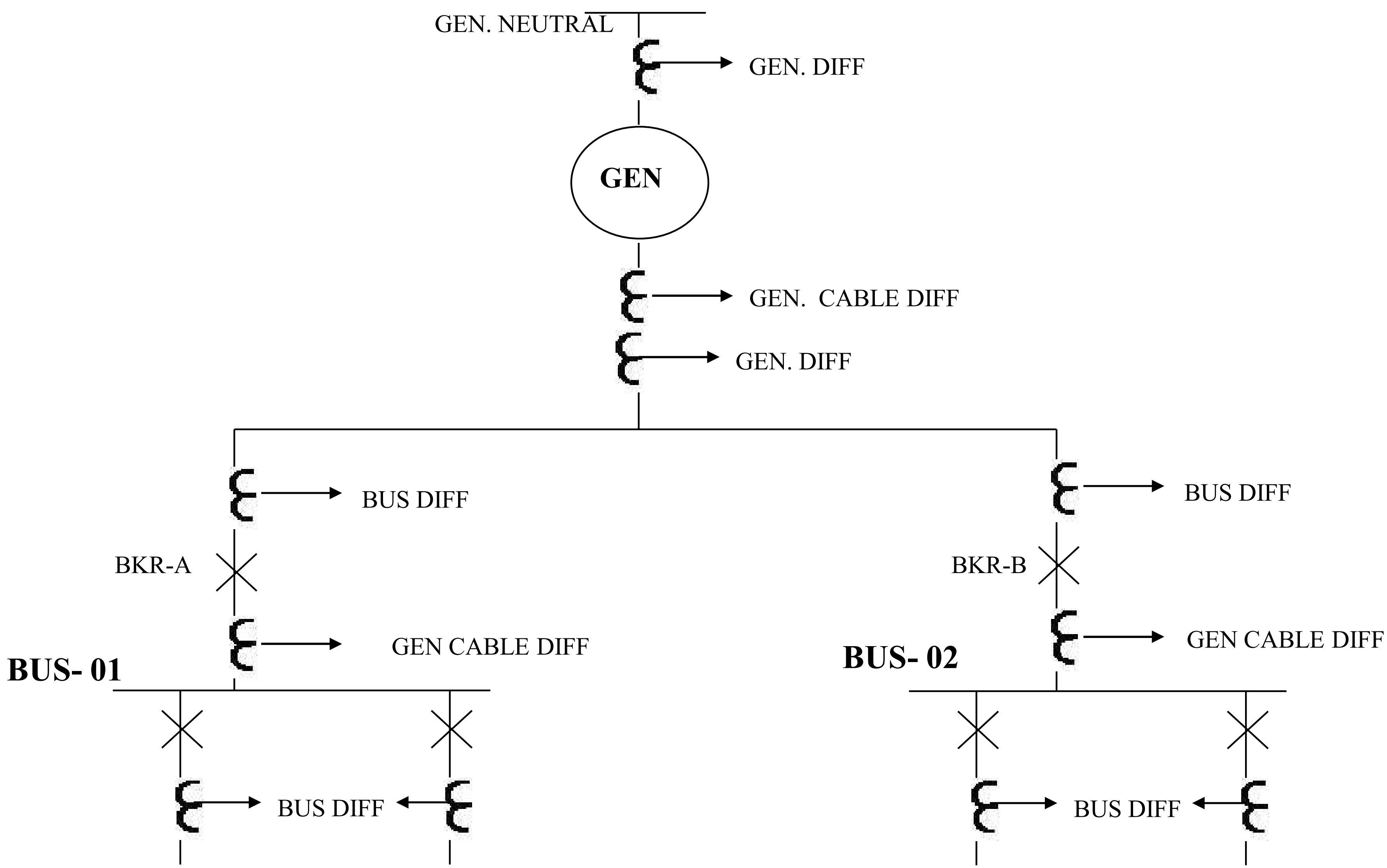
CONTROL SUPPLY CHANGE OVER SCHEME

DRG. NO. 2C.7



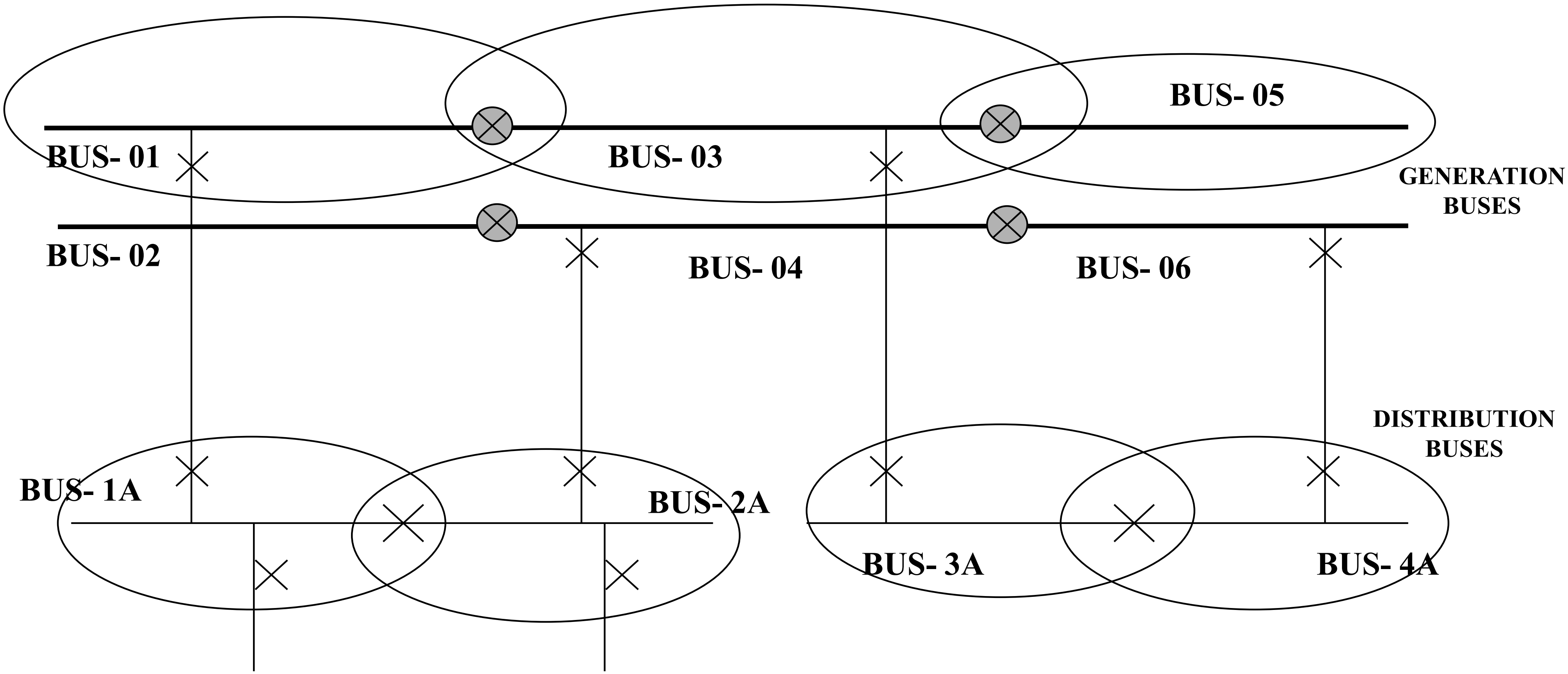
REDUNDANT DIODE TYPE CONTROL SUPPLY SCHEME

DRG. NO. 2C.8



DIFFERENTIAL PROTECTION SCHEME FOR GENERATOR

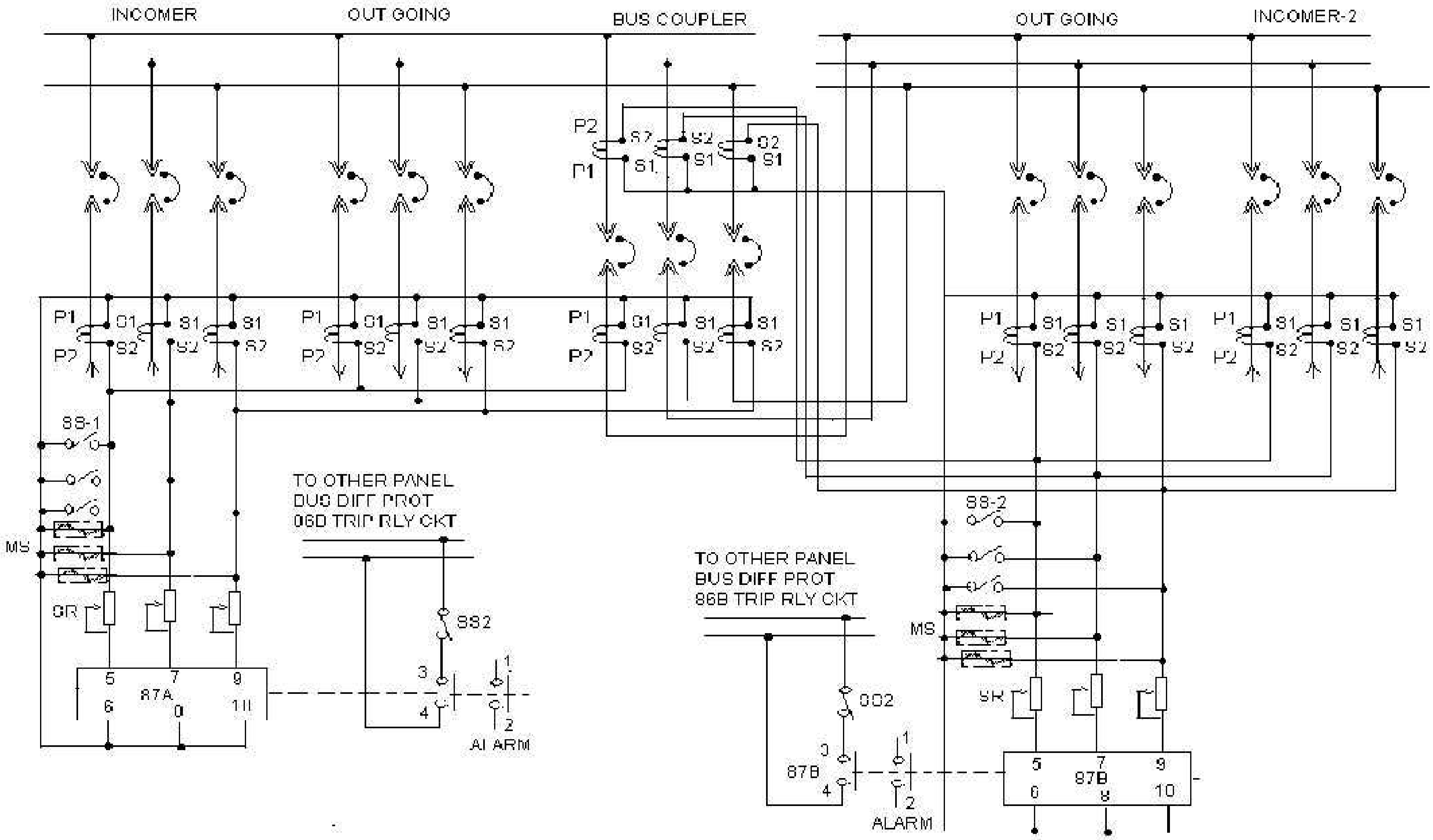
DRG. NO. 2C.9



SCHEME FOR BUS-02 / 04 / 06 SHALL BE SIMILAR TO BUS-01 / 03 / 05

SCHEMATIC DISPLAY OF BUS DIFFERENTIAL SCHEME ZONE CROSSOVERS

DRG. NO. 2C.10A

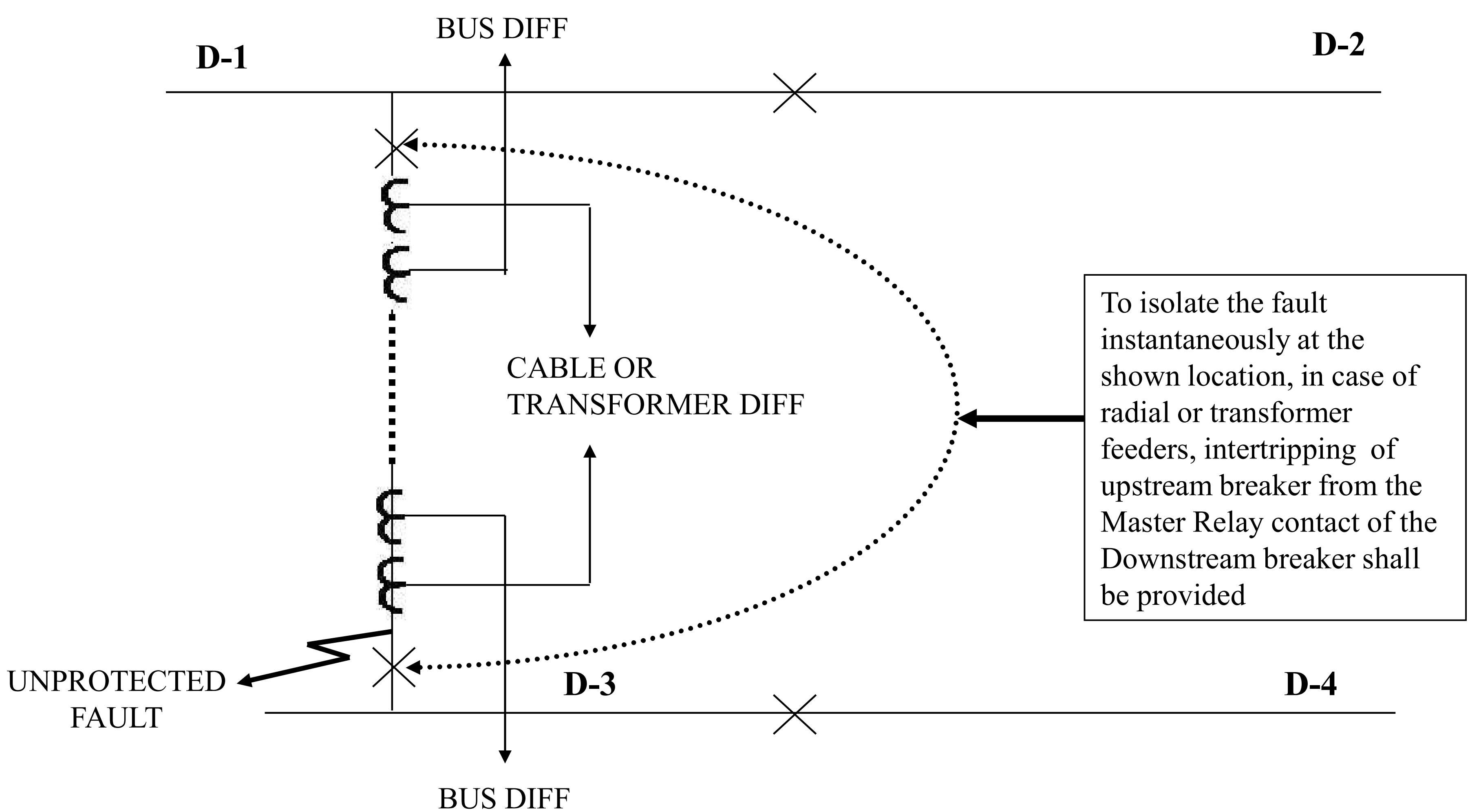


TYPICAL WIRING SCHEME FOR BUS DIFFERENTIAL PROTECTION

DRG. NO. 2C.10B

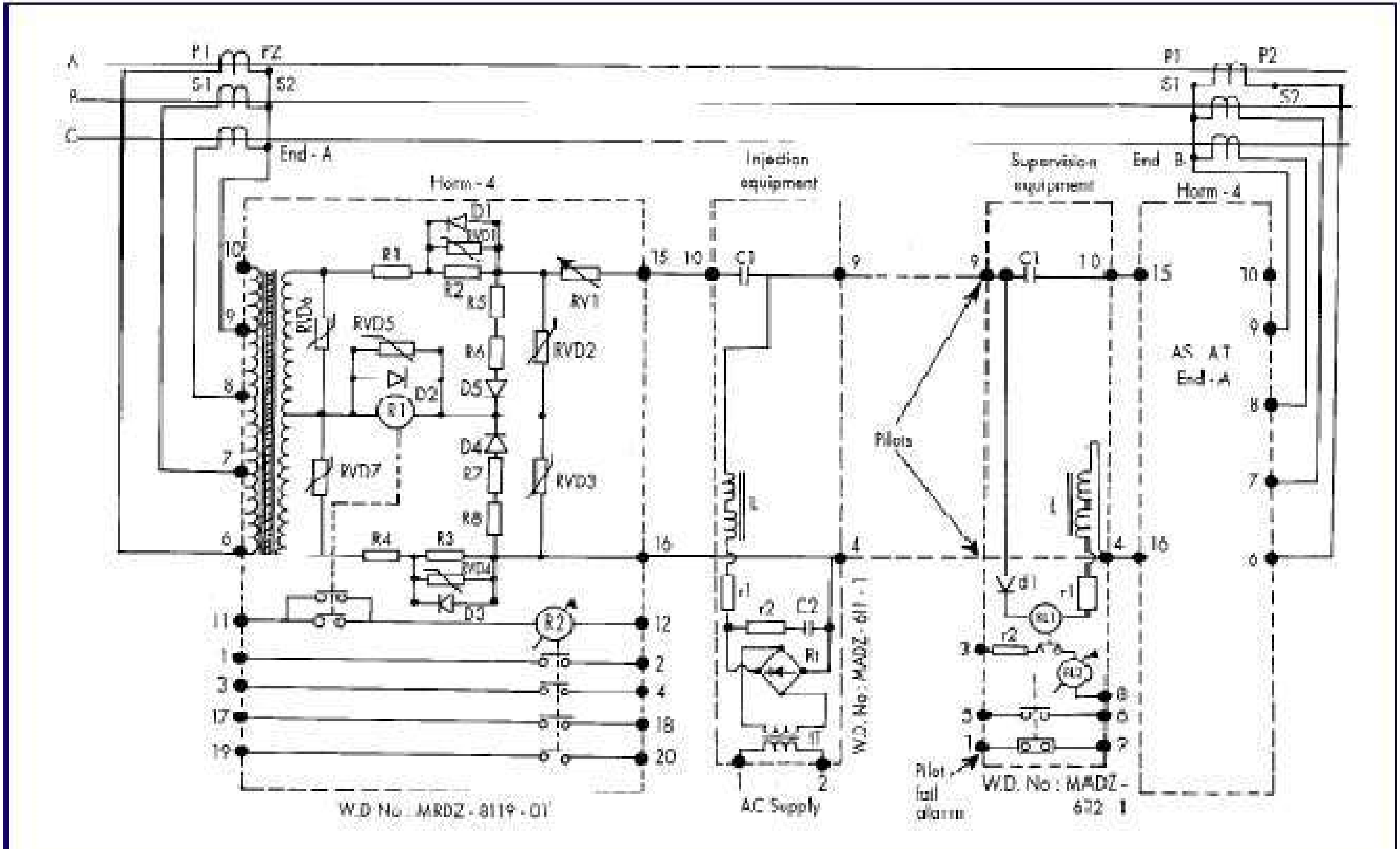
DISTRIBUTION SYSTEM WITH EMERGENCY TIES

DRG. NO. 2C.12



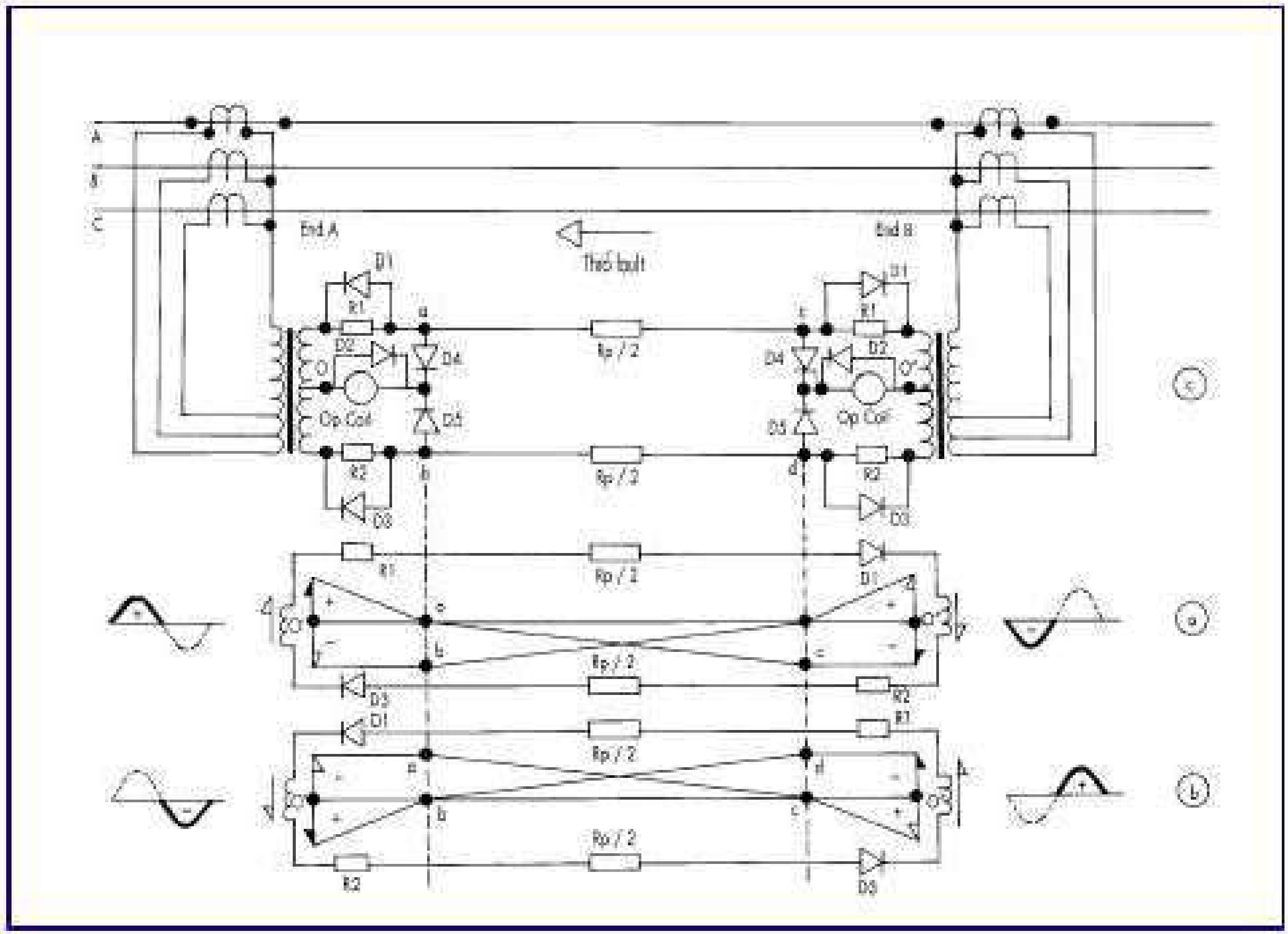
PILOT WIRE SCHEME CONNECTION CONFIGURATION

DRG. NO. 2C.13A



PILOT WIRE SCHEME CONNECTION CONFIGURATION

DRG. NO. 2C.13B



<u>ANNEXURE 2D.1</u>

<u>SAMPLE CALCULATION FOR STABLISING RESISTANCE VALUE</u>

BUS DIFFERENTIAL PROTECTION

Data	**1**	Bus Voltage		11	kV
	2	CT Ratio		2500 / 1	A
	3	Knee Point Voltage	**>**	250	V
	4	Max. CT Resistance		12	Ohms
	5	Bus Differential Relay		CAG34	
	6	Settings available		0.1 - 0.4	
	7	Existing Setting		0.2	
	8	Stabilising Resistor		200	Ohms

Calculations

1 Stability Level

A.1 Stability level of busbar protection taking future extenction into account // switchgear rating

= 39.36 kA   750 **MVA**

A.2 The busbar protection **primary fault seting** is normally between
2 % to 10 % of stability level i.e **787.3** A to **3936** A

A.3 C. T. Ratio **2500 / 1** A

A.4 CT Secondary Lead Length L - 10 M   Assumed

A.5 CT Secondary Lead Resistance   Legth **-** 10 m

= R L   Choosing 2.5 sq.mm

= 7.41 x 0.02 Ohm   Cu Conductor

= 0.1482 Ohm   7.41 Ohm/kM

A.6 Relay Setting Voltage Setting

$V_R = I_F (R_{CT} + RL)$

Where

I_F - steady state secondary through fault current in A

RL - CT lead loop resistance to relay tapping point , for worst case in Ohms

R_{CT} - Resistance of CT secondary winding in Ohms

= 15.75 (12 + 0.148) R_{CT} 12 Ohm

= 191.2845 Volts   given

$\mathbf{V_R \sim}$ **192 Volts**

A.7 The required knee point voltage

Vk > 2 x V_R

> 2 x 192

> **384 V**

A.9 Relay Effective PFSC

Primary Fault Setting Current

PFSC = (IR + nIm) x CT Ratio

Where,

IR - Relay circuit current setting = 0.1

n - number of CTs in parallel = 4

= (0.1 + 4 x 0.030) x 2500

= 550 A

2 Stabilising Resistor

B.1 Setting To Be Selected 10 %

B.2 **Stabilising Resistor** — Relay Burdan at highest Tap: 1 VA - CAG34

$= (V_R/I_R) - (VA / I_R^2)$

$$= \frac{192.00}{0.10} - \frac{1}{0.10^2}$$

= 1820 Ohms

Recommended Settings

CT Ratio	**2500 / 1**
Class	**PS**
Vk >	**> 400 Volts**
Im	**<=30 mA at Vk/2**
Setting	**10 %**
Stabilising Resistance	**1820 Ohm**
Range	**0-1200 Ohm**

ONLINE TESTING PROCEDURE FOR HORM 4 RELAY

ANNEXURE 2D.2

PROCEDURE OF ON LOAD TESTING OF HORM-4 CABLE DIFFERANTAIL PROTECTION RELAY

A SPARE HORM - 4 RELAY SHALL BE MODIFIED FOR CHECKING THE STABILITY OF THE SCHEME ON LOAD CONDITIONS

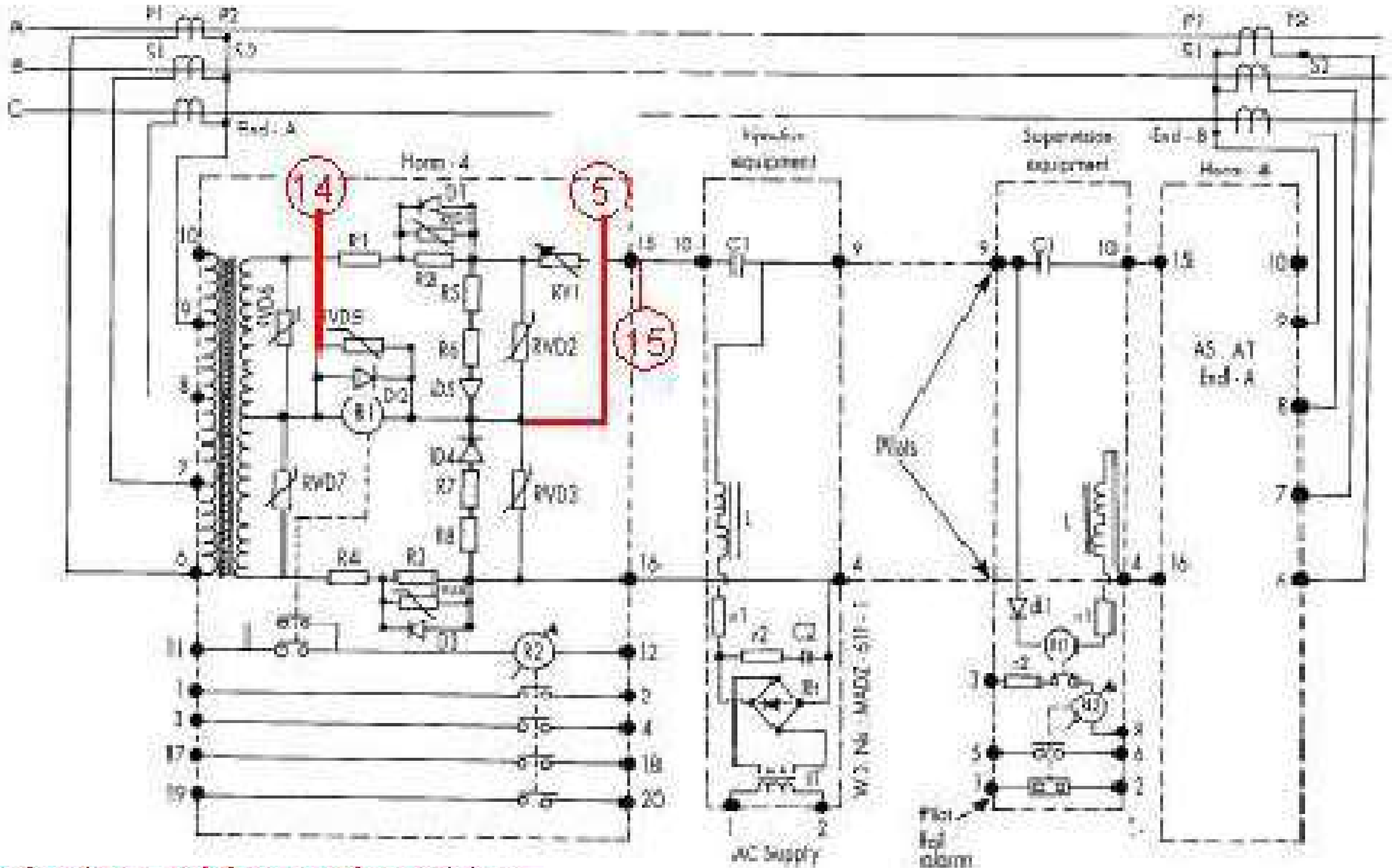
- The relay operating coil is connected between the mid point of diodes D4 / D5 and and centre-tap of the summation current transformer secondary winding

- Common wire is tapped from the mid point of the summation current transformer and terminated at spare terminal No. 14 of the relay.

- The second wire shall be tapped from the midpoint of diodes D4 / D5 and terminated at the spare terminal No. 5 of the relay.

- Modification drawing is shown at slide no. 3

- The relay stability is checked by measuring the voltages between the terminals 14 & 15 and between terminal no. 14 & 5.
- The voltage between terminal no. 14 & 5 shall be in millivolts (< 10 mv) i.e. system is stable. If the measured voltage is more than complete scheme is required to be checked along with the CT healthiness.
- The voltage between terminal no. 14 & 15 shall linearly vary with current i.e. around 2.0volt per 100 mA of CT secondary current.
- A sample table is with feeder load & terminal voltages is shown at slide no. –4. The values shown with red color are for the feeder with wrong connections / CT problems. Values are shown both before & after the corrections in the scheme.



wire tapped from relay wiring
and terminated relay terminal
no comm – 14 and next wire 5

81

S.NO	CTR	VOLTAGE VALUE BEFORE MODIFICATION OF CT			VOLTAGE VALUE AFTER MODIFOCATION OF CT		
		FEEDER PRIMARY CURRENT	RELALY TERMINAL NO.14-15	RELAY TERMINAL NO.14- 5	FEEDER PRIMARY CURRENT	RELAY TERMINAL NO.14- 15	RELAY TERMINAL NO.14- 5
1	1200 / 1	204 amps	N - 4.08 V	P+ 0.004 V	205 amps	N - 4.08 V	P+ 0.004 V
2	1200 / 1	204 amps	N - 7.08 V	P+ 2.004 V	206 amps	N - 4.08 V	P+ 0.002 V
3	1200 / 1	100 amps	N - 1.93 V	P+ 0.007 V	100 amps	N - 1.93 V	P+ 0.007 V
4	1200 / 1	50 amps	N - 1.293 V	P+ 0.475 V	204 amps	N - 3.95 V	P+ 0.009 V
5	1200 / 1	200 amps	N - 4.63 V	P+ 0.33 V	240 amps	N - 4.92 V	P+ 0.006 V
6	1200 / 1	300 amps	N - 6.03 V	P+ 0.001 V	300 amps	N - 6.03 V	P+ 0.001 V
7	2000 / 1	301 amps	N - 1.53 V	P+ 0.001 V	301 amps	N - 1.53 V	P+ 0.001 V
8	2000 / 1	134 amps	N - 6.03 V	P+ 1.93 V	150 amps	N - 2.8 V	P+ 0.008 V
9	2000 / 1	303 amps	N - 1.50 V	P+ 0.001 V	303 amps	N - 1.53 V	P+ 0.001 V
10	2000 / 1	304 amps	N - 1.53 V	P+ 0.001 V	304 amps	N - 1.53 V	P+ 0.001 V
11	800 / 1	105 amps	N - 4.66 V	P+ 3.30 V	280 amps	N - 2.06 V	P+ 0.001 V
12	800 / 1	280 amps	N - 9.96 V	P+ 7.06 V	275 amps	N - 5.87 V	P+ 0.004 V

MANUFACTURING BUCHHOLZ RELAYS FOR 50 YEARS

The Weir Electrical Instrument Company was established in 1937 to manufacture electrical instruments.

In the mid 1940s, the Company identified a requirement for gas and oil operated (Buchholz) relays to protect oil filled transformers and the first production units were installed at that time. A continual development programme in conjunction with the Central Electricity Generating Board led to the production of the Mk10 Buchholz relay.

In 1992, the Weir Electrical Instrument Co. Ltd was acquired by the PBSI Group and a new company, P&B Weir Electrical, was formed at Corsham to continue the manufacture of the Weir products together with a range of portable earthing equipment.

P&B Weir Electrical maintains a quality assurance system, certified in accordance with BS EN ISO 9001.

PBSI Ltd trading as
P&B WEIR ELECTRICAL

Unit 10 Leafield Way
Leafield Industrial Estate, Corsham
Wiltshire SN13 9SW
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Web: www.pbweir.com

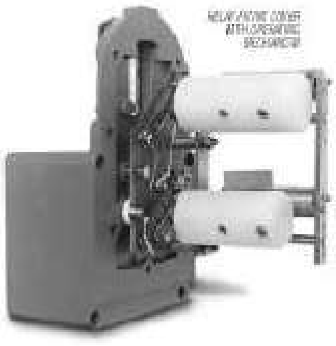
Mk 10 BUCHHOLZ RELAYS
FOR THE PROTECTION OF OIL FILLED TRANSFORMERS

SEISMIC PROOF BUCHOLZ RELAY

ANNEXURE -2D.3

MARK 10 BUCHHOLZ RELAYS

GENERAL INTRODUCTION



APPLICATIONS

Most faults in an oil filled transformer are accompanied by the generation of gas. By using a suitable relay the formation of this gas can be used as a warning of a developing fault.

Double element relays can be used for detecting minor or major faults. The alarm element will operate after a specified volume of gas has collected to give an alarm indication. Examples of incipient faults are:

a. Broken-down core bolt insulation
b. Shorted laminations
c. Bad contacts
d. Overheating of part of the windings

The alarm element will also operate in the event of oil leakage or if air enters the cooling system.

The trip element will be operated by an oil surge in the event of more serious faults such as:

a. Earth faults
b. Winding short circuits
c. Puncture of bushings
d. Short circuits between phases

The trip element will also operate if a rapid loss of oil occurs.

MOUNTING POSITION

The relay should be mounted in the connecting pipe between the transformer and the conservator tank. This pipe should be as long and as straight as possible, and must be arranged to slope upwards, towards the conservator, at an angle within the limits of 3 to 7 degrees to the horizontal.

There should be a straight run on the transformer side of the relay of at least five times the internal diameter of the pipe, and at least three times this diameter on the conservator side. A machined surface is provided on the relay body for the purpose of testing the mounting of the relay both in the inclined direction and at right angles to the pipe where it should be horizontal.

CONNECTIONS

The terminal boxes on double element relays are normally drilled and tapped M20 x 1.5mm for bottom entry by conduit or cable gland. Side entries and alternative thread sizes can be supplied for most types upon request. Alarm and tripping circuit connections are made to OBA terminal studs, in the terminal box, and secured by OBA nuts and washers. The maximum recommended torque value should not be exceeded when making connections.

NOTE: If the relay is repainted on site, care should be taken that the vent/drain hole in the terminal box is not obstructed.

TESTING ON SITE

Double element relays are provided with a separate ballvalve to enable the injection of compressed air to be used for testing on site.

To test the operation of the alarm element, air from an air bottle should be admitted slowly so that the alarm element falls gradually until the switch operates.

To test the trip element, the valve controlling the bottle is opened quickly so that the air rushes in, impinges on the flap and depresses it, operating the switch. The pressure required is dependent upon the equipment used. To facilitate on-site testing a portable foot pump providing air which has been passed through a desiccant is available.

NOTE: It should be appreciated that this test is no substitute for a proper works calibration of the relay.

ROUTINE TESTING

Relays are individually calibrated in accordance with BEBS T2 (1966). Values are recorded for loss of oil/gas collection to operate the alarm switch and steady oil flow to operate the trip switch. The unit is also observed to ensure the trip switch operates due to a complete loss of oil.

Assembled relays are pressure tested with transformer oil at 1.4 bar for 6 hours. Electrical circuits are flash tested at 2000 Volts r.m.s. and the insulation resistance measured at 500 Volts is not less than 10 Megohms in air.

Although specifically designed to function with transformer oil according to BS148, successful tests have also been conducted utilising silicone coolant.

MERCURY SWITCH TYPE
MARK 10 BUCHHOLZ RELAYS

CONSTRUCTION AND METHOD OF OPERATION

The relay consists of a lightweight container fitted with two pivoted elements. It is situated in the pipe line between the transformer and the conservator tank, so that under normal conditions it is full of oil. The operating force relies upon the principle that when a body is immersed in a liquid it appears to lose weight. There are no floats or open containers which can be punctured or collect sludge, with consequent loss of buoyancy.

MERCURY SWITCHES

Mercury switches are employed of a special design to prevent mal-operation due to excessive transformer vibration. A sample relay of this type has been submitted to a continuous 3000 hour vibratory type test. During this test the relay was vibrated to an amplitude of 0.01 in. peak to peak at a frequency of 100 Hz. The mercury switches were connected to sensitive detecting equipment and no mal-operations were recorded.

The mercury switches are spring mounted within the switch cylinders and protected from possible damage. Alarm and trip circuit mercury switches will make, break and carry continuously 2 Amps at 250 Volts A.C. or D.C. They will also make and carry for 0.5 sec. 10 Amps at 250 Volts A.C. or D.C.

PRINCIPAL OF OPERATION

The operating mechanism consists of a solid non-metallic cylinder containing the mercury switch, counterbalanced by a smaller solid metal cylinder. Both cylinders are joined and free to rotate about the same axis, the amount of rotation being controlled by stops. When the relay is empty of oil, the weight of the switch cylinder predominates and the switch system rests against the bottom stop, the mercury switch being in the closed circuit position.

When the relay is full of oil, both cylinders appear to lose weight. Due to the different densities, the switch cylinder appears to lose enough weight to enable the weight of the counterbalance cylinder to predominate and rotate the whole system until it reaches the top stop, with the mercury switch in the open position.

"ALARM" OPERATION

When a slight or incipient fault occurs within the transformer, the gas generated will collect in the top of the relay housing. As gas collects, the oil level will fall and increasing amounts of the alarm switch will appear above the oil level. This results in gradual restoration of the apparent lost weight, until the weight of the switch cylinder predominates. The element rotates as the oil level continues to fall and eventually the alarm switch operates.

TRIP OPERATION

When a serious fault occurs, the generation of the gas is so rapid that an oil surge is set up through the relay. This oil flow will impinge upon the flap fitted to the trip element causing it to rotate about its axis and so bring the mercury switch to the closed position, which in turn operates the tripping devices.

In the event of serious oil loss from the transformer, both alarm and trip elements operate in turn, in the manner previously described for gas collection. The oil level in the double element relay can be monitored against a graduated scale on the windows both sides.

SEISMIC PROOF BUCHOLZ RELAY

ANNEXURE -2D.3

REED SWITCH TYPE

MARK 10 BUCHHOLZ RELAYS

For use in situations subject to SEISMIC DISTURBANCES and mining activities such as BLASTING.

Shock and vibration acting along the axis of a conventional mercury switch can cause the mercury within it to move and momentarily bridge the switch electrodes, even though the switch is tilted in the open position. This is considered to be a mal-operation of the relay in that it is caused by external influences and not by a fault within the transformer. Consequently where relays are to be used in situations as described above a more suitable alternative to the usual mercury switch is required. Magnet operated reed switches were selected specifically for this purpose and this choice is supported by the following type tests which were successfully withstood.

ABILITY TO WITHSTAND POWER FREQUENCY VIBRATIONS

The device, having its contact electronically monitored by means of an instrument capable of registering and recording a contact closure of 1ms duration, shall be subjected to a sinusoidal vibration having a frequency of 100 Hz and an amplitude of 0.25 (0.05 mm peak to peak (thus a maximum acceleration of 5g) in the plane of movement of the contact making arrangement for a period of 1000 hours, during which there shall be no mal-operation of the contacts.

ABILITY TO WITHSTAND VIBRATION DUE TO EARTH TREMORS AND BLASTING

Immediately before, and again immediately after, the vibration test, the stability of the device and its contacts under earth tremor conditions shall be proved by subjecting the device, whilst being vibrated under the conditions of the vibration test above, to further vibrations superimposed on the 100Hz vibration and supplied separately in each of the three perpendicular axes one of which shall lie in the same plane as the 100Hz vibration.

These vibrations shall have a constant peak to peak amplitude of 2.5mm and shall be carried by a continuous slow sweep over the range of 0.1 to 30Hz (at which frequency the maximum acceleration will be 5.5g) in order to search out resonances.

The appearance of these relays is the same as mercury switch types but they are distinguished from them by the symbol /VO or /Vc/o following their type markings. The letter V (for vibration) indicates that the relay contains reed switches, the letter O that the contacts are normally open and the symbol c/o for change-over contact reeds. Thus a Type 2DE/VO signifies a 2" (Pipe Size) Double Element Relay with normally open Reed Switches (normally means with the relay full of oil).

OPERATION

In the double element relay, collection of gas causes the oil level within the relay to fall. This in turn causes the upper element to rotate on its pivots, bringing the magnet it carries into a position where it operates the alarm switch.

An oil surge through the relay will cause the lower element to rotate about its pivots and bring its magnet into a position so as to operate the tripping switch.

OPERATIONAL CHARACTERISTICS

All double element relays are adjusted so that their performance lies within the limits specified in BEBS T2 (see table 2). Alternative values may be available upon specific request. These switches have Rhodium contacts, located midway along the length of their glass tubes. The tubes contain an atmosphere of Nitrogen.

Connected in series with each reed switch, and mounted within the terminal box, is an inductor of approximately 30 microhenries and 0.04ohm. These inductors are intended to protect the reed switch contacts from the effects of capacitive loads, such as are imposed by long leads or pilot cables, and must not be removed from relays in service.

Protection of reed switch contacts against the effect of inductive loads, such as are imposed by tripping Relays, is achieved by means of a diode wired across each load. This diode must be rated with forward current at least as high as the steady load current and connected observing polarity so as to absorb the back e.m.f. A protection unit, designated D2, fitted with suitably rated diodes for this purpose is available.

TABLE 1: REED SWITCH DATA

	Single Contact	Change-over Contact
Type	Gunther Type 1526	Gunther Type 1621
Switch Capacity	Max. 250 VA/W	Max. 60 W/60VA
Switching Current	Max. 5A	Max. 2A
Switching Voltage (0-60Hz)	Max. 250 V	Max. 220V
Initial Contact Resistance	Max. 100 milliohms	Max. 100 milliohms
Breakdown Voltage	Min. 600 v r.m.s.	500/400 V d.c.
Resonance Frequency	900Hz	-
Shock Resistance	Max. 50g (duration 11ms)	Max. 50g (duration 11ms)
Vibration Resistance	Max. 35g (50-500Hz)	Max. 35g (50-500Hz)
Temperature range	-55°C to +150°C	-40°C to +50°C

WARNING: It is essential for the satisfactory operation of these relays that their contacts be protected against the effects of capacitive and inductive loads as described.

SINGLE ELEMENT AND TAP-CHANGER TYPES

MARK 10 BUCHHOLZ RELAYS

Single element type relays are available for 1" bore size, designated 1 SE, which operate indiscriminately for Gas or Oil collection and are suitable for small oil filled transformer, capacitor and potential transformer protection. A special range of single element relays are also available for Tap-Changer type transformers which operate for a surge condition or loss of oil only and allow gas, normally produced during tap-changing operations, to pass freely. The single element relay has only one operating element and operates in a similar manner to that described for the double element types.

A special open frame unit designated RS75/1 suitable for fitting inside the head or tank of tapchangers which operate due to gas collection, oil loss and surge conditions, is available.

A protective diode unit type D1 can also be provided to protect Reed switches employed in single element units.

DESIGNATION INDEX

DE	Double Element Relay
SE	Single Element Relay
V	Unit fitted with reed switches
O	Switches normally open
K	Switches normally closed
AKTO	Alarm switch normally closed and Trip switch normally open
c/o	Change-over state reed switches fitted
HF	High calibration units
ML	Mechanical latched element
3 DE/HF2	Special high calibration relay to meet the requirements of C.E.G.B. Standard 998412 TPS4/25.

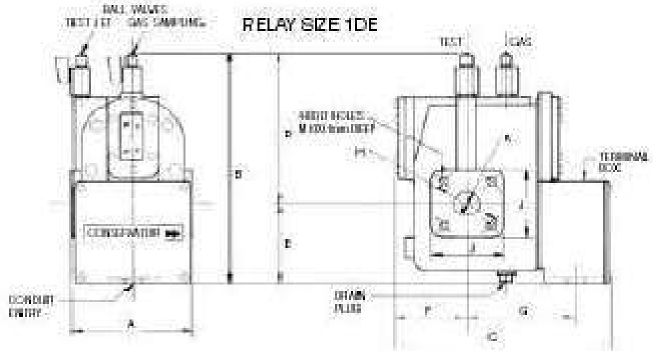
TABLE 2: OPERATIONAL CHARACTERISTICS FOR P & B WEIR BUCHHOLZ RELAYS

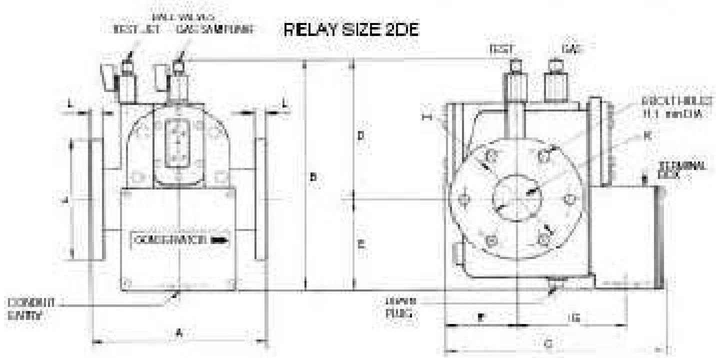
Model Designation	Steady Oil Flow (mm/sec) to Operate Trip Element Switch: Pipe angle 1° Not less than	Pipe angle 5° Not more than	Oil Level (cc) to operate Alarm Element Switch @ 5° Inclination: min	max	For Equipment Containing
1 SE	650	900	140	200	
1 SE/VO	650	900	120	160	
1 SE/VK/ML	900	1050	150	200	
1 SET 1 SET/K 1 SET/VO	450	600	N/A		
1 SET/HF	480	780	N/A		
1 DE 1 DE/K 1 DE/AKTO 1 DE/VO 1 DE/Vc/o	1000	1300	200	300	up to 1000 litres 1000 KVA
2 DE 2 DE/K 2 DE/AKTO 2 DE/VO 2 DE/Vc/o	1100	1400	200	300	1001/10,000 litres 1001/10,000 kVA
3 DE 3 DE/K 3 DE/AKTO 3 DE/VO 3 DE/Vc/o	1200	1600	200	300	10,000/50,000 litres 10,000 kVA/100 MVA
3 DE/HF2 3 DE/HF2/VO	1900	2500	250	350	50,000 litres plus 100 MVA and above

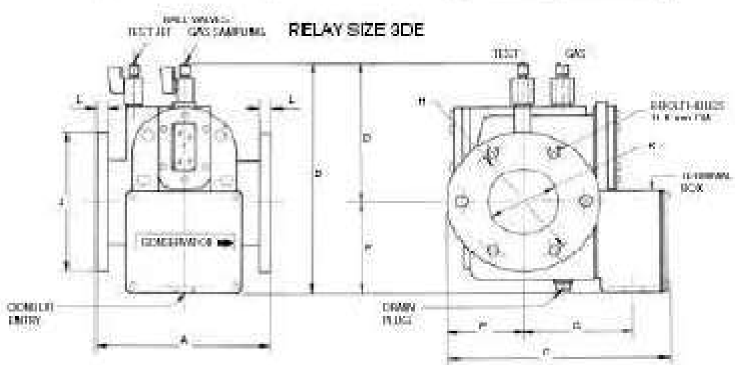
Other values may be available upon specific request.

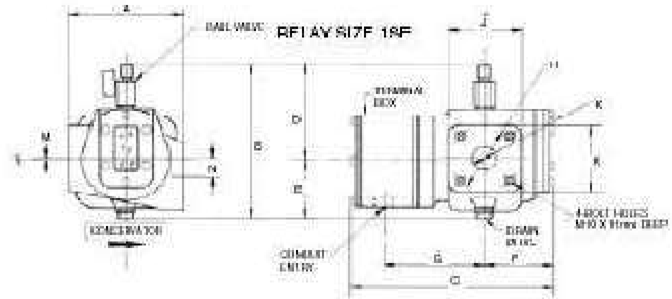
SEISMIC PROOF BUCHOLZ RELAY

ANNEXURE -2D.3









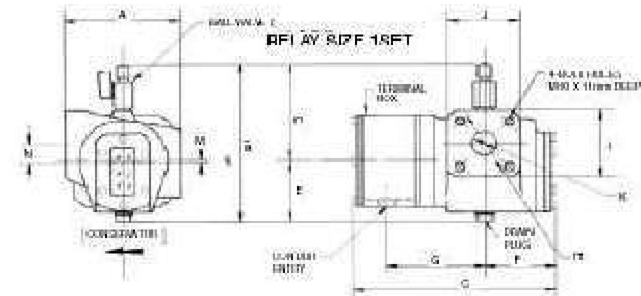


TABLE 3. DIMENSIONS

Size and type	Units	A	B	C	D	E	F	G	H	J	K	L	M	N
1DE	mm	127	269	232	171	98	76	114	72	76	25	-	-	-
	in.	5.0	10.6	9.13	6.75	3.9	3.0	4.5	2.84	3.0	1.0	-	-	-
2DE	mm	184	256	232	155	111	76	114	110	139	51	13	-	-
	in.	7.25	10.0	9.13	6.2	4.37	3.0	4.5	4.00	5.5	2.0	0.5	-	-
3DE	mm	184	300	234	168	111	80	114	130	160	78	15	-	-
	in.	7.25	11.8	9.21	6.6	4.37	3.15	4.5	5.12	6.31	3.1	0.6	-	-
1SE	mm	120	174	212	110	64	76	100	72	76	25	-	3.0	22
	in.	4.75	6.85	8.35	4.33	2.52	3.0	4.0	2.84	3.0	1.0	-	0.13	0.85
1SET	mm	120	174	212	104	70	76	100	72	76	25	-	3.0	22
	in.	4.75	6.85	8.35	4.1	2.75	3.0	4.0	2.84	3.0	1.0	-	0.13	0.85

SEISMIC PROOF BUCHOLZ RELAY

ANNEXURE -2D.3

SAMLE DATA SHEET FOR MONITORING OF NUMERICAL RELAY SETTINGS
(FOR ALSTOM MAKE MICOM P122 RELAY)

	FEATURE	SETTINGS		FEATURE	SETTINGS
1	**SWITCHGEAR DETAILS**		7	**PROTECTION G2**	DISABLED
	BUS NO	21		SETTINGS AS 6.0 ARE TO BE KEPT	
	PANEL NO	211			
	FEEDER NAME	XYZ	8	**AUTOMAT CTRL**	
	RELAY TYPE	MICOM P122	8.1	**TRIP COMMANDS (RL1)**	
				TRIP t I >	YES
	RELAY FEATURES			TRIP t I e >	YES
2	**OUTPUT PARAMETERS**			ALL OTHER PROTECTIO	NO
	FREQUENCY	50			
	DATE SETTING	DD.MM.YY	8.2	**LATCH FUNCTION**	
	TIME SETTING	00.00.00		ALL PROTECTIONS	NO
3	**CONFIGURATION**		8.3	**BLOCKING LOGIC**	
3.1	**DISPLAY**			ALL PROTECTIONS	NO
	DEFAULT DISPLAY (RMS)	A			
	PHASE A TEXT	A	8.4	**LOGIC SELECT**	
	PHASE B TEXT	B		ALL PROTECTIONS	NO
	PHASE C TEXT	C			
	E/GND TEXT	N	8.5	**OUTPUT RELAYS (RL2-R**	8765432
				TRIP	0000000
3.2	**CT RATIO**			t I >	0101000
	LINE CT PRIMARY			t I e >	0110000
	LINE CT SEC			52 FAIL	1000000
	E/GND CT PRIMARY			ALL OTHER SETTINGS	0000000
	E/GND CT SECONDARY				
			8.6	**INPUTS**	
3.3	**LED**			INPUT 1	TCH
	LED-5	t I >		INPUT 2	TCH
	LED-6	t I e >		INPUT 3	TCH
	LED-7	N/A		INPUT 4	NOT USED
	LED-8	TCH		INPUT 5	NOT USED
				INPUT 6	NOT USED
3.4	**GROUP SELECT**			INPUT 7	NOT USED
	SETTING GROUP (1 OR 2)	1		INPUT 8	NOT USED
4	**MEASUREMENTS**	DISPLAY ONLY	8.7	**BROKEN COND.**	
				BRKN. COND	NO
5	**COMMUNICATION**				
	MODBUS/COURIER/IEC	MODBUS	8.8	**COLD LOAD PICK UP**	
	COMMUNICATION	YES		COLD LOAD PU	NO
	BAUD RATE	9600			
	PARITY	NONE	8.9	**CB FAIL**	
	DATA BITS	8		CB FAIL	NO
	STOP BITS	1			
	RELAY ADDRESS		8.10	**CB SUPERVISION**	
				TC SUPERVISION	YES
6	**PROTECTION G1**			T TRIP CIRCUIT (msec)	200
6.1	**50/51 PHASE O/C**			CB OPEN SUPERVISION	NO
	I > (ENABLE / DISABLE)	YES		CB CLOSE SUPERVISIO	NO
	I > (PLUG SETTING)			CB OPEN ALARM	NO
	DELAY TYPE (DT/IDMT/RI)	IDMT			
	IDMT CHARACTERISTIC	IEC_SI	9	RECORD	
	TMS		9.1	FAULT RECORD	DISPLAY ONLY
	T RESET		9.2	DISTURB. RECORD	
				PRE TIME (SEC)	1
	I > >	NO		POST TIME (SEC)	2
	I > > >	NO		DISTURB REC TRIG.	ON INST.
			9.3	TIME PEAK VALUE (min)	5
6.2	**50N / 51N / E/GND**				
	Ie> (ENABLE / DISABLE)	YES			
	Ie > (PLUG SETTING)				
	DELAY TYPE (DT/IDMT/RI)	IDMT			
	IDMT CHARACTERISTIC	IEC_SI			
	TMS				
	T RESET				
	Ie > >	NO			
	Ie > > >	NO			
6.3	**46 NEG SEQ OC**				
	I 2 >	NO			
6.4	**49 THERMAL OL**				
	THERM OL	NO			
6.5	**37 UNDER CURRENT**				
	I <	NO			
6.7	**79 AUTORECLOSE**				
	AUTORECLOSE	NO			

Check List 2E1

Chapter -2 HT DISTRIBUTION SYSTEM (Primary & Secondary)

Area/ Location:- (to be filled)

Note:- Gaps in the existing system and actions to be taken are to be indicated by ***BOLD ITALICS in RED COLOUR***

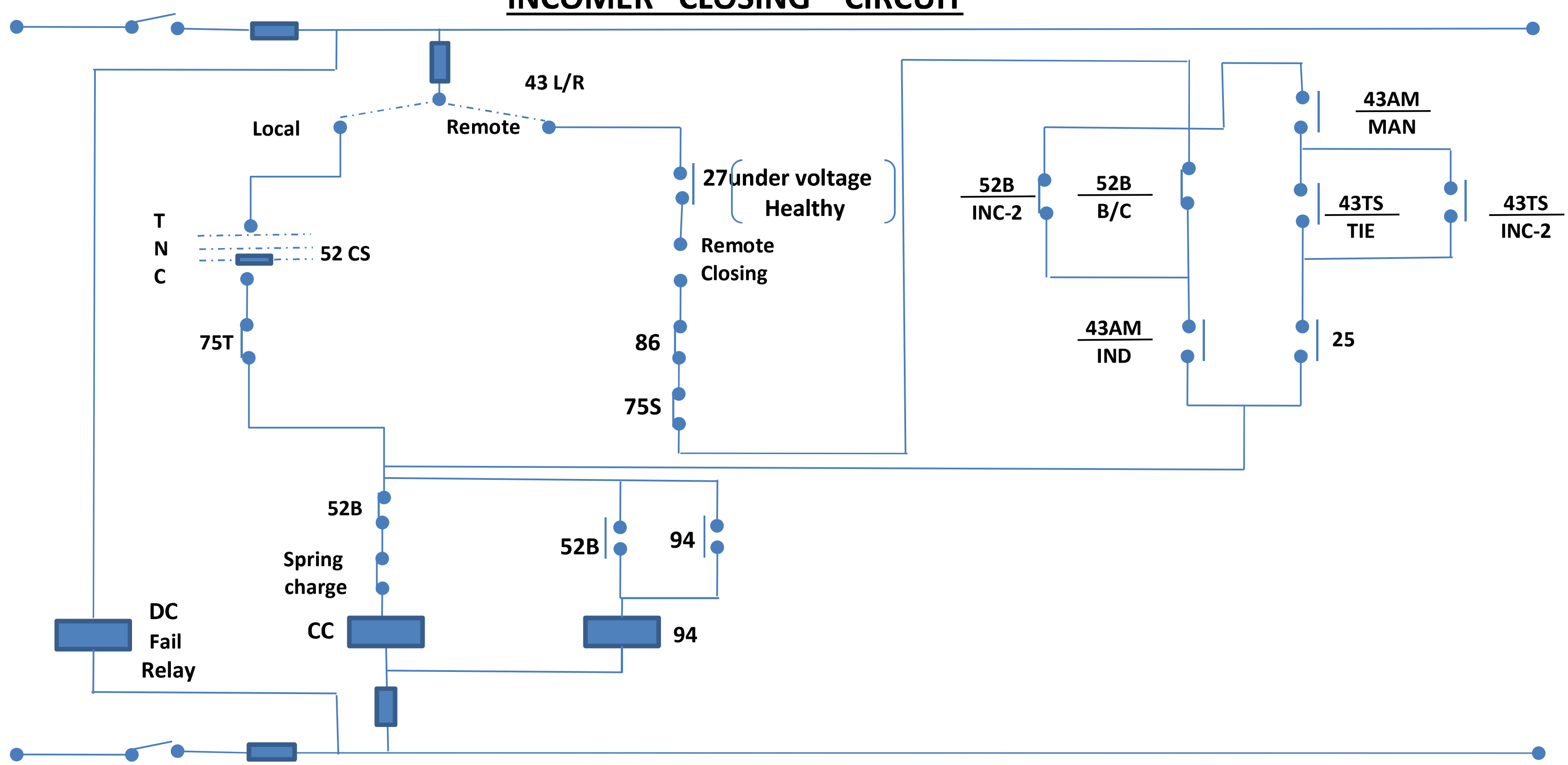
S.No.	Recomm. Ref.		**Area/ Sub Station →**													
			Switch Board No. → ↓ **Reliability check point**													
1	**2.1.1**	**New project**	Adequacy of Switchgear Fault Level w.r.t. Generation System	**Adequate / Less**												
2	**2.1.1**	**New project**	Adequacy of Switchgear Fault Level w.r.t. parallel operation of Transformers	**Adequate / Not Adequate**												
3	**2.1.2**	**New project**	Double Bus configuration for Generation Bus	**Double Bus / Single Bus**												
4	**2.1.2**	**New project**	Status of Bus Coupler between Generation Buses during normal operation (if exists)	**Open / Closed**												
5	**2.1.2**	**New project**	Separate Generation and Primary Distribution Bus	**Separate / Common**												
6	**2.1.2**	**New project**	Provision of Bus coupler in Distribution bus	**Yes /No**												
7	**2.1.3**	**New project**	Provision of Sectionalizing Breakers in each Generation Bus	**Yes /No**												
8	**2.1.4**		Status of Sectionalizing Breakers in each Generation Buses during normal operation (if exists)	**ON/OFF**												
9	**2.1.4**		Auto closing provision in Sectionalizing Breakers in Generation Buses. (if exists)	**Do not exists / Exists**												
10	**2.1.4**		Provision of Manual closing of Sectionalizing Breakers in Generation Buses from control room with Check synchronizing scheme. (if exists)	**Exists / Do not exists**												
11	**2.1.5**		Feeding of two adjacent distribution bus is not from same generation bus	**Yes /No**												
12	**2.1.7**		Existence of exposed / bare outdoor HT switchgear, except grid facility.	**No/Yes**												
13	**2.1.8**		Adequacy of switchgears regarding phase barriers / HT tapes / sleeves.	**Yes /No**												
14	**2.1.9**		Proper structural support / clamps provided for HT cables.	**Yes /No**												
15	**2.1.10**	**New project**	Using of 2.1.10 String insulators with high creepage distances in transformers	**Yes /No**												
16	**2.1.11**		Provision of circuit breaker failure protection in generation and distribution bus	**Yes /No**												
17	**2.2.1**		Provision of DC control supply for each HT section.	**Yes /No**												
18	**2.2.1**		**Has adequate back up control supply scheme provided in each switchgear**	**Yes /No**												
19	**2.2.2**		Provision of dedicated control supply for the numerical relays.	**Yes /No**												
20	**2.2.3**		Provision of control supply failure alarm at manned locations.	**Yes /No**												
21	**2.2.4**		Review of DC system for fuse proper coordination.	**Yes /No**												

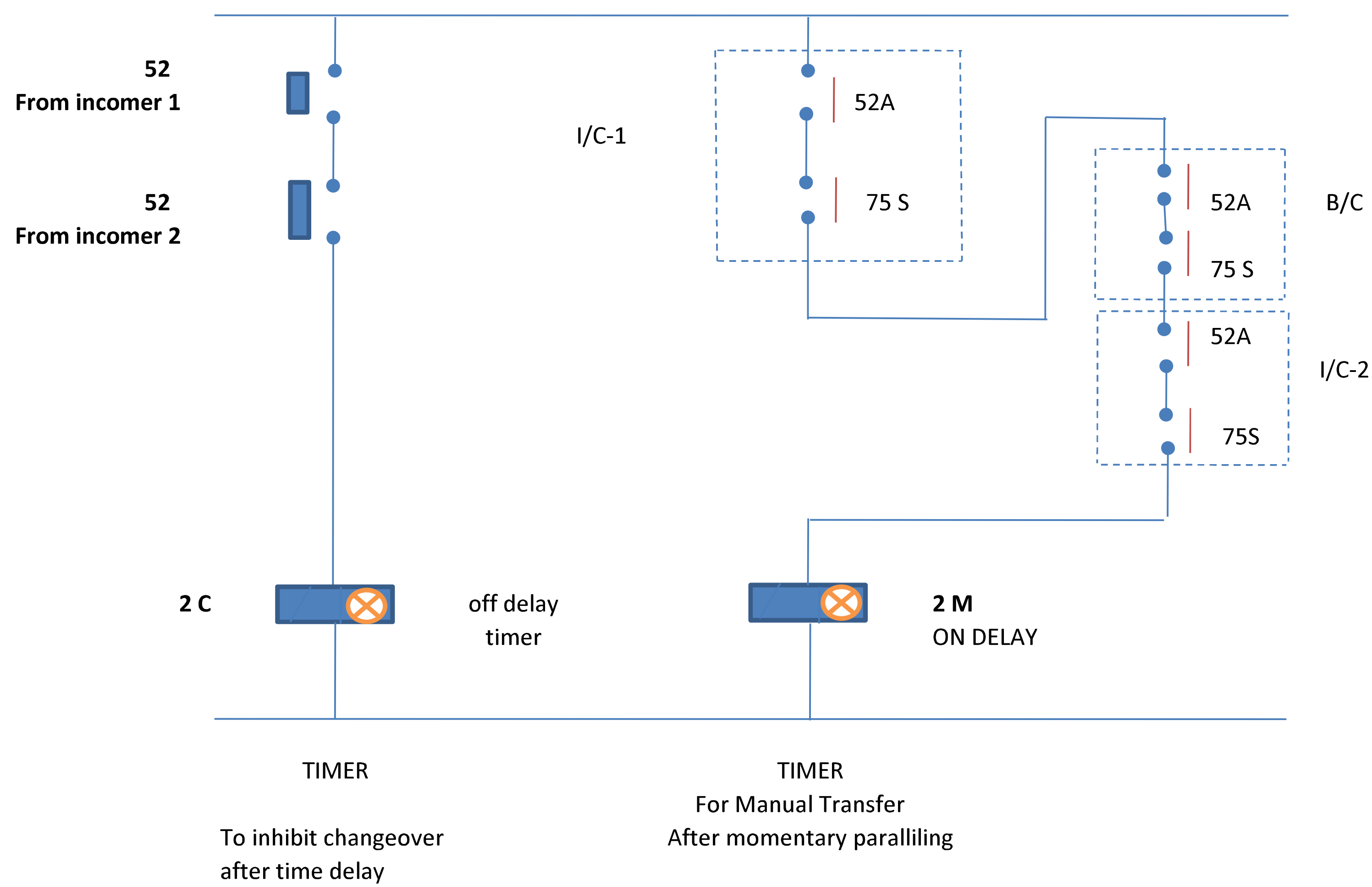
S.No.	Recomm. Ref.		**Area/ Sub Station →**																
			Switch Board No. → ↓ **Reliability check point**																
22	**2.2.5**		Labeling of control fuse rating in the panels above the fuse base	**Done/ Not done**															
23	**2.2.5**		Display of DC distribution drg. with fuse rating in switchgear room.	**Displayed / Not displayed**															
24	**2.2.6**		Confirm failure of the DC control supply shall not trip any breaker / process equipment	**Yes /No**															
25	**2.3.1**		Date of last system study / review of overall Protection coordination	**Give date**															
26	**2.3.3**		Use of ICT in Bus/ cable differential protection.	**No / Yes**															
27	**2.3.4**		Availability of differential protection in all the HT switchgears.	**Yes /No**															
28	**2.3.5**		Adequacy of the differential CT's w.r.t. knee point voltage.	**Yes /No**															
29	**2.3.6**	**New project**	Confirmation regarding similarity of CT characteristics.	**Yes /No**															
30	**2.3.7**		Use of Dedicated CT for differential protection	**Yes /No**															
31	**2.3.8**		Prominent marking on differential CT's for differentiation with other CT's.	**Yes /No**															
32	**2.3.9**		Confirm that each sectionalize generation bus is provided with ONLY differential scheme with cross over zones and no other protection is provided.	**Yes /No**															
33	**2.3.10**		Review of differential scheme that entire switchgear including breaker is covered.	**Yes /No**															
34	**2.3.11**		To confirm that bus differential is having overlapping with other differential zones.	**Yes /No**															
35	**2.3.12**		To confirm that Differential protection is based on proven current balance principle.	**Yes /No**															
36	**2.3.13**		Provision of numerical relays for differential protection with spill current display or practice of periodic spill current measurement available.	**Yes /No**															
37	**2.3.14**		Adequacy of the differential scheme w.r.t. stabilizing resistance.	**Yes /No**															
38	**2.3.15**		Provision of dedicated control supply for the differential protection relays.	**Yes /No**															
39	**2.3.16**		Inter-tripping of upstream incomer on actuation of differential relay of the downstream switchgear.	**Yes /No**															
40	**2.3.17**		Provision of tripping of each (Incoming and out going) breaker of a particular switchgear section on differential protection.	**Yes /No**															
41	**2.3.18**		Provision of CT supervison in bus differential protection	**Yes /No**															
42	**2.3.19**		Provision of cable differential protection in all HT radial feeders.	**Yes / (Name feeders if not provided)**															
43	**2.3.20**		Provision of instantaneous protection in non critical/ long feeders where cable diff. Protection is not installed	**Yes /No**															

S.No.	Recomm. Ref.		Area/ Sub Station →															
			Switch Board No. → ↓ Reliability check point															
44	**2.3.21**		Zone crossover of cable differential protection with bus differential protection in upstream / downstream switchgear.	**Yes /No**														
45	**2.3.22**		Alarming of OFC pilot wire supervision scheme at manned location.	**Provided / Not provided**														
46	**2.3.23**		Checking of adequacy of knee point voltage of cable differential CTs in line with relay vendor recommendation.	**Adequate/ Not adequate**														
47	**2.3.24**		Confirmation regarding similarity of CT characteristics at both ends.	**Same / Different**														
48	**2.3.25**		Proper CT connection configuration at both ends as per relay vendor guidelines.	**OK/ Not OK**														
49	**2.3.26**		Confirmation regarding stability of the scheme as per recommendation s.no 2.3.25	**OK/ Not OK**														
50	**2.3.27**		Inter tripping has been provided using FO cable and cable differential relay soft link.	**Yes /No**														
51	**2.3.28**		Provision of window type CT's in critical switchgears (Name switchgear where not provided)	**Provided / Not provided**														
52	**2.3.29**		Proper dressing / clamping of control wire in the panels.	**Done/ Not done**														
53	**2.3.30**		Provision of transformer differential protection in transformer having HV primary & secondary windings.	**Yes/ No**														
54	**2.3.31**		Ensuring that instantaneous (High Set) Over current protection in HT breaker of transformer feeders is in line.	**Provided / Not provided**														
55	**2.3.32**		Inter-tripping of upstream breaker from the master relay contact of the downstream incomer breaker.	**Provided / Not provided**														
56	**2.3.33**		Availability of trip circuit supervision thru continuous monitoring in all HT switchgears	**Provided / Not provided**														
57	**2.3.33**		Alarm of trip circuit supervision scheme at manned locations.	**Provided / Not provided**														
58	**2.3.34**		Are binary inputs to numerical relays for critical interlocks, for long cable lengths, are provided directly or through interposing relays	**Yes/ No**														
59	**2.3.35**		List obsolete relays of critical feeders for replacement with latest numerical relays.	**Required / Not required**														
60	**2.3.36**		Availability of numerical relay failure alarm (watch dog) at manned locations, through self contact of relay, .	**Provided / Not provided**														
61	**2.3.37**		Is the location seismic prone.	**Yes/ No**														
62	**2.3.37**		Identification of transformers for replacement of Mercury Switch type Bucholz relays with seismic proof relays in earthquake prone areas.	**List**														
63	**2.3.38**		Is clean & dedicated earthing provided for the numerical relays in each panel.	**Provided / Not provided**														

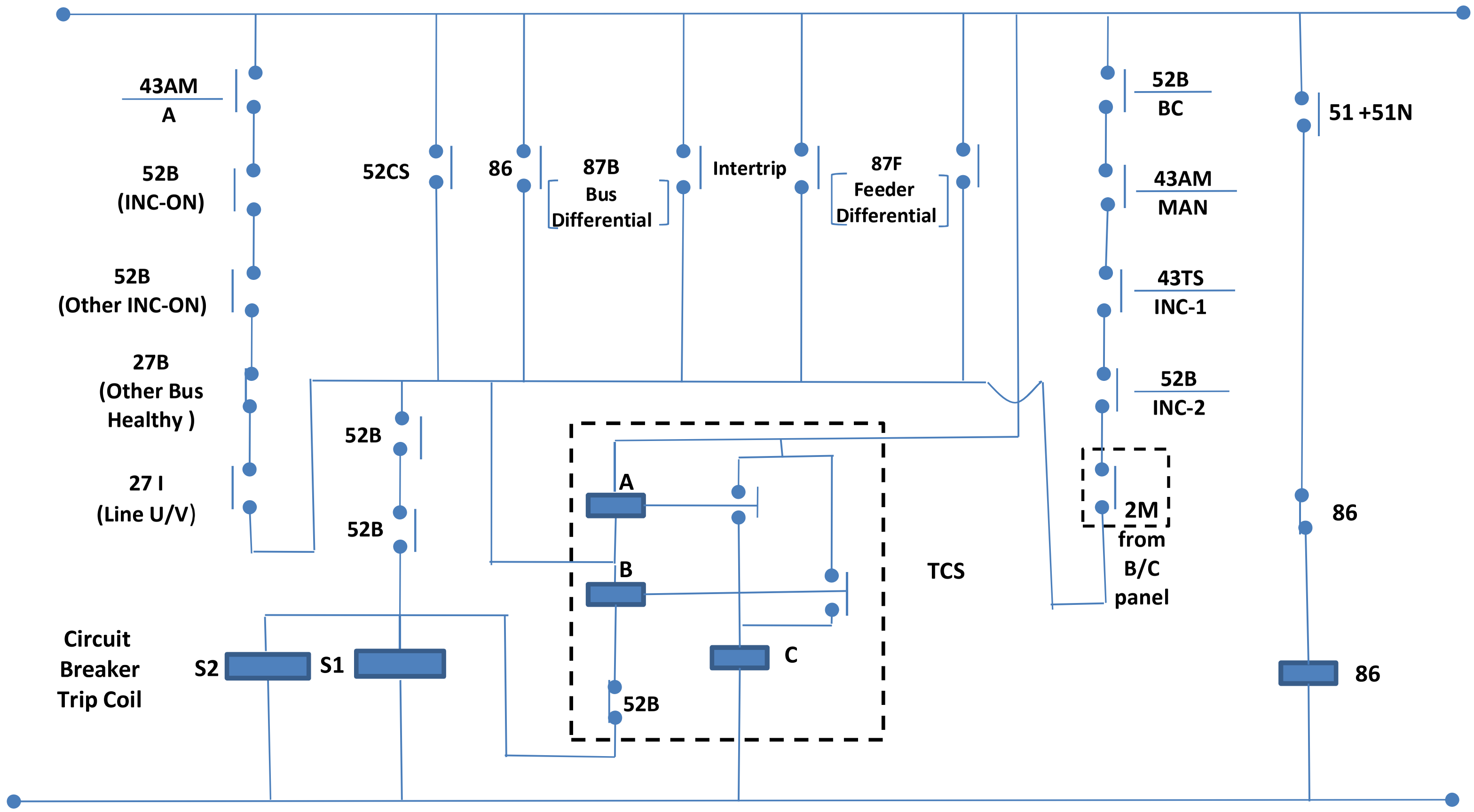
S.No.	Recomm. Ref.		Area/ Sub Station →															
			Switch Board No. →															
			↓ Reliability check point															
64	**2.3.39**		Availability of standard relay setting data sheet as ready reference for each make & model of numerical relay	**Available / Not available**														
65	**2.3.40**		Ensuring direct tripping of breaker from field PB and TNC switch at panel without involving Numerical relay	**Provided / Not provided**														
66	**2.3.41**		The breaker service position contact should not be included in the tripping logic of breakers	**OK/ Not OK**														
67	**2.3.42**		Provision ofLocal breaker back-up (LBB) protection for circuit breaker failure at generation bus	**Yes/No**														
68	**2.3.43**		Review of the The control fuse ratings of protection schemes like CDV / bus bar differential scheme/under voltage scheme etc	**Done/Nor done**														
69	**2.3.44**		VAJH relays in master trip relay	**Provided / Not provided**														
70	**2.3.45**		Provision of The surge arrestors provided in the vacuum circuit breakers of Motor Feeders with rating maximum continuous operating voltage	**Yes/No**														
71	**2.3.46**		Are surge arerstor installed out of bus differential zone	**Yes/No**														
72	**2.3.47**		Esnuring of 2.3.47 Time synchronization of sequence of event recorders (SOE), generator relays, distribution relays	**Yes/No**														
73	**2.3.48**		Provision of chartless recorders / Numerical disturbance recorder (NDR)	**Yes/No**														
74	**2.3.49**		Provision of double trip coil for generator breakers and for 33KV circuit breakers	**Yes/No**														
75	**2.3.50**		HT switchgear at TPS i.e. generation bus and distribution bus shall be rated for short circuit current of preferably 3 second	**Yes/No**														
76	**2.3.51**		All outgoing HT feeders from TPS are to be provided with cable differential protection	**Yes/No**														
77	**2.3.52**		Provision of a minimum time gradation of about 0.15 to 0.2 sec. between bus coupler and incomer	**Yes/No**														
78	**2.3.53**	**New projects**	all HT switchgears shall be of metal clad type	**Yes/No**														
79	**2.3.54**		Stabilising resistance shall be provided in instantaneous earth fault protection of transformer feeders	**Yes/No**														
80	**2.3.55**	**New projects**	All transformer feeders shall be provided with CBCT for sensitive Earth Fault protection	**Yes/No**														
81	**2.4.1**		Identification of critical alarms from primary sub station for taking to control room	**Done/Not done**														
82	**2.4.1**		Availability of identified critical alarms of primary sub station in TPS control room	**Available / Not available**														
			REMARKS															

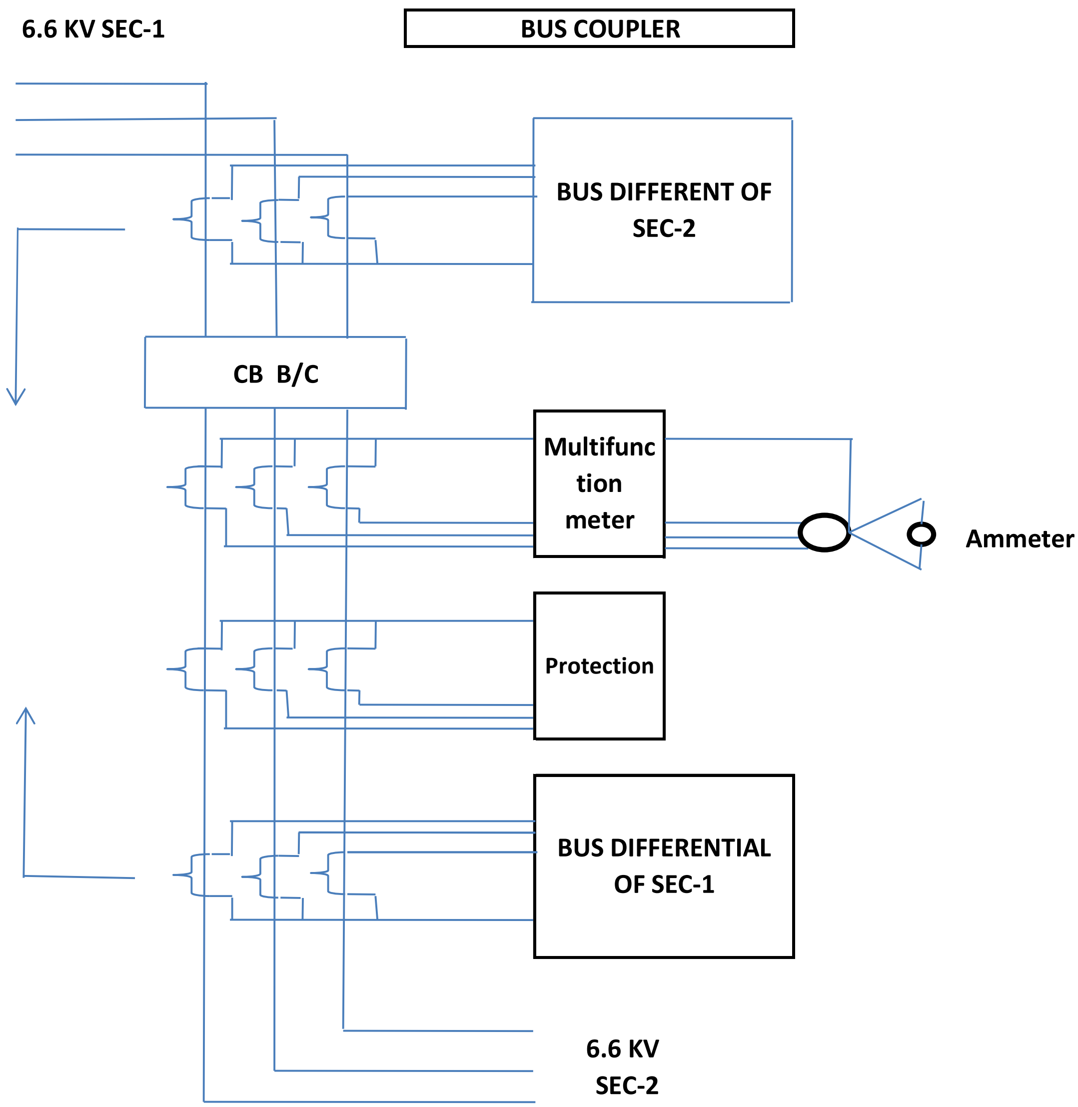
INCOMER CLOSING CIRCUIT



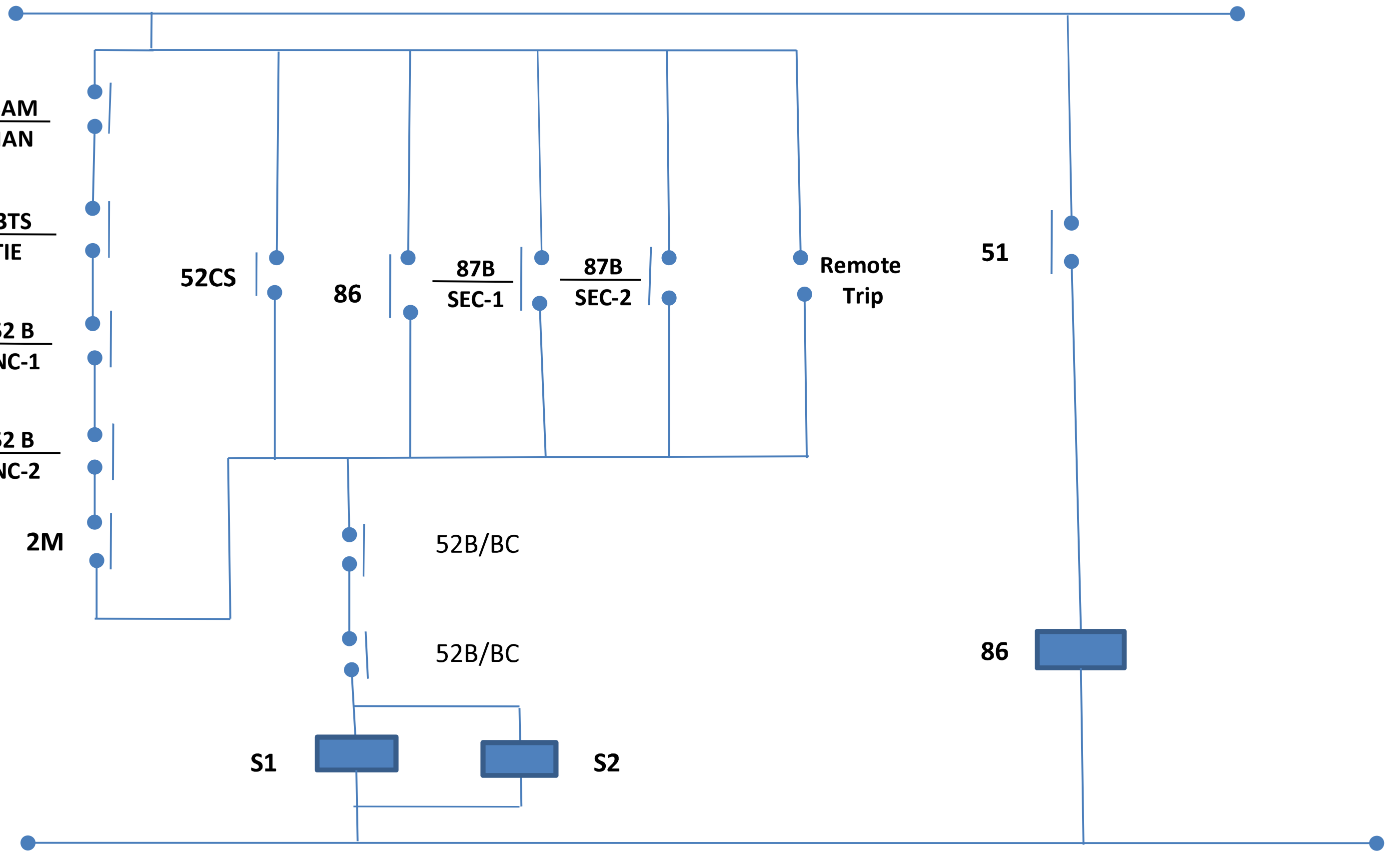

52
From incomer 1
52
From incomer 2
I/C-1
52A
75 S
52A
75 S
B/C
52A
75S
I/C-2
2 C
off delay
timer
2 M
ON DELAY
TIMER
To inhibit changeover
after time delay
TIMER
For Manual Transfer
After momentary parallilling

INCOMER TRIPPING CIRCUIT

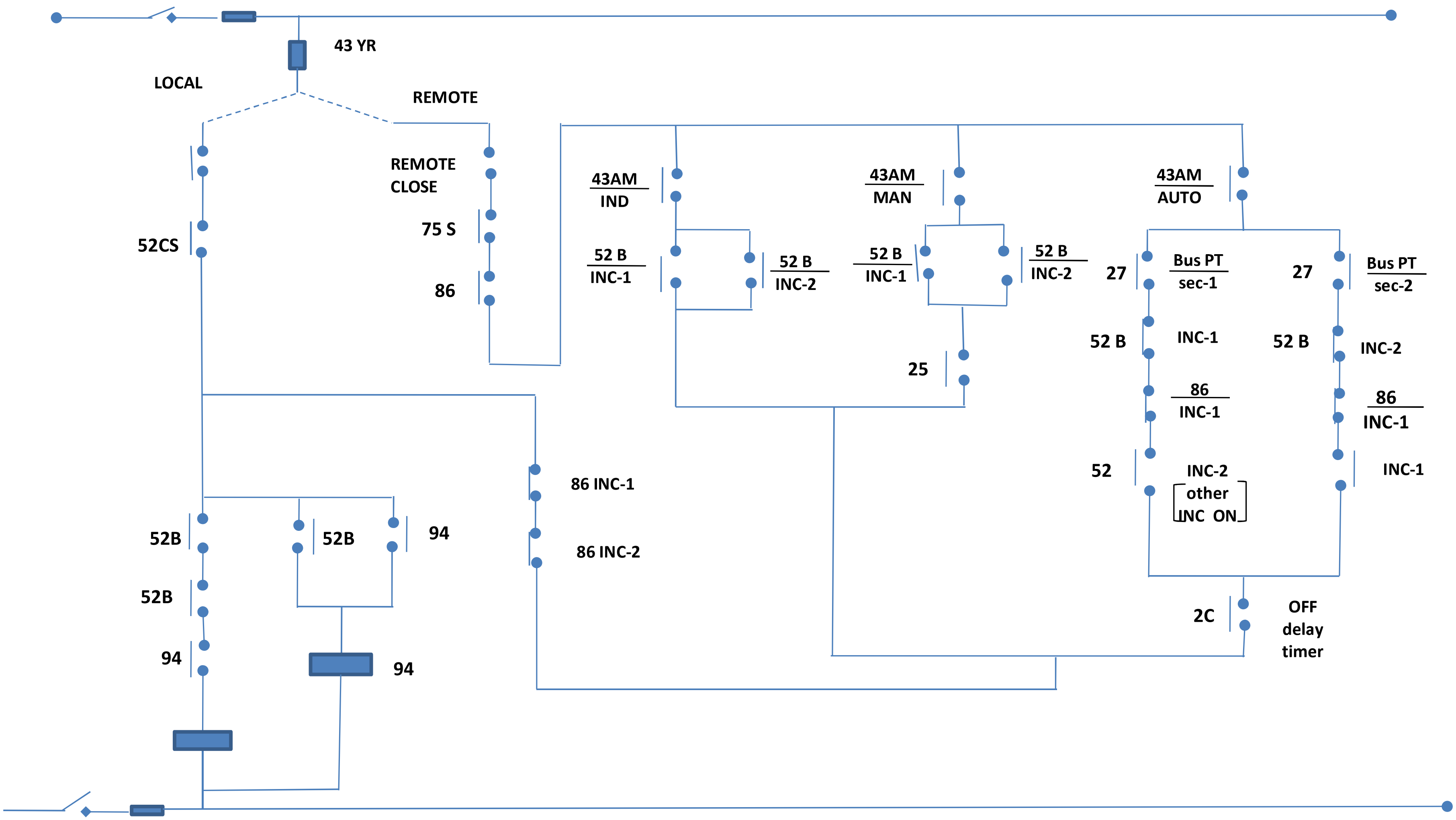



6.6 KV SEC-1
BUS COUPLER
BUS DIFFERENT OF SEC-2
CB B/C
Multifunction meter
Ammeter
Protection
BUS DIFFERENTIAL OF SEC-1
6.6 KV SEC-2

BUS COUIPLER TRIPPING CIRCUIT



BUS COUPLER Closing Circuit



POINTS TO BE TAKEN CARE:

1) 27 (Under voltage Protection) to be operated only in case of 3-Phase under voltage.
2) 27 (Under voltage Protection) should be provided with blocking input from PT MCB contact.
3) All breaker contact shown in scheme (like 52B/52B…)should be actual breaker contact. No multiplying contact to be used.
4) 94 Trip circuit supervision relay should be VAX type.
5) 86 relay should be VAJH type.

<u>Chapter-3</u>

HT MOTOR FEEDERS, OPERATION & CONTROL OF HT MOTORS

HT motors play a vital role in operation of the process units. The reliability related issue in operation of the HT motors are basically in the connection of 6.6 KV incomers to correct location in upstream bus, Bus Supply change over, operation / starting of HT motors during system disturbances, Adequate protection according to size of HT motor, secured control supply, selection of right starting device, on line monitoring of motor parameters, and more critically the adequacy of Auto start scheme for motors.

3A <u>RECOMMENDATIONS</u>

Following actions are desirable for safe and reliable operation & control of HT motors. Detailed explanation to these recommendations marked as (◄) has been enclosed at Section 3B of this chapter.

For better focus and clarity, the actionable points the reliability related issues related to operation & control of HT motors have been have been divided into following sub groups:

1. HT Motor switch gear configuration
2. Protection and control
3. Auto start of HT motors
4. Under Voltage Trip Scheme

3.1 HT Motor switchgear configuration

3.1.1 ***Power feeding of critical HT auxiliary motors of the Power Plant should be done in such a manner that outage of any primary generation or distribution bus shall not affect the power plant operation due to the tripping of any of the auxiliary drives e.g. CW pumps / BFP / GBC / Fans / Compressor etc.*** ◄

3.1.2 ***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.*** ◄

3.1.3 ***It is desirable to use Metal Oxide type Surge arresters in Vacuum Circuit Breakers for motor feeders in consultation with OEMs*** ◄ *(New Facilities/ Projects)*

3.1.4 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.

3.1.5 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.

3.2 Protection and control

3.2.1 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*.

3.2.2 Critical contacts used for providing process interlocks should be direct hard contacts and these shall not be taken from the multiplying contactors / auxiliary relays, if feasible.

3.2.3 Relay setting of the distribution bus incomer shall be done suitably considering the maximum current flow due to simultaneous re-acceleration of the motors connected on that bus during power system voltage *dips*. ***The same shall be a part of the power system study also.***

3.2.4 In view of the safety of the HT motor, all standard protections for HT motors shall be provided.

3.2.5 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.

Numerical relays provided with doubling features or having time delay in E/F should also be provided with "Instantaneous Tripping" with a suitable stabilizing resistance.

3.2.6 Dynamic setting / doubling feature of numerical motor protection relay should be avoided.

3.2.7 All process trip relays should have self reset Contacts and Hand reset Flag or reset facility from control room through PLC/ DCS.

3.2.8 In case of numerical relays, all unwanted protections (high-high, very high etc.) to be kept disabled

3.2.9 It is recommended to develop a standard document/ data sheet as ready reference for a particular make & model specific numerical relay to prevent any unwanted human

errors. A sample sheet is enclosed as Annexure 3D.1 (for ABB make SPAM relay).

3.2.10 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.

3.2.11 The breaker service position contact should not be included in the tripping logic of breakers.

3.2.12 All HT motor feeders shall be provided with CBCT for sensitive Earth Fault protection. Residual E/F connection not be used.(new projects/New procurements).

3.2.13 Wherever two NO contacts available in Emergency push button & LCS STOP PB of all breaker fed HT & LT Motors, one NO contact shall be wired to trip breaker directly & other shall be wired to binary input of numeric motor protection relay.

3.2.14 Hard contacts of the breaker shall be used for providing interlocks in the schemes mainly for auto change over, tripping, feedback, closing and process interlocks. In the absence of sufficient hard contacts, latched contactors/ relays to be used for contact multiplication.

3.2.15 Control supply of local panel of air compressor shall be provided with UPS reliable power supply. Multiple compressors shall be provided with separate UPS supply to avoid total failure.

3.3 Auto start of HT motors

3.3.1 The critical motors of power plants should 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, based on 1 out of 2 logic or 2 out of 3 logic.

3.3.2 The control supply for auto-change over scheme should be provided from a reliable source.

3.3.3 System should be developed for periodic checking of the healthiness of Auto changeover scheme for motors in P&U operation. The observations in respect with shortcomings, if any, during actual operation of Auto changeover should form the part of failure analysis report.

3.4 Under Voltage Trip Scheme for HT motors

3.4.1 ***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.***

3.4.2 ***The setting of under voltage relays should not be less than 60% for tripping of HT motors.***

3.4.3 ***The voltage input to under voltage relay shall be derived from the Bus PT of the switchgear section from which the motors are connected.***

In case conventional relays are installed, voltages of at least two phases shall be used for under voltage tripping of the motors.

3.4.4 **Blocking of under voltage (U/V) tripping of motors to be provided in case of PT fuse failure. Fuse Failure relays/ PT supply MCB contact shall be used for Blocking of U/V trip.**

3.4.5 ***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.***

3.4.6 ***Under voltage command for trip motors shall be direct to breaker and not through the motor feeder Master Trip Relay.***

3.5 Reliability Enhancement Practices

3.5.1 Failure analysis of all motor failures i.e. bearings, insulation etc. shall be carried out with root cause analysis & reviewed in the weekly Planning Meeting. Data bank of the failures with failure mode of different range of motors to be compiled for statistical analysis. The list of typical failure modes is enclosed as Annexure-II.

3.5.2 For effective condition monitoring of critical motors, trending of its polarization index to be maintained and a system of quarterly review to be ensured. For further analysis, in cases of deterioration, offline condition monitoring test like C Tan Delta, Partial Discharge etc. to be carried out and accordingly corrective actions to be taken.

3.5.3 Surge arrester of adequate rating (based on grounded/ ungrounded system) to be provided on motor feeders controlled through VCB. The guidelines for selection of surge arrestors for ungrounded system is as under :

- First, check MCOV rating. It must be equal to HSV.
- Second, check nominal discharge current. It should be minimum 5 KA for motor protection.
- Third, check the residual voltage at nominal discharge current. It must be less than the BIL of the motor (typically it will be 4U+5).
- The protection margin must be above 1.2 (Protection margin = BIL of motor / residual voltage).

3.5.4 For critical motors having provision of winding / bearing temperature measurement is to be routed for alarm & tripping.

3.5.5 In order to facilitate full implementation of above recommendations by identifying GAPs and preparing action plan, a check list has been developed for reference and is given at Section 3E of this chapter.

New Point Annexure-II
Ref. Pt.3.5.1 of Ch.3

MOTOR FAILURE MODE & EFFECT ANALYSIS

Sl. No.	Causes of failures
	Failure initiator
1	**Transient over voltage**
2	**Overheating**
3	**Other insulation breakdown**
4	**Mechanical breakage**
5	**Electrical fault or mal function**
6	**Stalled motor**
7	**Not specified**
	Failure contributor
1	**Persistent overloading**
2	**High ambient temperature**
3	**Abnormal moisture**
4	**Abnormal voltage**
5	**Abnormal frequency**
6	**High vibration**
7	**Aggressive chemicals**
8	**Poor lubrication**
9	**Poor ventilation or cooling**
10	**Normal deterioration from age**
11	**Not specified**
	Failure underlying cause
1	**Defective component**
2	**Poor installation / testing**
3	**Inadequate maintenance**
4	**Improper operation**
5	**Improper handling / shipping**
6	**Inadequate physical protection**
7	**Inadequate electrical protection**
8	**Personnel error**
9	**Outside agency – not personnel**
10	**Motor driven equipment misalignment.**
11	**Not specified**

Chapter-3

HT MOTOR FEEDERS, OPERATION & CONTROL OF HT MOTORS

2B - EXPLANATION TO RECOMMENDATIONS

Reference	Explanation
3.1.1	Feeding of the critical HT motors shall be done from the distribution network in such a way that outage of any primary generation or distribution source shall not affect the plant operation.
3.1.2	HT motors provided with EMERGENCY STOP BUTTON (Lockable Mushroom type) at the field with direct tripping of breaker (tripping should not be taken through PLC / DCS. However, a trip alarm may be wired to DCS / PLC indicating "Motor tripped from field) for the purpose of recording, if required.
3.1.3	In order to protect impact of high voltage on HT motors, particularly in case of VCB's due to current chopping phenomenon, it is desirable to provide Metal Oxide Surge Arresters. In case other type of surge arresters is working satisfactorily then replacement of arrester is not recommended.
3.1.4	In case of system voltage dips, it has been experienced that the power supply to exciter panels of synchronous motors, if provided from the system supply, also experience the voltage dip & lead to the tripping of these critical synchronous motors. In view of this, it is recommended to feed the power supply to these exciter panels through UPS supply. If required, the three phase UPS of small rating shall be provided for this purpose.
3.1.5	The availability and proper functioning of space heater in motors is a neglected area. There have been cases of lowering of IR value of idle motors particularly in the humid environment. This may lead to undesired outage of HT motor in case of requirement and uncalled maintenance on motors. To ensure the healthiness of space heaters of the motor, a dedicated ammeter for monitoring the space heater current may be installed in the panels. Modifications in this regard have been successfully incorporated at Mathura Refinery and found to be quite useful.
3.2.1	In case of numerical relays, it is desirable to have a separate control supply for the relays from the breaker control supply to protect the loss of history in case the feeder supply is switched "Off" after the fault, to isolate the breaker.

3.2.2	Any interruption in the switchgear DC control Supply shall not lead to tripping of the circuit breakers. To take care of this the contacts used in process interlocks should not be taken from the multiplying contactors/ auxiliary relays. (Not even from the multiplier contactor mounted in side the breaker)
3.2.3	It has been experienced that the current flow in bus incomer feeder is extremely high after severe under voltage due to simultaneous re-acceleration of all the connected motors on that bus. In view of above, the CT selection & relay setting of the incomer shall be done taking the above into consideration to prevent relay operation.
3.2.4	As a standard configuration, following minimum protections must be ensured in a HT motor protection relay: - • Thermal over load with thermal history • Short Circuit protection • Earth Fault Protection • Locked rotor or stalling protection • Negative Sequence or Voltage Unbalance protection. • Too many start Protections
3.2.5	The earth fault protections shall be provided with instantaneous protection. The CT are generally connected in residual mode or provided with CBCT. In residual connections suitable stabilizing resistance is to be provided in the circuit to prevent relay maloperation during starting high currents. By installation of stabilizing resistance, sensitivity of the relay may be affected to some extent but spurious operation of earth fault protection can be completely eliminated. The current setting of earth fault protection is so low that loosing sensitivity does not make much impact on the pickup of the relay. Moreover, use of stabilization resistance is standard technique which is used in all-current balance schemes e.g. differential protection, REF, 50N etc. Hence use the same in E/F protection will provide an opportunity to further reduce the current setting even up to 10%. The above shall be installed for both **conventional (electromagnetic) and numerical relays.**
3.2.6	It has been experienced that motors provided with dynamic setting / doubling feature may lead to spurious tripping during voltage dips if toggling of relay setting is done through the push buttons / breaker contact. During under voltage condition, when motors re-accelerates, the relay

	settings continue to remain at lower value as the condition of breaker/ PB remain unchanged and may result in undesired tripping. Ideally, the relay settings should toggle back to higher value, as parameters during re-acceleration are quite similar to fresh starting of motor. The re-acceleration is as good as a new starting and with the low settings; motors may trip due to spurious operation of protections on lower values. It is, therefore, desirable to adequately engineer the doubling feature to ensure sustained motor operation during system disturbances.
3.2.7	In order to facilitate immediate start of motors after tripping on process protection, it is desirable to have process trip relays with self reset contacts and Hand reset Flag or reset facility from control room through PLC / DCS.
3.2.8	In order to prevent unwanted tripping of motor feeders particularly with numerical relays, It is desirable to review the protections settings with enable / disable features and all unwanted settings e.g. high / high – high instantaneous settings to be kept disabled if only inverse / time delay settings are required.
3.2.9	This is essential for numerical relays to disable all unwanted settings as it can result in undesired trippings. This shall also ensure uniformity in the selection of features & settings. A sample sheet is enclosed as Annexure 3D.1)
3.2.10	In case of numerical relay applications, all the Tripping/ Stop commands (including emergency trip from field) are routed through the numerical relay. In the event of faulty numerical relay it will not be possible to isolate the breaker in emergency situations and during faults. Therefore, it is recommended to route all the trip/ Stop commands (including TNC switch) to directly trip the breaker without using any intermediate numerical / auxiliary relay for ensuring reliability and safety. In case the modification in this regard is cumbersome, an additional command to trip breaker directly be incorporated by using spare contact of PB / TNC switch.
3.2.11	It is essential that in case of emergency situation in field or a fault in the equipment the concerned breaker must trip. There have been instances that the motor did not trip during fault or when stopped from field due to problem in the Breaker service position limit switch contact. This situation arises for the schemes where the trip circuit of the breaker also involves a "breaker service position limit switch" contact. This may result into greater degree of damage either to equipment or to process.

	Some of the OEMs/ switchgear suppliers are of the view that it is desirable to have limit switch contact in trip circuit for sake operation of switchgear. If the equipment'sbreakers fails to trip due to problem in the Service position limit switch such situation should be taken care by the backup (ie. Upstream breaker) in case of fault in the running equipment. However, for certain conditions which result in partial increase in current like motor overloading, bearing failure, rotor rubbing due to bearing seizure or emergency requirements from field to stop the motor the back- up protection may also not be able to operate due to inadequate fault current seen by its CTS on account of marginal increase in loading of upstream feeder. Hence it is desirable to remove the service contact interlock from the tripping logic of all the equipment including motors.
3.2.12	Residual connected earth fault schemes require stabilising resistance for stability with some loss of sensitivity. CBCT allow sensitive Earth Fault protection.
3.2.13	Direct contact will ensure the tripping of breaker in the case of failure of protection relay. Digital input to numerical relay will provide stamping of the respective tripping command.
3.2.14	Auxiliary contacts shall not be used auto change over, tripping, feedback, closing and process interlocks as failure of auxiliary contactor/relay shall defeat the scheme. In the absence of sufficient hard contacts, latched contactors/ relays are to be used for contact multiplication.
3.2.15	Failure of single UPS control supply should not affect the operation of the multiple air compressors.
3.3.1	In order to prevent maloperation of Auto start scheme of critical motors, it is desirable to implemented the scheme based on 1 out of 2 or 2 out of 3 principal from interlock device e.g. pressure switch etc. Additional interlock may be provided from the breaker contacts / master relay contacts to avoid time delay
3.4.1	In order to unload the power system during sustain under voltage conditions, a under voltage trip scheme shall be provided for all HT & LT motors in the plant. Only extremely critical motors related to the operation of process units shall be excluded from the scheme. It is essential to time grade the under voltage scheme based on the criticality of the motor otherwise the recovery time of system becomes very high after under voltage condition due to simultaneous re-acceleration of all running motors. The sustained under voltage may even cause instability of the power system i.e. total collapse The motors shall trip at different time intervals depending upon the criticality of process units to which an individual motor is feeding. The

	criticality of the motor may be kept in line with the criticality of the process units considered for load shedding scheme and accordingly time gradation may be done. All non-critical units shall trip with a time delay of 0.5 seconds. In order to safe guard the TPS & Water Block operation, it is recommended to trip the critical motors of process units in the order of priority with time gradation up to a maximum delay of around 3.0 sec. However critical motors of TPS & Water Block should be selected to trip in the last stage.
3.4.2	Different units adopt different U/V trip settings. It is desirable that the setting of U/V relay should not be less than 60% in case of HT motors. This is in view of system stability and problems associated with re-acceleration of HT motors in under voltage conditions. Locations, which are having U/V settings above 60%, may retain their settings.
3.4.3	To achieve reliability in the scheme and to prevent maloperation, under voltage tripping relay of at least two phases shall be used for tripping. In case of numerical relays "AND" mode is to be selected, if applicable, or contacts derived from two phase shall be used as the single numerical relay is used for all the three phases
3.4.4	In case of PT fuse failure condition, the under voltage tripping scheme shall be blocked by Fuse failure relays or PT MCB's with auxiliary contacts used for blocking. In case of MCB’s, it is to be ensured during shutdowns that the PT MCB auxilary contact is functioning properly as incidents regarding mechanically strucking up of contacts during MCB tripping have been observed.
3.4.5	In order to achieve faster restoration of the system, under voltage tripping relay contact multiplication, if required, shall be provided through self reset relays.
3.4.6	In order to facilitate immediate start of motors after under voltage tripping, under voltage relay shall not activate master relay of individual motor feeder.

SAMLE DATA SHEET FOR MONITORING OF NUMERICAL RELAY SETTINGS
(FOR ABB MAKE SPAM 150 RELAY)

SNO.	**MOTORS**	**MOTOR-A**	**MOTOR-B**	**MOTOR-C**
1	RATED KW	180	220	460
2	RATED AMPS	21.1	26.4	52.5
3	STARTING AMPS	111.63	158.4	315
4	STARTING TIME	23 sec.	37 sec.	1.8 sec
5	WTH STAND TIME - HOT	39 sec	60 sec	30 sec
6	WTH STAND TIME - COLD	50 sec	90 sec	45 sec
7	VOLTAGE	6600	6600	6600
8	CONNECTION	STAR	STAR	STAR
9	MAKE	BHEL	BHEL	NGEF
	CURRENT TRANSFORMER			
1	CTR	125 / 5 / 5 A	150 / 5 / 5 A	300 / 5 / 5A
2	CLASS	5P10 , 1	5P10 , 1	5P10 , 1
3	BURDEN	15VA /15VA	15VA /15VA	15VA /15VA
4	CORE	2	2	2
	PROTECTION RELAY			
1	TYPE	SPAM150C	SPAM150C	SPAM150C
2	MAKE	ABB	ABB	ABB
3	AUX. VOLTS	220 VDC	220 VDC	220 VDC
4	MODEL NO	SPCJ 4D34	SPCJ 4D34	SPCJ 4D34
5	RATING	1 / 5 AMPS	1 / 5 AMPS	1 / 5 AMPS
	MOTOR PROTECTION RELAY SETTINGS			
1	Thermal unit = $I\theta$	0.88 / In	0.92 / In	0.86 / In
2	Max. safe stall time = t6x	40 sec.	60 sec.	6 sec.
3	Weighting factor for thermal unit curve = P	50%	50%	50%
4	Prior alarm for thermal over load = θ A	95%	95%	95%
5	Restart inhibit level for th. O/L cond. = θ I	57%	40%	70%
6	Cooling reduction factor = Kc	4 tc	4 tc	4 tc
7	Motor start current setting = Is	4.22 In	5.30 In	5.25In
8	Motor start time setting = ts	25,3 sec.	42.5 sec.	8.8 sec.
9	High set over current unit = I>>	6.32 In	8.0 In	7.86 In
10	High set operating time = t>>	0.05 sec.	0.05 sec.	0.05 sec.
11	Earth fault unit = Io	20%	20%	20%
12	Earth fault operating time = to	0.55 sec.	0.55 sec.	0.55 sec.
13	Unbalance protection Δ I	25%	17%	17%
14	Unbalance prot,operating time TΔ	60 sec.	50 sec.	30 sec.
15	Under current unit = I<	disabled	disabled	disabled
16	Under current operating time = t<	2.0 sec.	2.0 sec.	2.0 sec.
17	Time base start inhibit cont.in sec. = Σtsi	10 sec.	5 sec.	5 sec.
18	Countdown rate of the start time counter in seconds per hours = $\Delta\Sigma$ ts	3 sec / h	2 sec / h	2 sec / h
19	SGF	113-	113-	113-
20	SGB	0-	0-	0-
21	SGR	129-	129-	129-
22	SGR 1	126-	126-	126-

FUCTIONAL PROGRAMMING SWITCH GROUP - SGF

S. No	SWITCH	FUCTION	USER SETTINGS	WEIGHT VALUE
1	SGF - 1	High set over current	1	1
2	SGF - 2	High set over current stage double during a motor startup	0	2
3	SGF - 3	Earth fault trip inhibited on over current higher than	0	4
4	SGF - 4	Selected multiple of motor full load current	0	8
5	SGF - 5	Phase unbalance protection	1	16
6	SGF - 6	Incorrect phase sequence prot..	1	32
7	SGF - 7	Stall protection base on thermal stress supervision	1	64
8	SGF - 8	Under current protection	0	128
		Checksum for setting of SGF	**113**	*********

BLOCKING AND CONTROL INPUT SELECTOR SWITCH GROUP - SGB

S. No	SWITCH	FUCTION	USER SETTINGS	WEIGHT VALUE
1	SGB - 1	Stall information to relay from speed switch	0	1
2	SGB - 2	Restart of the motor inhibited by external command	0	2
3	SGB - 3	The phase unbalanced unit is blocked by the input signal	0	4
4	SGB - 4	The earth fault unit is blocked by the input signal	0	8
5	SGB - 5	External trip command carried out to output relay	0	16
6	SGB - 6	External relay reset command	0	32
7	SGB - 7	Latching of output relay for short ckt E/F , unbalanced trip	0	64
8	SGB - 8	Latching of any output relay for any tripping ,independent of the case	0	128
		Checksum for setting of SGB	**0**	**********

RELAY OUTPUT PROGRAMMINGSWITCH GROUP - SGR -1				
S. No	**SWITCH**	**FUCTION**	**USER SETTINGS**	**WEIGHT VALUE**
1	SGR -1/ 1	The thermal prior alarm link to SS2	1	1
2	SGR -1/ 2	The thermal trip signal link to SS2	0	2
3	SGR -1/ 3	The signal from stall protection linked to SS2	0	4
4	SGR -1/ 4	The signal for high set over current linked to SS2	0	8
5	SGR -1/ 5	The signal for current unbalance linked to SS2	0	16
6	SGR -1/ 6	The signal for earth fault linked to SS2	0	32
7	SGR -1/ 7	The signal for under current linked to SS 2	0	64
8	SGR -1/ 8	The earth fault unit trip link to SS 2	1	128
		Checksum for setting of SGR	**129**	*************

RELAY OUTPUT PROGRAMMING SWITCH GROUP - SGR - 2				
S. No	**SWITCH**	**FUCTION**	**USER SETTINGS**	**WEIGHT VALUE**
1	SGR -2/ 1	The thermal prior alarm linked to SS 1	0	1
2	SGR -2/ 2	The motor startup in for output linked to SS 1	1	2
3	SGR -2/ 3	The starting of the high-set over current linked to SS 1	1	4
4	SGR -2/ 4	The thermal trip signal linked to SS 3	1	8
5	SGR -2/ 5	The signal from stall protection linked to SS 3	1	16
6	SGR -2/ 6	The signal current unbalanced linked to SS 3	1	32
7	SGR -2/ 7	The signal for earth fault linked to SS 3	1	64
8	SGR -2/ 8	The signal for under current linked to SS 3	0	128
		Checksum for setting of SGR	**126**	**************

Check List 3E.1

Chapter -3 HT MOTOR FEEDERS, OPERATION & CONTROL OF HT MOTORS

Area/ Location:- (to be filled)

Note:- Gaps in the existing system and actions to be taken are to be indicated by ***BOLD ITALICS in RED COLOUR***

S.No.	Recom m. Ref.		Area/ Sub Station Switch Board No. Reliability check point																
1	**3.1.1**		Feeding of HT motors is proper so that tripping of primary source shall not affect plant operation	**Adequate / Not adequate**															
2	**3.1.2**		All HT motors are provided with direct tripping of the breaker through field Stop Push Button with out PLC	**Yes/ No**															
3	**3.1.2**		All HT motors are provided with direct tripping of the breaker through field Stop Push Button with out PLC	**Yes/ No**															
4	**3.1.3**	**New project**	Provision of metal oxide type surge arrester in VCB type motor feeders, if applicable.	**Available/ Not Available**															
5	**3.1.4**		Provision of UPS / reliable power supply for Exciter panels of synchronous motors without PMG's.	**Available/ Not Available**															
6	**3.1.5**		Provision of ammeter in space heater circuit.	**Available/ Not Available**															
7	**3.2.1**		Provision of dedicated control supply for numerical relays in motor feeders, if applicable.	**Yes/ No**															
8	**3.2.2**		Contacts used for providing process interlocks are direct hard contacts and not from the auxillary contacts.	**Yes/ No**															
9	**3.2.3**		Relay setting of the incomers done considering the re-acceleration requirement of the motors.	**Yes/ No**															

S.No.	Recomm. Ref.		Area/ Sub Station / Switch Board No. / Reliability check point																
10	**3.2.4**		All standard protections for HT motors are in line as per list provided in explanation to this recommendation.,	**Yes/ No**															
11	**3.2.5**		Instantaneous Tripping is provided for Earth Fault protection of Motor feeders.	**Yes/ No**															
12	**3.2.5**		Provision of stabilizing resistance for Earth Fault protection of Motor feeders.	**Yes/ No**															
13	**3.2.5**		Provision of stabilizing resistance for Earth Fault protection is also available in all type of Nemrical relays.	**Yes/ No**															
14	**3.2.6**		Whether Dynamic settings/ Doubling feature is used in Numerical relays.	**Yes/ No**															
15	**3.2.7**		Process trip relays are having self reset contact and hand reset flags	**Yes/ No**															
16	**3.2.8**		Review of numerical relay settings for disabling unwanted features.	**Reviewed / Not Reviewed**															
17	**3.2.9**		Availability of standard relay setting data sheet as ready reference for each make & model of numerical relay	**Available/ Not Available**															
18	**3.2.10**		Ensuring direct tripping of breaker from field PB and TNC switch at panel without involving Numerical relay	**Yes/ No**															
19	**3.2.11**		The breaker service position contact is not included in the tripping logic of breakers	**Not included / Included**															

S.No.	Recom m. Ref.		Area/ Sub Station Switch Board No. Reliability check point																
20	**3.2.12**	**New projects**	All HT motor feeders shall be provided with CBCT for sensitive Earth Fault protection.	**Available/ Not Available**														
21	**3.2.13**		Provion of 2 nos contacts of EPB and LCS to direct trippingand one relay	**Available/ Not Available**														
22	**3.2.14**		Hard contacts of the breaker shall be used for providing interlocks in the schemes mainly for auto change over, tripping, feedback, closing and process interlocks	**Yes/ No**														
23	**3.2.15**		Provision of reliable Control supply of local panel of air compressor	**Yes/ No**														
24	**3.3.1**		Use of breaker contact in Auto Start schemes	**Yes/ No**														
25	**3.3.1**		Use of low pressure signal in addition to breaker contact in Auto Start schemes	**Yes/ No**														
26	**3.3.1**		Redundancy of low pressure switch signal in Auto Start schemes	**Yes/ No**														
27	**3.3.1**		Voting logic provided in Auto Start schemes	**2-0-0-3 / 1-0-0-2**														
28	**3.3.2**		Control Supply to Auto start scheme of motors from reliable source.	**Yes/ No**														
29	**3.3.3**		Periodic simulation checking of the Auto Start Schemes.	**In practice / Not in practice**														
30	**3.4.1**		Under Voltage trip scheme provided for the motors.	**Yes/ No**														
31	**3.4.1**		Time Gradation provided in the scheme between the motors of various units.	**Yes/ No**														

S.No.	Recom m. Ref.		**Area/ Sub Station**																	
			Switch Board No. **Reliability check point**																	
32	**3.4.2**		Mention the under voltage setting for the HT Motors	**0,5/1/3/5 sec etc**																
33	**3.4.3**		Confirm under voltage input to relay derived from the Bus PT.	**Yes/ No**																
34	**3.4.3**		In case of conventional relays, confirm at least two phase voltage selected for the tripping	**2 Phase / 1 phase**																
35	**3.4.4**		Confirm blocking of UV trip scheme in fuse failure condition	**Yes/ No**																
36	**3.4.5**		Under voltage relay contact multiplication provided through self reset relay.	**Yes/ No**																
37	**3.4.6**		Confirm under voltage trip command is not operating master relay of individual motor feeder.	**Yes/ No**																
			REMARKS																	

Chapter-4

LT DISTRIBUTION SYSTEM, OPERATION & CONTROL OF LT MOTORS

LT distribution systems (PCCs, PMCCs, MCCs, ASBs) being major contributor to the process operation have to be given the similar order of attention as in case of maintaining the HT system. Though the skill requirement for these systems may be not so intense as in case of HT systems but the maintainability and reliable operation of the equipment associated with LT system, at the time of need, are the back bone for the process unit to operate at its full capacity. Since there are numerous small equipment connected to LT systems, the need is to build up such a high degree of reliability to the system that outage of any equipment should not disturb the process operation. This can only be achieved by ensuring that the faulty Power feeding section / equipment is immediacy taken over by a healthy system to ensure uninterrupted process operation.

4A ***RECOMMENDATIONS***

Following actions are desirable for reliable and healthy *LT Distribution System*. Detailed explanation to these recommendations marked as (◀) has been enclosed at Section 4B of this chapter.

For better focus and clarity, the actionable points the reliability related issues related to LT system have been have been divided into following sub groups:

1 PCC / MCC Configuration

2 Protection and Control Supplies.

3 Re -acceleration of LT Motors

4 Auto change over of LT motors

4.1 PCC / MCC configuration

4.1.1 ***Each PCC should be fed by two identical incomers and a bus coupler. Supply to transformer incomers should be sourced from different HT sections from the upstream. Care to be taken that the HT supply to PCC incomers should not be fed from the same generation bus or their adjacent sections. (Refer Schematic Drawing No. – 4C.1)*** ◀

For three-incomers scheme suitable feeding arrangement to be implemented.

4.1.2 ***Bus coupler with Auto - Manual bus transfer facility shall be in line with as discussed in Chapter 5.***

4.1.3 Both transformers should be of identical ratings and PCC bus suitable for continuous parallel operation with both transformers in service, unless there are limitations of bus fault level. ***(New Facilities / Projects)***

4.1.4 Due to limitations of fault level, momentary paralleling of incomers exists in certain existing setup. Issues related to reliable operation of bus transfer actions for momentary paralleling schemes are same as discussed in Chapter 5 Section 2 which may be referred and followed.

4.1.5 The control supply to PCCs may either be DC supply or AC control supply. In case of AC it should be derived from before the incomer breakers through control transformer forming a control bus.

There should be a suitable control supply change over scheme available in all PCCs.

4.1.6 ***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.***

4.2 Protection and Control Supplies.

(A) Protection System

4.2.1 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.

4.2.2 All PCC Transformer should have REF protection *(New Facilities / Projects)*

4.2.3 All the transformer auxiliary protections (Bucholz, Oil temp. / Winding temp / Minimum oil gauge) shall be provided with alarms / tripping. It is desirable to use Reed Switch type

Bucholz Relays in place of Mercury Switch type relays in seismic prone areas.

4.2.4 ***In order to achieve complete isolation of fault, it is desirable that master relay operation of any downstream PCC incomer breaker should also trip the upstream HT breaker.***

4.2.5 ***In order to prevent spurious tripping / relay mal-operation, It is recommended to replace critical obsolete / defective relays with latest relays in phased manner.***

4.2.6 ***In order to prevent problems pertaining to the earthing of numerical relays, it is recommended to provide clean & dedicated earthing for the numerical relays.***

4.2.7 ***The breaker service position contact should not be included in the tripping logic of breakers.***

(B) LT Motor Protection

4.2.8 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. *(New Facilities / Projects)*

4.2.9 All process trip relays shall be self reset type contacts with hand reset flags or reset facility from PLC / DCS.

4.2.10 ***All unwanted protections and high set protection features provided in numerical relays should to be kept disabled.***

4.2.11 ***Issues related to earth fault protection and need of stabilizing resistance have been discussed in Chapter 3 Clause 3.2.5.***

4.2.12 ***Issues related to prevent spurious tripping of motors during re-acceleration on account of doubling feature in numerical relays have been discussed in Chapter 3 Clause 3.2.6.***

(C) Under Voltage trip scheme for Incomers

The Under Voltage trip scheme for LT systems is discussed in detail in Chapter 5 may accordingly be adhered for implementation.

(D) Control Scheme

4.2.13 ***The control supply to protection relays shall be separate from the breaker control supply in the switchgear feeders where Numerical relays are used.***

4.2.14 ***It is recommended to mark individual control fuse rating in the panels/ module doors to eliminate chances of improper fuse selection by operation at the time of replacement.***

4.2.15 ***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.***

4.2.16 ***For the situations, where MCC control supply is through a control transformers forming a common control, the control supply to the critical equipment (affecting plant operation) may be modified to individual module based control supply scheme, if feasible. Rating of the each control fuse must be mentioned on every module.***

For the new projects, individual feeder based scheme with a dedicated transformer in each feeder shall be provided. *(New Facilities / Projects)*

4.2.17 **Wherever two NO contacts available in Emergency push button & LCS STOP PB of all breaker fed HT & LT Motors, one NO contact shall be wired to trip breaker directly & other shall be wired to binary input of numeric motor protection relay.**

4.2.18 **Hard contacts of the breaker shall be used for providing interlocks in the schemes mainly for auto change over, tripping, feedback, closing and process interlocks. In the absence of sufficient hard contacts, latched contactors/ relays to be used for contact multiplication.**

4.2.19 **In PMCC/MCC, For conversion of common control supply(through transformer) to distributed control supply from respective module, neutral connection shall be made at least at 4 points to avoid breaking of the neutral continuity.**

4.3 Re -acceleration of LT Motors

4.3.1 ***Re-acceleration scheme shall be provided for the selected extremely critical motors in the refinery. The updated list must be available with each unit in this regard.***

4.3.2 The control supply to re- acceleration scheme should preferably be DC / UPS.

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.

It is recommended to provide only PLC / DCS based re-acceleration schemes in new projects in view of ease of implementation. *(New Facilities / Projects)*

4.3.3 It is recommended to check the healthiness of the scheme for individual motor during shutdown.

4.4 Auto change over of LT motors

4.4.1 ***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*.**

4.4.2 To the extent possible, the control supply for auto-change over scheme should be either DC or UPS.

4.4.3 System should be developed for periodic checking of the healthiness of Auto changeover scheme. The observations in respect with shortcomings, if any, during actual operation of Auto changeover should form the part of failure analysis report.

4.5 Specific Requirements

4.5.1 During retrofitting of switchgear, engineering calculation for circuit breaker sizing, bus bar sizing, heat generation and dissipation etc. with necessary de-rating factors should be carried out for ensuring reliability.

4.5.2 All MCC modules shall be designed for type 2 co-ordination. The degree of enclosure for LT switchgear shall be preferably IP54 (New Projects).

4.5.3 The protection devices for air circuit breaker in PCC/ PMCCs/ MCCs shall be numerical relays and shall not be provided with releases.

4.5.4 Power supply to auxiliary services board where single phase / lighting loads are connected shall be through lighting / isolation transformer only. (New Projects / New Schemes by ES / Sub-station Revamp)

4.5.5 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.(New projects)

4.5.6 All LT motor feeders of motor rated above 55KW shall be fed from air circuit breaker with motor protection relay (New Projects).

4.5.7 Aux Contactors in critical feeders (I/C, B/C, HT Motor Soft starter etc) which remain energized in normal condition , shall be replaced every 4-5 years

In order to facilitate full implementation of above recommendations by identifying GAPs and preparing action plan, a check list has been developed for reference and is given at Section 4E of this chapter.

Chapter-4

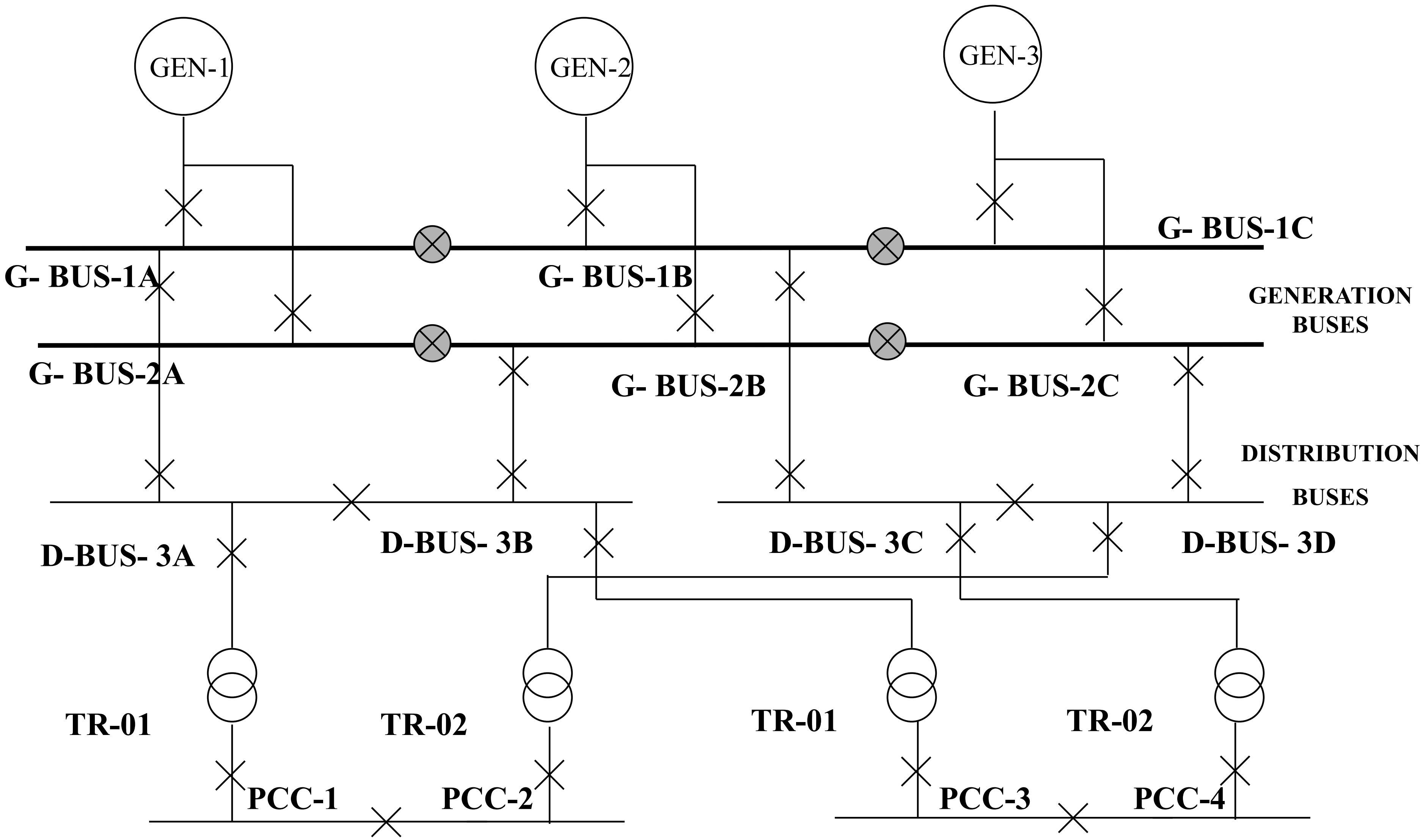
LT DISTRIBUTION SYSTEM, OPERATION & CONTROL OF LT MOTORS

4B- Explanation to Recommendations

Reference	Explanation
4.1.1	The distribution buses in the primary sub-station shall be fed from the main generation buses. It is to be to ensured that outage of any of the generation bus shall not affect the complete distribution system i.e. the simultaneous outage of both the distribution bus sections should not occur. (Refer Schematic Drawing No. – 4C.1)
4.1.2	Bus coupler with Auto- Manual transfer system shall be provided between two adjacent distribution buses. In case of manual transfer, the closing of bus coupler breaker should be though **check synchronization relay** The check-synchronizing relay should come into circuit only in case of Manual Closing of the bus coupler. This is to doubly ensure that the two adjacent live buses are in synchronism. This has more relevance with the increased complexity in the electrical system due to expansions and multiple primary generation / distribution sub stations. In auto mode (when one incomer trips the bus coupler closing is similar to the dead bus closing condition. Hence check synchronization is not required)
4.1.4	Unintended operation takes place during manual bus transfer operation due to wrong selection and giving tripping command to bus coupler instead of giving closing command to incomer breaker. Issues related to reliable operation of bus transfer actions for momentary paralleling schemes are same as discussed in Chapter 5 Section 2 and may be referred to and followed.
4.2.3	It is desirable to use in place of Mercury Switch type relays in seismic prone area. There have been instances that transformer have tripped on Bucholz protection due to mal-operation of mercury switch in the relay during earthquakes. To improve the operational reliability of the secondary distribution system Reed Switch type Bucholz Relays should be used.

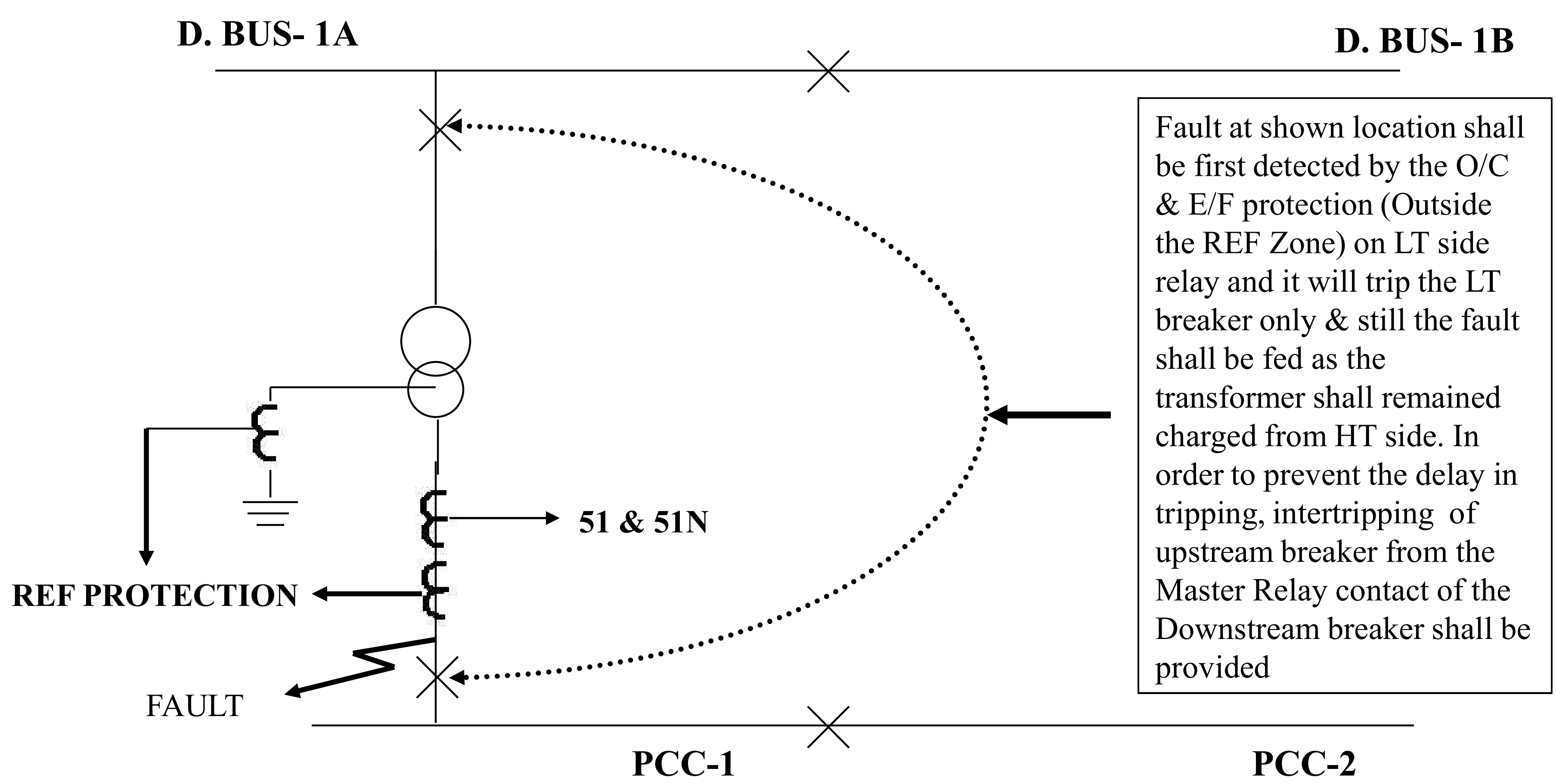
	Mark –10 Bucholz Relay of L&T (P&B) is one of such relay available in the market.
4.2.4	Normally, there is provision available to trip the up stream HT breaker in case of operation of REF protection. Referring to Schematic Drawing No. – 4C.2, in the event of fault in the portion between the CT and the breaker (as shown in the drawing) the fault will not be cleared by REF protection being a fault out side the REF zone. The fault will be cleared by the 51/ 51 N relays by tripping the PCC incomer trough master relay. The fault shall continue to be fed from the upstream side till the breaker trip on over current or earth fault protection with a considerable time delay as per the setting. It is therefore recommended to trip the upstream HT breaker immediately with the of LT breaker on fault. To eliminate such situation, the tripping may be provided from the downstream master relay contact to the upstream breaker. This shall ensure in complete isolation of the fault under such conditions.
4.2.7	It is not desirable to prevent the tripping of any breaker in case of emergency in field and fault conditions. There have been instances that the motor did not trip during fault or when stopped from field due to problem in the Breaker service position limit switch contact or its wiring resulting into greater degree of damage either to equipment or to process. Some of the OEMs/ switchgear supplier say that this situation should be taken care by the backup (ie. Upstream breaker) in case of fault in the running equipment. This may not be true for conditions which result in partial increase in motor current like over load , bearing failure, rotor rubbing due to bearing seizure or emergency requirements from field to stop the motor. Hence it is desirable to remove the service contact interlock from the tripping logic of all the equipments including motors.
4.2.8	It becomes very difficult to coordinate the PCC / MCC relay settings with fuse ratings higher than 160 Amp hence provision of earth leakage relays may be done at such locations. The earth fault current in the motors having long length cables is comparatively low. This phenomenon leads to tripping of incomer breaker of MCC on earth fault protection rather than blowing of fuse of individual motor. Therefore, it is desirable to protect all such motors with earth fault protection.
4.2.10	The numerical relay normally comes with many inbuilt features such as advanced tripping options, high set tripping for E/F and other undesirable protections. It is very essential that proper review of all

	the protection features available in numerical relays is made and other those protection features are to be enabled which are part of Standard protection schemes as used in IOCL's electrical system. A sample sheet showing such features for particular make of relay is enclosed as Annexure 4D.1 for reference. It is also desirable to keep a data sheet of relay setting of different feeders for all models / make of relays being used in the system.
4.2.13	In case the control supply to numerical relay is same as breaker control supply, in case of isolation while switching off control supply the supply to numerical relay is list and the history of the relay gets erased.
4.2.14	In order to maintain proper fuse coordination in the distribution system & to avoid complete control supply interruption, it is recommended to mark individual control fuse rating in the panels/ module doors to eliminate chances of improper fuse selection, normally the ratings are marked in the control schemes and not readily available in the switchgear rooms.
4.2.17	Direct contact will ensure the tripping of breaker in the case of failure of protection relay. Digital input to numerical relay will provide stamping of the respective tripping command.
4.2.18	Auxiliary contacts shall not be used auto change over, tripping, feedback, closing and process interlocks as failure of auxiliary contactor/relay shall defeat the scheme. In the absence of sufficient hard contacts, latched contactors/ relays are to be used for contact multiplication.
4.2.19	To avoid failure due to breaking of neutral at one single point, neutral connection shall be made at least 4 points. This will ensure the continuity of the control supply of the PMCC/MCC feeders in the event of breaking of any neutral connection.
4.3.1	In order to ensure re-acceleration (automatically restart) of contactor controlled LT motors, after a severe voltage dip in the system, a re-acceleration scheme shall be provided for the selected extremely critical motors in the refinery. All auxiliary drives of the critical equipments (Turbines / Compressors / BFP etc.) shall also be provided with re- acceleration scheme.
4.3.2	For the feeders provided with re-acceleration scheme, the control supply scheme shall be provided with DC / UPS system so that the scheme remains unaffected during the voltage dips.



TYPICAL PCC FEEDING ARRANGMENT

DRG. NO. 4C.1



INTER TRIPPING SCHEME FOR DISTRIBUTION TRANSFORMER

DRG. NO. 4C.2

SAMLE DATA SHEET FOR MONITORING OF NUMERICAL RELAY SETTINGS
(FOR ABB MAKE SPAM 150 RELAY)

SNO.	MOTORS	MOTOR-A	MOTOR-B	MOTOR-C
1	RATED KW	180	220	460
2	RATED AMPS	21.1	26.4	52.5
3	STARTING AMPS	111.63	158.4	315
4	STARTING TIME	23 sec.	37 sec.	1.8 sec
5	WTH STAND TIME - HOT	39 sec	60 sec	30 sec
6	WTH STAND TIME - COLD	50 sec	90 sec	45 sec
7	VOLTAGE	6600	6600	6600
8	CONNECTION	STAR	STAR	STAR
9	MAKE	BHEL	BHEL	NGEF
	CURRENT TRANSFORMER			
1	CTR	125 / 5 / 5 A	150 / 5 / 5 A	300 / 5 / 5A
2	CLASS	5P10 , 1	5P10 , 1	5P10 , 1
3	BURDEN	15VA /15VA	15VA /15VA	15VA /15VA
4	CORE	2	2	2
	PROTECTION RELAY			
1	TYPE	SPAM150C	SPAM150C	SPAM150C
2	MAKE	ABB	ABB	ABB
3	AUX. VOLTS	220 VDC	220 VDC	220 VDC
4	MODEL NO	SPCJ 4D34	SPCJ 4D34	SPCJ 4D34
5	RATING	1 / 5 AMPS	1 / 5 AMPS	1 / 5 AMPS
	MOTOR PROTECTION RELAY SETTINGS			
1	Thermal unit = Iθ	0.88 / In	0.92 / In	0.86 / In
2	Max. safe stall time = t6x	40 sec.	60 sec.	6 sec.
3	Weighting factor for thermal unit curve = P	50%	50%	50%
4	Prior alarm for thermal over load = θ A	95%	95%	95%
5	Restart inhibit level for th. O/L cond. = θ I	57%	40%	70%
6	Cooling reduction factor = Kc	4 tc	4 tc	4 tc
7	Motor start current setting = Is	4.22 In	5.30 In	5.25In
8	Motor start time setting = ts	25,3 sec.	42.5 sec.	8.8 sec.
9	High set over current unit = I>>	6.32 In	8.0 In	7.86 In
10	High set operating time = t>>	0.05 sec.	0.05 sec.	0.05 sec.
11	Earth fault unit = Io	20%	20%	20%
12	Earth fault operating time = to	0.55 sec.	0.55 sec.	0.55 sec.
13	Unbalance protection Δ I	25%	17%	17%
14	Unbalance prot,operating time TΔ	60 sec.	50 sec.	30 sec.
15	Under current unit = I<	disabled	disabled	disabled
16	Under current operating time = t<	2.0 sec.	2.0 sec.	2.0 sec.
17	Time base start inhibit cont.in sec. = Σtsi	10 sec.	5 sec.	5 sec.
18	Countdown rate of the start time counter in seconds per hours = ΔΣ ts	3 sec / h	2 sec / h	2 sec / h
19	SGF	113-	113-	113-
20	SGB	0-	0-	0-
21	SGR	129-	129-	129-
22	SGR 1	126-	126-	126-

FUCTIONAL PROGRAMMING SWITCH GROUP - SGF

S. No	SWITCH	FUCTION	USER SETTINGS	WEIGHT VALUE
1	SGF - 1	High set over current	1	1
2	SGF - 2	High set over current stage double during a motor startup	0	2
3	SGF - 3	Earth fault trip inhibited on over current higher than	0	4
4	SGF - 4	Selected multiple of motor full load current	0	8
5	SGF - 5	Phase unbalance protection	1	16
6	SGF - 6	Incorrect phase sequence prot..	1	32
7	SGF - 7	Stall protection base on thermal stress supervision	1	64
8	SGF - 8	Under current protection	0	128
		Checksum for setting of SGF	**113**	*********

BLOCKING AND CONTROL INPUT SELECTOR SWITCH GROUP - SGB

S. No	SWITCH	FUCTION	USER SETTINGS	WEIGHT VALUE
1	SGB - 1	Stall information to relay from speed switch	0	1
2	SGB - 2	Restart of the motor inhibited by external command	0	2
3	SGB - 3	The phase unbalanced unit is blocked by the input signal	0	4
4	SGB - 4	The earth fault unit is blocked by the input signal	0	8
5	SGB - 5	External trip command carried out to output relay	0	16
6	SGB - 6	External relay reset command	0	32
7	SGB - 7	Latching of output relay for short ckt E/F , unbalanced trip	0	64
8	SGB - 8	Latching of any output relay for any tripping ,independent of the case	0	128
		Checksum for setting of SGB	**0**	**********

RELAY OUTPUT PROGRAMMINGSWITCH GROUP - SGR -1				
S. No	**SWITCH**	**FUCTION**	**USER SETTINGS**	**WEIGHT VALUE**
1	SGR -1/ 1	The thermal prior alarm link to SS2	1	1
2	SGR -1/ 2	The thermal trip signal link to SS2	0	2
3	SGR -1/ 3	The signal from stall protection linked to SS2	0	4
4	SGR -1/ 4	The signal for high set over current linked to SS2	0	8
5	SGR -1/ 5	The signal for current unbalance linked to SS2	0	16
6	SGR -1/ 6	The signal for earth fault linked to SS2	0	32
7	SGR -1/ 7	The signal for under current linked to SS 2	0	64
8	SGR -1/ 8	The earth fault unit trip link to SS 2	1	128
		Checksum for setting of SGR	**129**	*************

RELAY OUTPUT PROGRAMMING SWITCH GROUP - SGR - 2				
S. No	**SWITCH**	**FUCTION**	**USER SETTINGS**	**WEIGHT VALUE**
1	SGR -2/ 1	The thermal prior alarm linked to SS 1	0	1
2	SGR -2/ 2	The motor startup in for output linked to SS 1	1	2
3	SGR -2/ 3	The starting of the high-set over current linked to SS 1	1	4
4	SGR -2/ 4	The thermal trip signal linked to SS 3	1	8
5	SGR -2/ 5	The signal from stall protection linked to SS 3	1	16
6	SGR -2/ 6	The signal current unbalanced linked to SS 3	1	32
7	SGR -2/ 7	The signal for earth fault linked to SS 3	1	64
8	SGR -2/ 8	The signal for under current linked to SS 3	0	128
		Checksum for setting of SGR	**126**	**************

Check List 4E.1

Chapter -4 LT DISTRIBUTION SYSTEM, OPERATION & CONTROL OF LT MOTORS

Area/ Location:- (to be filled)

Note:- Gaps in the existing system and actions to be taken are to be indicated by ***BOLD ITALICS in RED COLOUR***

S.No.	Recomm. Ref.		**Area/ Sub Station →** **Switch Board No. →** ↓ **Reliability check point**															
1	**4.1.1**		PCC is having two identical incomer breakers	**Yes / No**														
2	**4.1.1**		Both PCC incomer are not falling on same generation bus/ or their sections.	**Yes / No**														
3	**4.1.2**		PCC is having Bus coupler between two sections with Auto - Manual bus transfer facility.	**Yes / No**														
4	**4.1.3**	**New project**	Both the PCC incomers are fed through identical transformers.	**Yes / No**														
5	**4.1.4**		Adequacy of interlocks in Momentary paralleling scheme	Yes / No														
6	**4.1.4**		Display of suitable operating instructions at panel regarding Momentary paralleling Scheme.	Yes / No														
7	**4.1.5**		Control supply to PCC (DC / AC derived from before the incomer breaker.	**Yes / No**														
8	**4.1.5**		The existence of suitable control supply change over scheme in PCCs	**Yes / No**														
9	**4.1.6**		Availability of critical alarms from each sub station to manned location.	**Yes / No**														
10	**4.2.1**		Adequacy of protection in Transformer feeders in line with recommendation no. 4.2.1	**Yes / No**														
11	**4.2.1**		Existence of High set O/C tripping in transformer feeder.	**Yes / No**														
12	**4.2.2**		Existence of REF protection in PCC transformers.	**Yes / No**														
13	**4.2.2**		Existence of Standby E/F protection in PCCs with transformers above 500LVA	**Yes / No**														
14	**4.2.3**		Alarm and trip protection in Bucholz relay.	**Yes / No**														
15	**4.2.3**		Alarm and trip protection in oil temp high / winding temp high in transformers.	**Yes / No**														
16	**4.2.3**		Existence of Seismic proof Bucholz relay in earthquake prone areas.	**Yes / No**														
17	**4.2.4**		Tripping of upstream breaker in case LT incomer trips on master trip relay.	**Yes / No**														
18	**4.2.5**		List obsolete relays of critical feeders for replacement with latest numerical relays.	**List**														
19	**4.2.6**		Is clean & dedicated earthing provided for the numerical relays in each panel.	**Yes / No**														
20	**4.2.7**		The breaker service position contact is not included in the tripping logic of breakers	**Not included / Included**														
21	**4.2.8**		Provision of Earth fault protection in LT motors above 37 KW	**Yes / No**														

S.No.	Recomm. Ref.		Area/ Sub Station →																
			Switch Board No. → ↓ Reliability check point																
22	4.2.9		Process relays to be with self reset CONTACTs and Hand reset Flag.	**Yes / No**															
23	4.2.10		Review of selecting only desired protection features in numerical relays.	**Done / Not done**															
24	4.2.10		Availability of standard relay setting data sheet as ready reference for each make & model of numerical relay	**Available / Not Available**															
25	4.2.11		Instantaneous Tripping is provided for Earth Fault protection of Motor feeders.	**Yes/ No**															
26	4.2.11		Provision of stabilizing resistance for Earth Fault protection of Motor feeders.	**Yes/ No**															
27	4.2.11		Provision of stabilizing resistance for Earth Fault protection is also available in all type of Numerical relays.	**Yes/ No**															
28	4.2.12		Whether Dynamic settings/ Doubling feature is used in Numerical relays.	**Yes/ No**															
29	4.2.12		If, yes. Mode / contact through which Toggling of Dynamic settings/ Doubling feature is achieved	**Give Type of contact used for toggling**															
30	4.2.13		Provision of dedicated control supply for the numerical relays.	**Available / Not Available**															
31	4.2.14		Marking of individual control fuse rating in the panels/ module doors of PCC/MCC feeders.	**Done / Not done**															
32	4.2.15		AC control supply to MCCs	**Individual/ Control Bus**															
33	4.2.16		For the situations, where MCC control supply is through a control transformers forming a common control, the control supply to all the critical equipment (affecting plant operation) shall be individual module based control supply.	**Done / Not done**															
34	4.2.17		Provion of 2 nos contacts of EPB and LCS to direct trippingand one relay	**Available/ Not Available**															
35	4.2.18		Hard contacts of the breaker shall be used for providing interlocks in the schemes mainly for auto change over, tripping, feedback, closing and process interlocks	**Yes/ No**															
36	4.2.19		Control supply Neutral in MCC to be tapped from at least 4 places	**Yes/ No**															
37	4.3.1		Availability of re-acceleration scheme to all identified critical motors for each unit.	**Available / Not Available**															
38	4.3.2		Availability of reliable re-acceleration schemes.	**Available / Not Available**															
39	4.3.3		Checking of healthiness of re-acceleration scheme is included in standard shut down job list	**Available / Not Available**															
40	4.4.1		Availability of Auto change over scheme to all identified critical motors for each unit.	**Available / Not Available**															
41	4.4.2		DC/UPS control supply to Auto change over schemes.	**Available / Not Available**															

S.No.	Recomm. Ref.		Area/ Sub Station →															
			Switch Board No. → ↓ **Reliability check point**															
42	**4.4.3**		System for periodic checking of the healthiness of Auto changeover scheme of critical motors.	**In place/ Not in place**														
43	**4.5.1**		Consideraion of derating factors during retrofittings	**Yes/no**														
44	**4.5.2**		MCC modules shall be designed for type 2 co-ordination	**Yes/no**														
45	**4.5.3**		Usage of releases in air ciruit breakers	**Yes/no**														
46	**4.5.4**		Provison of lighting transformer for lighting	**Yes/no**														
47	**4.5.5**		Tapping of control supply from individual module and not from the control transformer	**Yes/no**														
48	**4.5.6**		All LT motor feeders of motor rated above 55KW shall be fed from air circuit breaker	**Yes/no**														
49	**4.5.7**		Practice of replacemnet of auxiliary contactors in 4-5 years	**Yes/no**														
			REMARKS															

Chapter-5

UNDER VOLTAGE MANAGEMENT
&
BUS TRANSFER SCHEMES (HT and LT)

5 A- ***RECOMMENDATIONS***

Following actions are desirable for reliable and healthy ***Under Voltage Management and Bus Transfer Schemes.***. Detailed explanation to these recommendations marked as (🔈) has been enclosed at Section 5B of this chapter.

5.1 Under Voltage Management

5.1.1 All Bus incomer breakers up to the PCC level shall be provided with the "Under Voltage Tripping Scheme". 🔈

5.1.2 Upstream (primary side) feeders for Transformer & PCC outgoing breaker to MCC shall not be provided with U/V tripping. 🔈

5.1.3 The complete under voltage tripping scheme provided for the distribution system at various voltage levels should 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.

5.1.4 Under Voltage tripping of the incomer breakers shall not be given through the master relay. 🔈

5.1.5 The under voltage tripping shall be initiated from the line side PT of the incomer breaker and should not be from bus PT.

5.1.6 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.

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.

5.1.7 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***

5.1.8 Blocking of under voltage (U/V) tripping of motors is to be provided in case of PT fuse failure. Fuse Failure relays/ PT supply MCB contact shall be used for Blocking of U/V trip.

5.1.9 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.

5.1.10 Under voltage tripping of motors and their reacceleration shall be based on studies with regard to adequacy of voltage recovery subsequent to fault conditions. This is necessary for ensuring quick voltage recovery after fault clearance in HT system. The adequacy to be ensured by Testing Department during system study.

5.1.11 The under voltage schemes in HT systems to be examined for ensuring that the line under voltage & bus under voltage work on the same voltage base i.e. both shall sense either Ph-N or Ph-Ph voltage at the same time to prevent mal-operation during earth faults. The same shall be ensured by Testing Department from the drawings and verify physically during the scheduled protection testing.

5.2 Bus Transfer Schemes.

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

5.2.2 In case of manual transfer in Bus Coupler, the closing of bus coupler breaker should be though check synchronization relay wherever there are chances of paralleling of two unsynchronized sources.

In the new projects, all Bus Couplers shall be provided through check synchronization facility in manual closing. (New Projects)

5.2.3 To the extent possible, the control supply for auto-changeover scheme should be taken from reliable source e.g. DC, UPS etc. ✓

5.2.4 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. ✓

5.2.5 It is desirable to block the closing command to bus coupler breaker (i.e. to de-activate the auto change over scheme) after a suitable time gap on tripping of any of the incomer breaker, wherever feasible. Blocking may be provided through a timer activated from the dead bus condition of the unhealthy bus. ✓ ***(New projects)***

5.2.6 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***

5.2.7 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).

The change over schemes having separate monitoring with above settings can be provided with instantaneous changeovers. ✓

5.2.8 Locations having 60 % U/V relays for bus healthy condition should replace the relays with 80% relays. If it is not feasible to replace that relays, a suitable tome delay should be incorporated in the "Healthy Bus Sensing Input " in bus coupler logic, such that adequate time is allowed to build up the voltage upto at least 80% on the affected bus

5.2.9 Schemes provided with single U/V relay in a Bus section for detecting both healthy and unhealthy bus conditions

should be modified to have separate U/v relays for monitoring bus healthy and unhealthy condition.

5.2.10 ***In order to achieve reliability of the auto transfer scheme, it is recommended to review the scheme that only critical interlocks are taken into circuit.***

5.2.11 ***It is desirable to have breaker at both the upstream & downstream ends of a distribution section. In the distribution configurations where cable is directly connected to the bus section or through adopters, it is desirable to provide breakers in such panels to ensure operational reliability and effective bus transfer during upstream faults (faults out side the bus zone). (Refer Schematic Drawing No. – 5C.1)***

5.2.12 ***It is to be ensured that downstream Bus coupler changeover scheme should not get 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.***

5.2.13 ***In case of transformer protection, the trip command from REF protection should not actuate the master trip relay of the LT breaker to enable auto changeover of the bus coupler.***

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

5.2.15 ***Momentary Paralleling Scheme For Bus Sections:***
Following points to be ensured in operating the momentary bus paralleling option (manual bus transfer mode) of the bus transfer schemes. The actions below mainly focus on the inadvertent tripping of wrong incomer/ bus coupler.

- ***While giving shutdown/ normalization, the action to be initiated only by giving closing command to the desired breaker and not by giving tripping command to the breaker which is intended to be opened.***
- ***In "Momentary Paralleling Mode" of bus transfer scheme, manual open command to the breaker should be defeated.***

- ***It is also desirable to incorporate suitable time delay (5 to 10 sec) in the monetary paralleling mode of the scheme such that the tripping command to the intended breaker is initiated only after successful transfer operation.***

5.2.16 In order to ensure the healthiness of Bus coupler auto changeover scheme, it is desirable to incorporate Bus coupler "Auto Circuit Supervision Scheme" for all bus couplers utilizing the concept of trip circuit supervision scheme. (Refer Schematic Drawing No. – 5C.2 -A/B/C) (New projects).

5.2.17 It is recommended to provide auto change over scheme completely through logic in Numerical relay of bus coupler (New Projects/ Facilities)

5.2.18 Facility of fast bus transfer (FBT) scheme to be provided in switchboard having high residual voltage during voltage dip.
Fast bus transfer scheme implemented at PR, this may be adopted by others.

In order to facilitate full implementation of above recommendations by identifying GAPs and preparing action plan, a check list has been developed for reference and is given at Section 5E of this chapter.

Chapter-5

UNDER VOLTAGE MANAGEMENT & BUS TRANSFER SCHEMES (HT and LT)

5B- Explanation to Recommendations

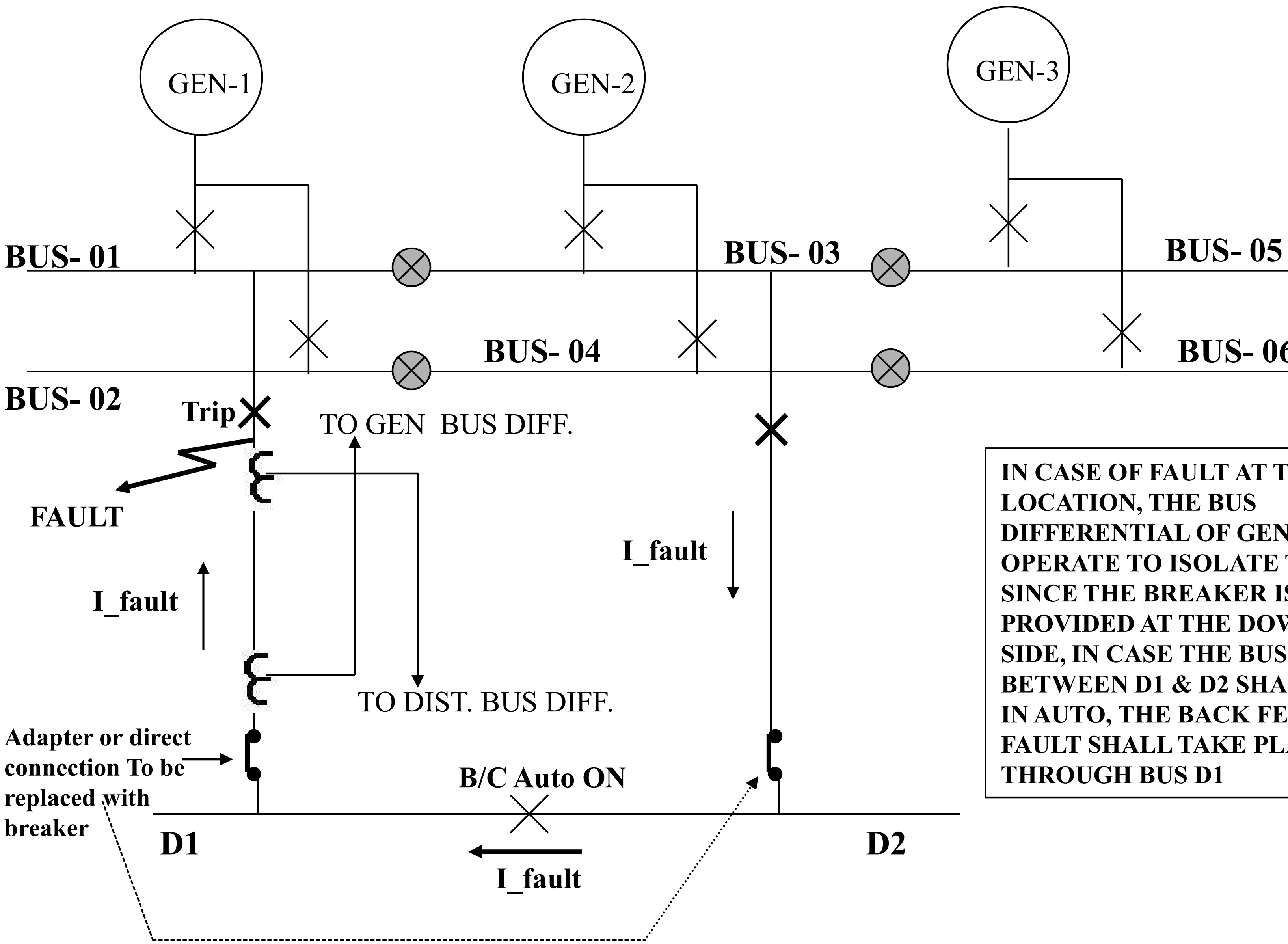
Reference	Explanation
5.1.1	To facilitate "Auto" operation of the Bus coupler during system disturbances / plant emergencies,
5.1.2	HT side of transformer is not required to trip on U/V unless there is fault condition, which will automatically be taken care by other protections provided for fault management and have been discussed separately at relevant section. The purpose of U/V isolation of PCC incomer is to facilitate fast Bus Transfer operation of the Bus coupler when the power to PCC incomer is lost. Since MCCs are not provided with Bus transfer schemes and there may be many motors feeders provided with re-acceleration scheme, it is not desirable to trip MCC incomer breaker on U/V for quick process restoration.
5.1.3	Normally, the philosophy of time gradation in under voltage protection co-ordination adopted is such that • There is minimum time delay at the highest voltage of the system and subsequent graded increase at lower voltage levels. (TOP Down approach) OR • The time delay at the highest voltage level is maximum and subsequent graded decrease at lower voltage levels (Bottom up approach). The first option is preferable as the system reliability is enhanced during under voltage conditions as the number of auto change over taking place in the distribution system shall be minimum. Further the efforts required for normalization of the system is also less. With TOP Down approach the PCC breaker will have the highest time setting (2-3 sec.). There may be fear that the change over will take place at PCC level after the designated time delay, but in case of U/V in single PCC incomer due to fault in its transformer or cable, the HT breaker will trip and will instantaneously trip the DOWNSTREAM breaker through inter-tripping (as recommended in

	Chapter 2 point no 2.3.30 and Chapter 4 point no 4.2.4 of this document) A typical U/V coordination diagram, with Top- Down approach, is attached as Annexure 5D.1 for reference Refineries to review the under voltage co-ordination accordingly.
5.1.4	In order to prevent blocking of auto transfer of bus coupler, Under Voltage tripping of the incomer breakers shall not be given through the master relay.
5.1.7	Under voltage tripping scheme of a particular incomer shall also monitor the healthiness of other bus section before initiating a under voltage trip command. Scheme shall be blocked if the other bus section is also experiencing under voltage. The healthiness of other section shall be derived from U/V relay connected to the bus PT (2 phases) to avoid incomer tripping when other bus in under shutdown or charged through bus coupler. This is to be ensured in all buses up to PCC level.
5.1.8	In order to prevent mal-operation of the scheme due to incomer PT fuse failure condition, fuse failure monitoring relays shall be provided to monitor the healthiness of PT fuses. The under voltage tripping scheme shall be blocked in case of operation of PT fuse failure relay. MCB's with auxiliary contacts used for blocking shall not be used as the contacts got mechanically struck up during MCB tripping leading to mal-operation of the scheme.
5.2.1	It is not desirable that any of the main distribution panel whether HT or LT should suffer the loss of power on account of outage of its incoming supply. The bus coupler change over should be through automatic closing of breaker without any loss of time.
5.2.2	The check-synchronizing relay should come into circuit only in case of Manual Closing of the bus coupler. This is to doubly ensure that the two adjacent live buses are in synchronism. This has more relevance with the increased complexity in the electrical system due to expansions and multiple primary generation / distribution sub stations. In auto mode (when one incomer trips the bus coupler closing is similar to the dead bus closing condition. Hence check synchronization is not required)
5.2.3	The control supply to Bus coupler changeover scheme should be reliable and free from system disturbances. It is therefore recommended to have either DC or UPS based control supply for such scheme

5.2.4	For system reliability, it is not desirable that bus coupler should close in the fault condition (either on Bus faults or on the thru' faults). Therefore, Closing operation of Bus coupler shall be blocked in any mode (Auto / Manual / Paralleling) if the master relay of any of the incomer has actuated. Some of the locations are also having interlock for tripping the master relay of bus coupler with master relay of incomer. Such provision, though provide additional security, but may also result in mal tripper of bus coupler when incomer is under shut down and master relay of incomer get operated during testing /simulation checks (Primary Injection) on the incomer. Therefore, the same may accordingly be reviewed at locations, where such provision exists.
5.2.5	Ideally, the bus coupler auto change over scheme does not permit the BUS Coupler Breaker to close when either of the Incomer breaker trips on fault (86 relay). In such an event, at a later moment if the master relay of the incomer is manually resetted, the bus coupler breaker will close automatically. This may result in feeding the fault through bus coupler. Blocking of scheme is essential in to built in operational safety and to prevent undesired closing of Bus coupler in case of accidental resetting of master relay of the incomer. It is, therefore, recommended to block the auto changeover logic after a suitable time delay (5 sec. or more) of the incomer tripping. Blocking may be provided through a timer activated from the dead bus condition of the unhealthy bus.
5.2.6	It is desirable to trip the downstream breaker of the feeder in case of tripping of upstream feeder. This will prevent back feeding as well as quick restoration of supply to downstream bus thru' fast change over. The tripping of downstream breaker in such cases should not be done thru' the master trip relay as it will block the bus coupler change over at that level, which is not desirable.
5.2.8	As per the standard schemes provided by OEMs, it is desired that bus coupler should close only when the healthy bus is above 80% voltage level. This to ensure that healthy bus is stable or sufficiently recovered to take care re-acceleration of motors. Since, some of the locations are having 60% U/V relays for monitoring bus healthy condition, it is desirable to build up a suitable time delay (at least 1sec.) in the bus coupler closing logic to enable building up of voltage to around 80% level, for such cases.
5.2.9	Ideally it is recommended to provide bus coupler changeover scheme with separate relays for monitoring the bus healthy condition with a relay setting of 80% and bus Unhealthy condition with a relay setting of 40% to achieve safe & reliable changeover

	operation. Schemes are also available with a single relay installed in each Bus section with a single setting of 60 % to meet both the requirements of healthy & unhealthy conditions. The relay remains in energized state for healthy condition & gets de-energized for unhealthy state. Such schemes are not desirable to achieve fast changeovers, as the proper monitoring of both healthy & unhealthy condition is not properly carried out with a single relay.
5.2.10	In order to make the bus transfer scheme simple and reliable, it should use only critical interlocks in the logic. For example, non-essential interlocks of Fuse failure relay of the buses / incomer is not required as dead bus condition is also supplemented by breaker open contact. Similarly, the contact of timer provided for the under voltage tripping of the incomer breaker shall not come in series into circuit for bus coupler auto changeover scheme as it will add up undesirable time delay in the scheme.
5.2.11	With reference to (Refer Schematic Drawing No. – 5C.1) **When there is no breaker provided at the down stream:** Considering a fault in the portion between upstream breaker and the CT for the downstream bus, the incomer breaker will trip and the Tie at downstream bus will also not close (due to its blocking by the master relay of the incomer breaker). If bus coupler operation is made permissible in such cases then it will lead to back feeding of fault thru' tie-breaker. In both the cases, it is an undesirable operation, in view of plant safety and reliability. The above conditions can also not be met by relocating CTs above breaker. To take care of such situations, it is desirable to have breaker at the downstream as well in place of direct connection / adopter. With the implementation of this modification, it will be possible to apply standard bus coupler scheme in the downstream bus.
5.2.14	In order to prevent non-operation of the bus coupler scheme during desired situation on account of wrong selection of Auto / Manual switch, it is recommended to provide alarm in control room / manned location for the manual mode selection of the bus changeover scheme.
5.2.15	Some of the locations are having momentary paralleling scheme instead of continuous paralleling due to limitations of switchgear fault level. Ideally, for continues paralleling, the fault level of switchgear should be higher than the combined fault level of both the incomer transformers when operated in parallel. With the momentary paralleling scheme, there have been instances of tripping of both the sections of the bus while giving shut down of

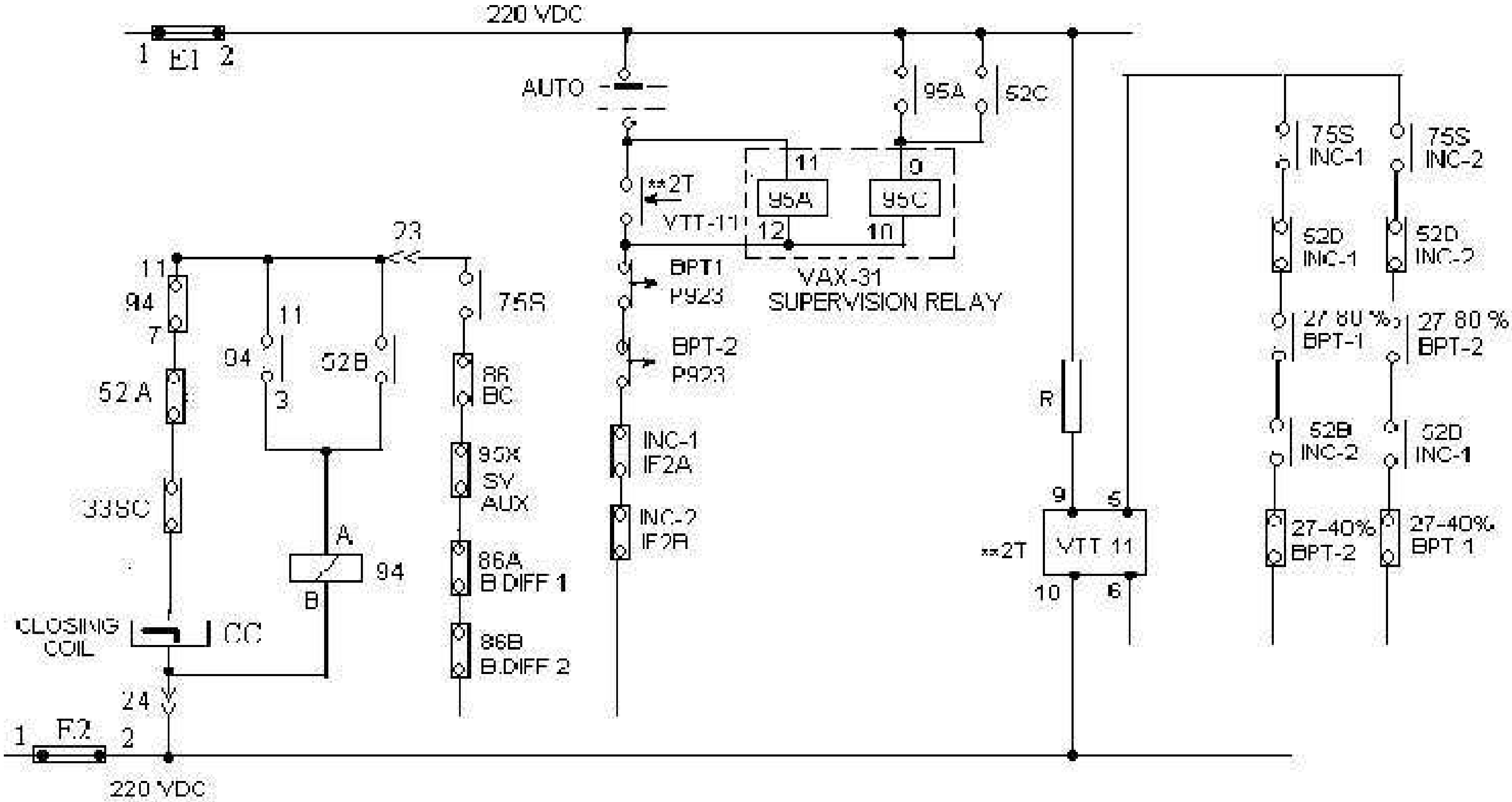
	one of the incomer breaker or while normalizing the same.This problem is due to inadequate exposure of the operator on handling such scheme. The operator inadvertently gives the trip command to (Incomer/ Bus coupler) instead of initiating a Close command so that the selected breaker trips. Therefore the concern is to build up adequate security into the system by providing adequate arrangements / interlocks at such locations to prevent wrong operation during manual bus transfer actions by operator.
5.2.16	***Auto Circuit Supervision Scheme*** The scheme works on the concept that most of the contacts remains in "NC" condition under the normal operating conditions. The scheme continuously monitors the control supply voltage across the few "NO" contacts in the scheme. For monitoring purpose all the "NO" contacts are provided serially (i.e. one after the another"). The supervision scheme monitors the healthiness of auto changeover circuit during "Auto" mode selected condition with an alarm at manned location. The scheme implemented for BHEL/ Siemens/ NGEF switchgears is attached for reference. (Refer Schematic Drawing No. 5C.2 -A/B/C) However a specific scheme is required to be developed for each switchgear in the same manner.
5.2.17	The recommended scheme will involve lesser number of physical contacts like breaker contacts, 86 relay contacts etc. which will make the scheme more reliable. Monitoring of Auto change over scheme healthiness can be done by checking the status of the digital inputs.
5.2.18	Auto change over takes place after considerably longer time in switchboard having high residual voltage. With FBT, changeover delay time can be reduced and ACO effectiveness will increase.



IN CASE OF FAULT AT THE SHOWN LOCATION, THE BUS DIFFERENTIAL OF GEN. BUS SHALL OPERATE TO ISOLATE THE FAULT, SINCE THE BREAKER IS NOT PROVIDED AT THE DOWNSTREAM SIDE, IN CASE THE BUS COUPLER BETWEEN D1 & D2 SHALL OPERATE IN AUTO, THE BACK FEEDING OF FAULT SHALL TAKE PLACE THROUGH BUS D1

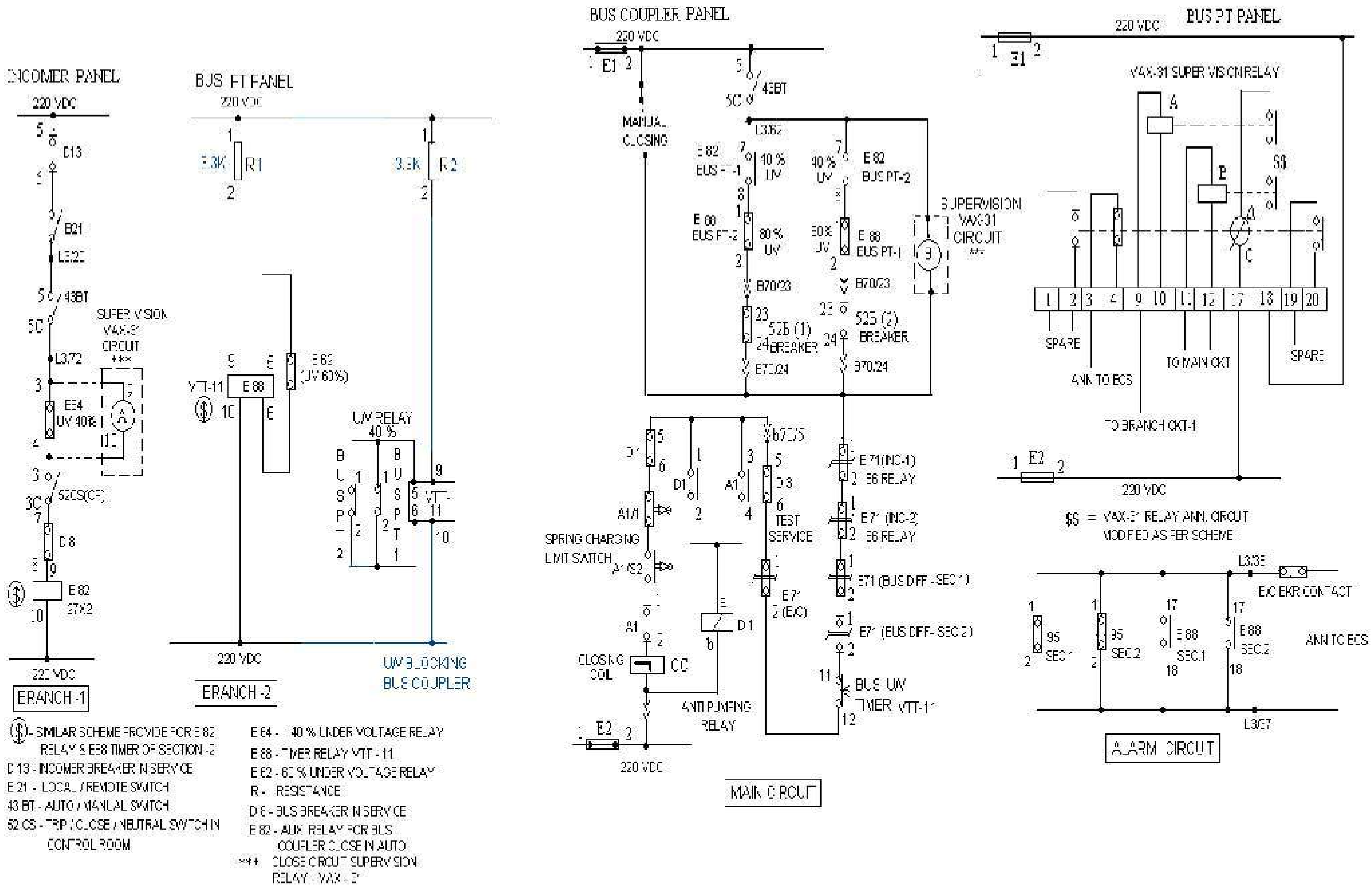
DISTRIBUTION BUS ARRANGEMENT WITHOUT BREAKER AT DOWNSTREAM

DRG. NO. 5C.1

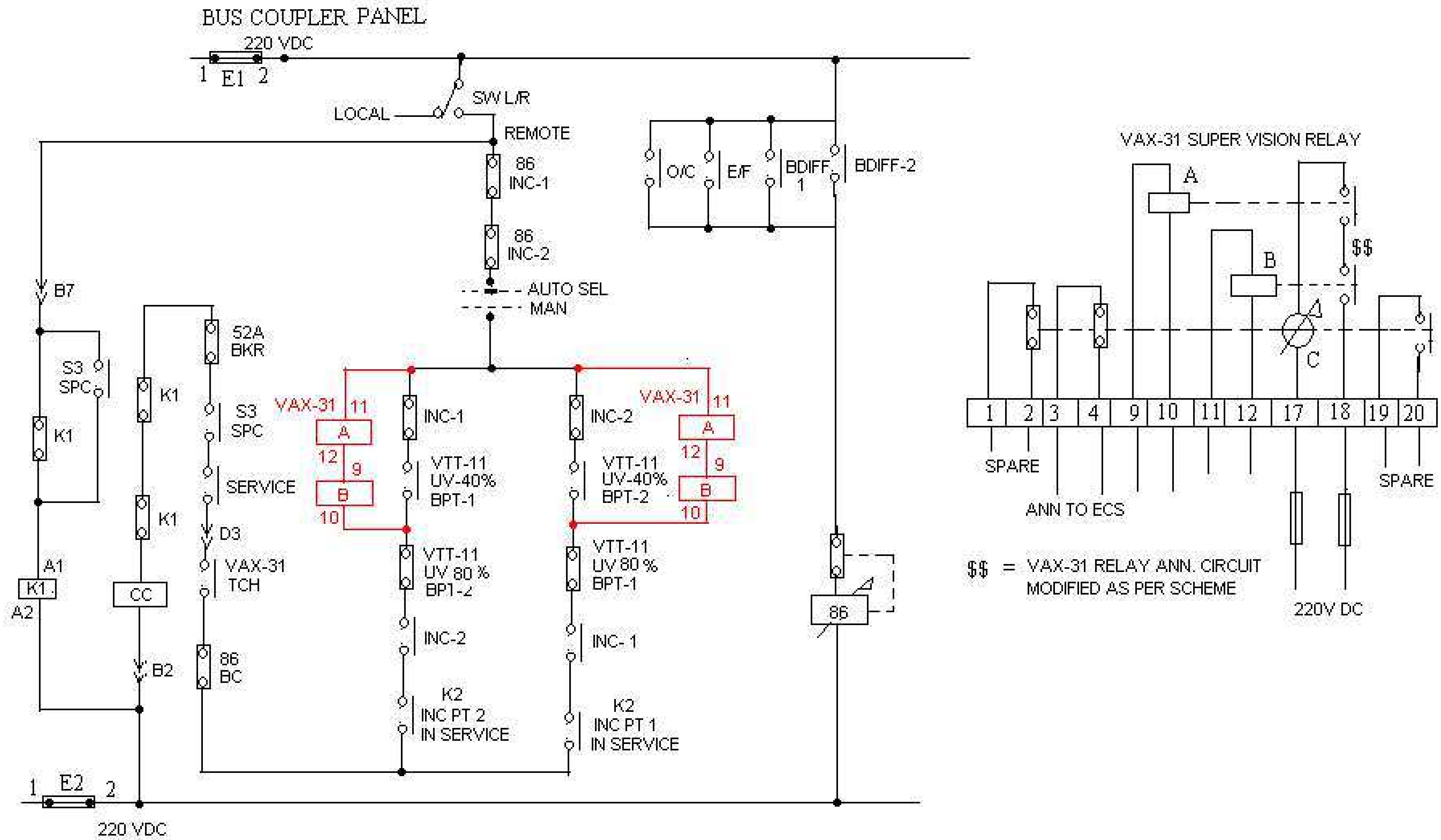


BUSCOUPLER AUTO CIRCUIT SUPERVISION SCHEME FOR BHEL PANEL

DRG. NO. 5C.2A

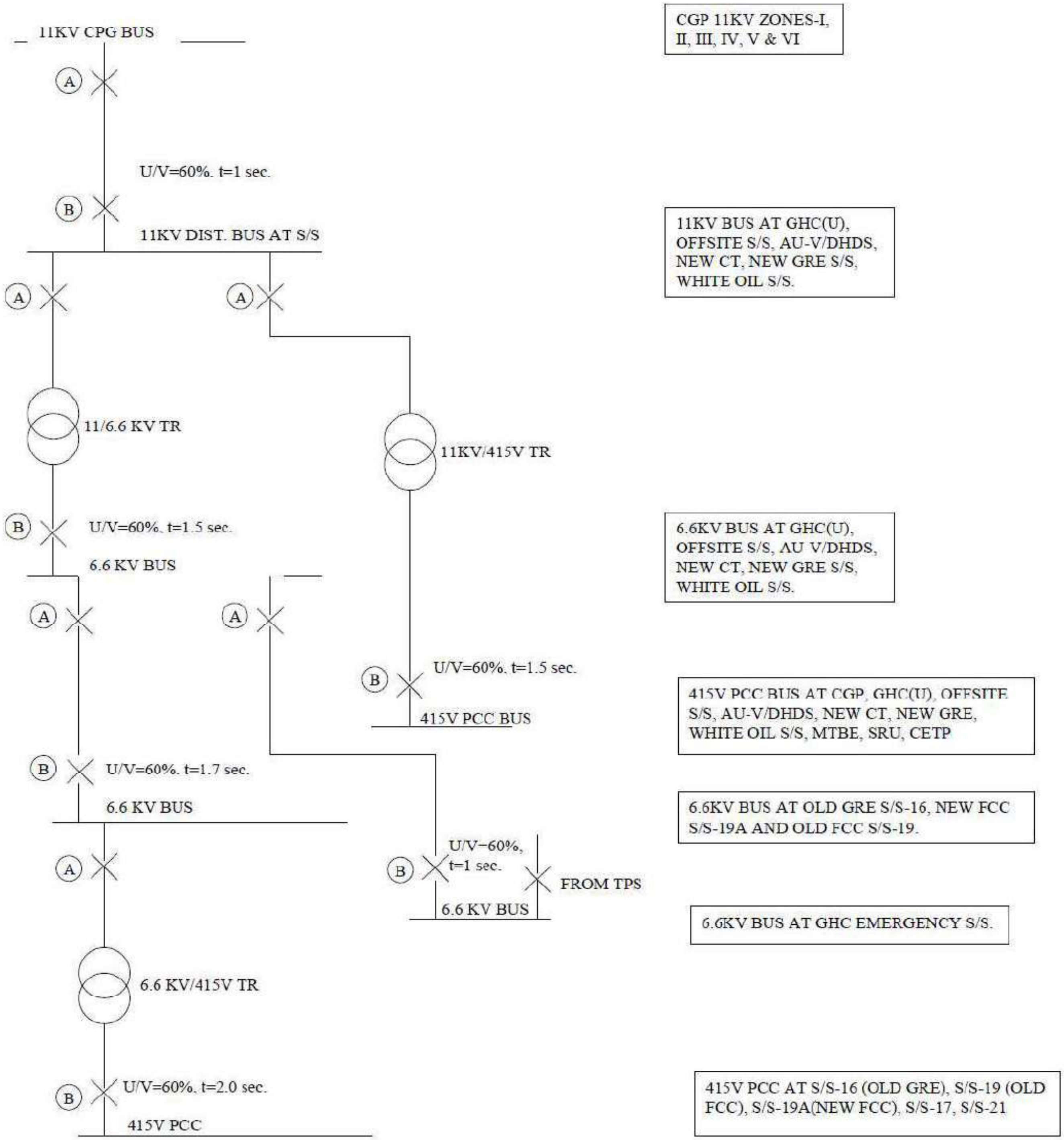


BUSCOUPLER AUTO CIRCUIT SUPERVISION SCHEME FOR NGEF PANEL **DRG. NO. 5C.2B**



BUSCOUPLER AUTO CIRCUIT SUPERVISION SCHEME FOR SIEMENS PANEL **DRG. NO. 5C.2C**

Annexure 5D.1



NOTE :

INTERTRIPPING BETWEEN UPSTREAM AND DOWN STREAM BREAKERS HAS TO BE PROVIDED.
(EX. TRIPPING OF BREAKER (A) SHALL TRIP BREAKER (B) IMMEDIATELY)

UNDER VOLTAGE CO-ORDINATION OF POWER DISTRIBUTION SYSTEM

Check List 5E.1

Chapter-5 UNDER VOLTAGE MANAGEMENT and BUS TRANSFER SCHEMES (HT and LT)

Area/ Location:- (to be filled)

Note:- Gaps in the existing system and actions to be taken are to be indicated by ***BOLD ITALICS in RED COLOUR***

S.No.	Recomm. Ref.		Area/ Sub Station →																	
			Switch Board No. → ↓ Reliability check point																	
1	5.1.1		All incomer breakers up to the PCC level are having Under Voltage Tripping Scheme	Yes / No																
2	5.1.2		Upstream (primary side) feeders for Transformer & MCC incomers are not provided with U/V tripping	Not provided / Provided																
3	5.1.3		The under voltage tripping scheme provided for entire distribution system at various voltage levels is time graded	Yes / No																
4	5.1.4		Under Voltage tripping of the incomer breakers shall be direct and not through the master relay.	Yes / No																
5	5.1.5		The under voltage tripping is initiated from the line side PT of the incomer breaker and not from bus PT	Line PT/ Bus PT																
6	5.1.6		Inputs from two phases are used for U/V tripping	2 Phase / 1 Phase																
7	5.1.7		Blocking of under voltage tripping in case both the Incomers are experiencing U/V.	Yes / No																
8	5.1.8		Blocking of under voltage tripping scheme in case of PT fuse failure	Available/ Not available																
9	5.1.9		In order to achieve faster restoration of the system after total power failure, under voltage tripping relay contact multiplication (if required) shall be provided through self reset relays.	Provided / Not provided																
10	5.2.1		All critical distribution sections are provided with Bus Coupler Changeover Scheme	Available/ Not available																
11	5.2.2		**Provision of check sync. Relay for Manual mode, whereever applicable.**	Available/ Not available																
12	5.2.3		Reliable control Supply to bus coupler changeover scheme.	Available/ Not available																
13	5.2.4		Blocking of bus coupler thru' Master relay contact of incomers	Done / not done																
14	5.2.5		Time out of B/C change over scheme.	Provided / Not provided																
15	5.2.6		Inter tripping provided for downstream breaker (Y/N)	Provided / Not provided																
16	5.2.6		whether inter tripping is direct or thru master relay	Direct/ Thru master Relay																
17	5.2.6		Breaker contact used for inter tripping (Direct/ Aux)	Direct / Auxillary																
18	5.2.7		U/V relay setting for Unhealthy bus (Dead Bus) is 40 % or less.	Yes / No																

S.No.	Recomm. Ref.		Area/ Sub Station →																
			Switch Board No. → ↓ Reliability check point																
19	5.2.7		U/V relay setting for Healthy bus is 80 %	Yes / No															
20	5.2.7		No time delay in provided in Auto C/O scheme	Yes / No															
21	5.2.9		Confirm provision of separate U/v relays for detecting Bus healthy and bus unhealthy condition	Yes / No															
22	5.2.10		Review of C/O logic for keeping only critical Interlocks in service.	Yes / No															
23	5.2.11		Confirm connection of power cables at Downstream substation is provided through Breaker	Yes / No															
24	5.2.12		Confirm Cable Differential Protection is not blocking the bus coupler auto change over at downstream substation.	Yes / No															
25	5.2.13		Direct tripping of LT incomer breaker (without Master relay) on REF Protection	Direct/ Thru master Relay															
26	5.2.14		Alarm of manual mode selection of B/C scheme at manned location	Provided / Not provided															
27	5.2.15		Adequacy of interlocks in Momentary paralleling scheme	Yes / No															
28	5.2.16		Display of suitable operating instructions at panel regarding Momentary paralleling Scheme.	Yes / No															
29	5.2.16		Provision of " Auto C/O Supervision scheme" for Bus couplers, if feasible.	Yes / No															
30	5.2.17	For new projects	Provision of auto change over scheme completely through logic in Numerical relay of bus coupler	Yes / No															
31	5.2.18		Facility of fast bus transfer (FBT) scheme in switchboard having high residual voltage	Provided/Not provided															

Chapter-6

DC SYSTEMS

6 A ***RECOMMENDATIONS***

Following actions are desirable for safe and reliable operation DC Systems. Detailed explanation to these recommendations marked as (◄) has been enclosed at Section 6B of this chapter.

6.1 It is desirable to have a separate dedicated DC system for each HT sub station complex. In the existing system, it may be adopted wherever feasible.

6.2 Each DC System should be provided with a redundant battery charger with paralleling operation scheme or auto changeover feature for switching to standby battery charger in case of fault in main (running) charger or vice – versa. (Refer Schematic Drawing No. – 6C.1).

6.3 The two incoming power supply sources of the battery charger system shall not fall on the same primary Generation / distribution source at 11 kV level. (Refer Schematic Drawing No. – 6C.2). ◄

6.4 The battery charger supply should be taken from the switch fuse units / MCB's and not from contactor based modules. ◄

6.5 The battery charger should 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. ◄

6.6 The DC distribution system should have dual DCDB with a coupler switch. In the existing system, it may be adopted wherever feasible. (Refer Schematic Drawing No. – 6C.2)

6.7 In case single battery charger is feeding to large number of Process units, feasibility of installation of an additional battery charger may be explored. The loads may be distributed accordingly on two DCDBs by giving redundancy in supply to critical loads.

6.8 For critical DC loads, where failure of DC supply leads to tripping of the critical equipment (Fail safe) should be provided with redundant DC supply fed from different feeder of DCDB.

6.9 It is desirable to provide an emergency interconnection between the two DC systems having the same voltages either in the same sub station or from nearest sub station. (Refer Schematic Drawing No. – 6C.3)

6.10 It is recommended to provide a DC ground fault alarm in the control room / manned locations. All ground fault alarms to be attended at the earliest.

Scheme shall be provided with a milliamp meter at DCDB / contol room or in ECS to monitor the extent of leakage current in the system (New project).

6.11 Complete DC distribution system to be reviewed in totality to ensure proper fuse coordination between the upstream & downstream sections.

6.12 The ratings of each fuse shall be marked on the panel above the fuse base. It is desirable to have updated DC system distribution diagram showing fuse ratings up to downstream end for each DCDB. This diagram should be displayed at a suitable location in the switchgear.

6.13 It is recommended that each HT bus section shall be provided with redundant DC control supply. Each bus section should be fed from separate DC feeder. The redundant DC control supply shall be designed for changeover to the alternate backup DC supply in case of failure of the main supply.

6.14 It is recommended to have a boost charging alarm of the chargers at the manned location / control room.

6.15 It is recommended to provide battery charger fail alarms at the manned location / control room. If required single summary fault contact alarm may be provided.

6.16 Alarm shall be provided for filter capacitor bank fuse failure for taking timely action to control high ripple content. Ripple content to be checked and recorded during schedule maintenance without battery. (Ripple content should be less than 2% of the rated voltage). Additionally battery AC current with clip-on meter to be checked and recorded on scheduled basis.

6.17 The battery bank provided with the battery charger should be in healthy condition and of adequate capacity to provide sufficient backup in case of power failure. It is desirable to develop a system for carrying out load test of the battery bank at the every available opportunity.

6.18 DC systems commonly feeding to both Instrumentation system and emergency light should be separated by having separate DC systems for each. (New Projects)

6.19 Measurement on DC system shall be done with floating signal probe and not with grounded shield probe, if oscilloscope is being used.

6.20 Based on the OEM recommendations on life cycle of critical components like capacitors, cards etc. replacement of such components shall be carried out. Normally, the frequency of replacement varies between 8 to 10 years.

6.21 Use of VRLA batteries shall be avoided.

6.22 **Electronic cards of system like UPS, battery charger, VFD, SCADA, Heater control system shall be ISA-G3 compliant as per Std. S.71.04. (For new projects/New procurements)**

6.23 Preferably copper cables shall be used in Battery Charger DCDB & Battery Charger DCDB to downstream distribution systems. Only copper cables to be considered for new projects.

6.24 Complete redundant configuration shall be provided with Dual battery chargers, Dual battery banks & Dual DCDB sections. Two independent DC systems with individual DCDB shall be provided. Two feeders from individual DCDB using diode O ring shall be employed at critical utility point. (For new projects/ New procurements)

In order to facilitate full implementation of above recommendations by identifying GAPs and preparing action plan, a check list has been developed for reference and is given at Section 6E of this chapter.

Chapter-6

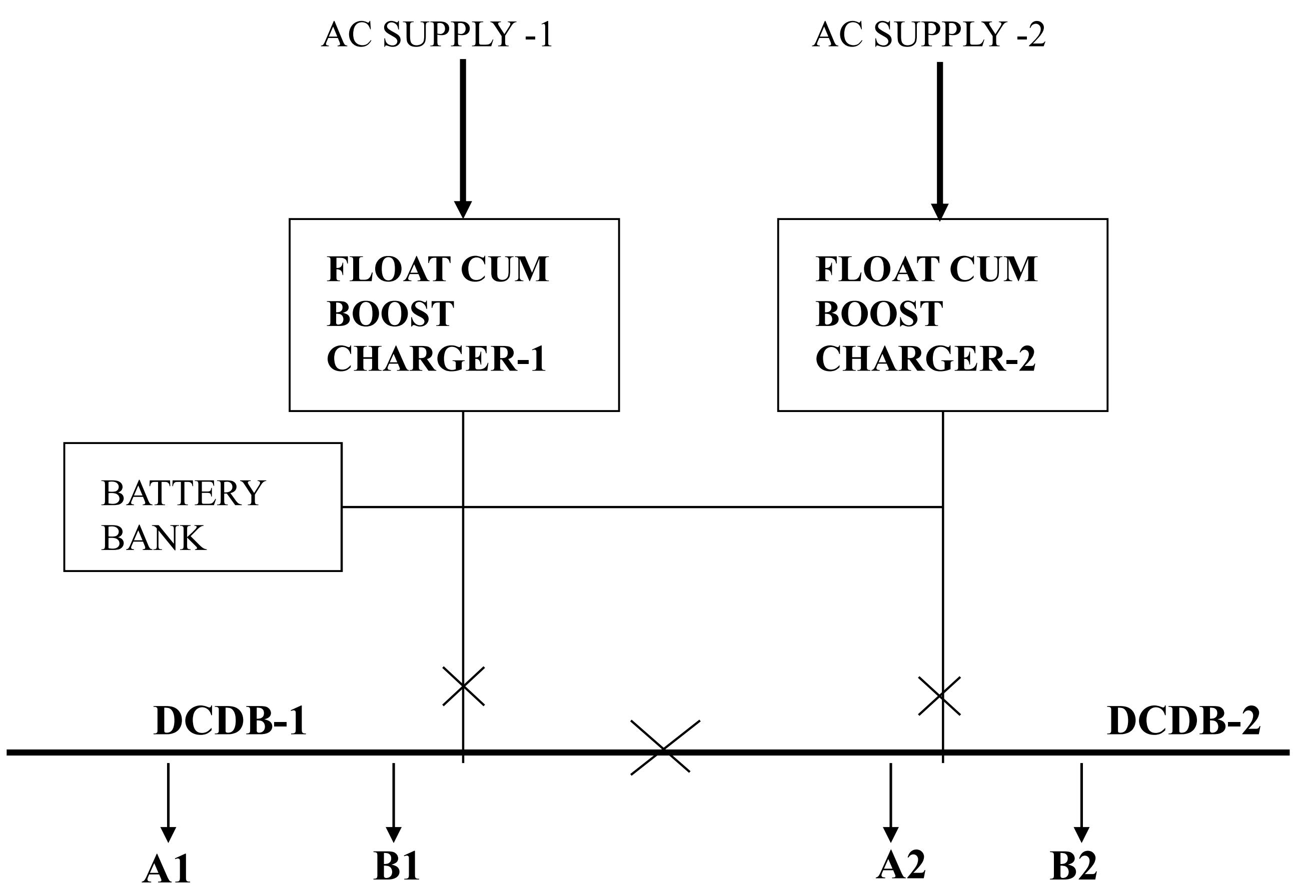
DC System

6B - EXPLANATION TO RECOMMENDATIONS

Reference	***EXPLANATION***
6.3	The reliability of the incoming power supply sources is to be ensured in order to prevent the simultaneous tripping of both the sources. The power supply sources shall not fall on the same primary Generation / distribution source at 11 kV level. (Refer Schematic Drawing No. – 6C.2)
6.4	It is recommended to review the chargers control schemes to meet the requirement of providing uninterrupted AC supply to battery chargers particularly after voltage dips in the power system. The power supply sources shall not be provided with contactor based modules, only MCB or SFU are to be provided in MCC / PDB.
6.5	In case chargers are provided with contactor type arrangement for switching with AC control supply, the contactors may drop during voltage dips and load will be switched over to battery bank. Hence proper measures are required to be taken to automatically restart the chargers after voltage dips. To care of this, shorting of start push button may be done to pick up the charger immediately after voltage dips. The push button shorting may be done through a toggle switch to perform planned shutdown of the battery charger.
6.9	In order to ensure the healthiness of battery bank, periodic charging & discharging is mandatory as per the recommended practice of the OEM. In view of the single battery bank, it becomes very difficult to meet the load testing requirements. To provide safe isolation of the battery bank for battery discharging, it is proposed to provide an emergency interconnection between the nearest DCDB's of the two same voltages. The interconnection shall be made "On" after ensuring the difference between the two DC systems is almost equal; necessary voltage adjustment shall be done from the battery charger.
6.10	In order to continuously monitor the extent of ground fault in the DC supply system and to prevent mal-operation of control circuits due to DC leakage, it is recommended to provide a DC ground fault

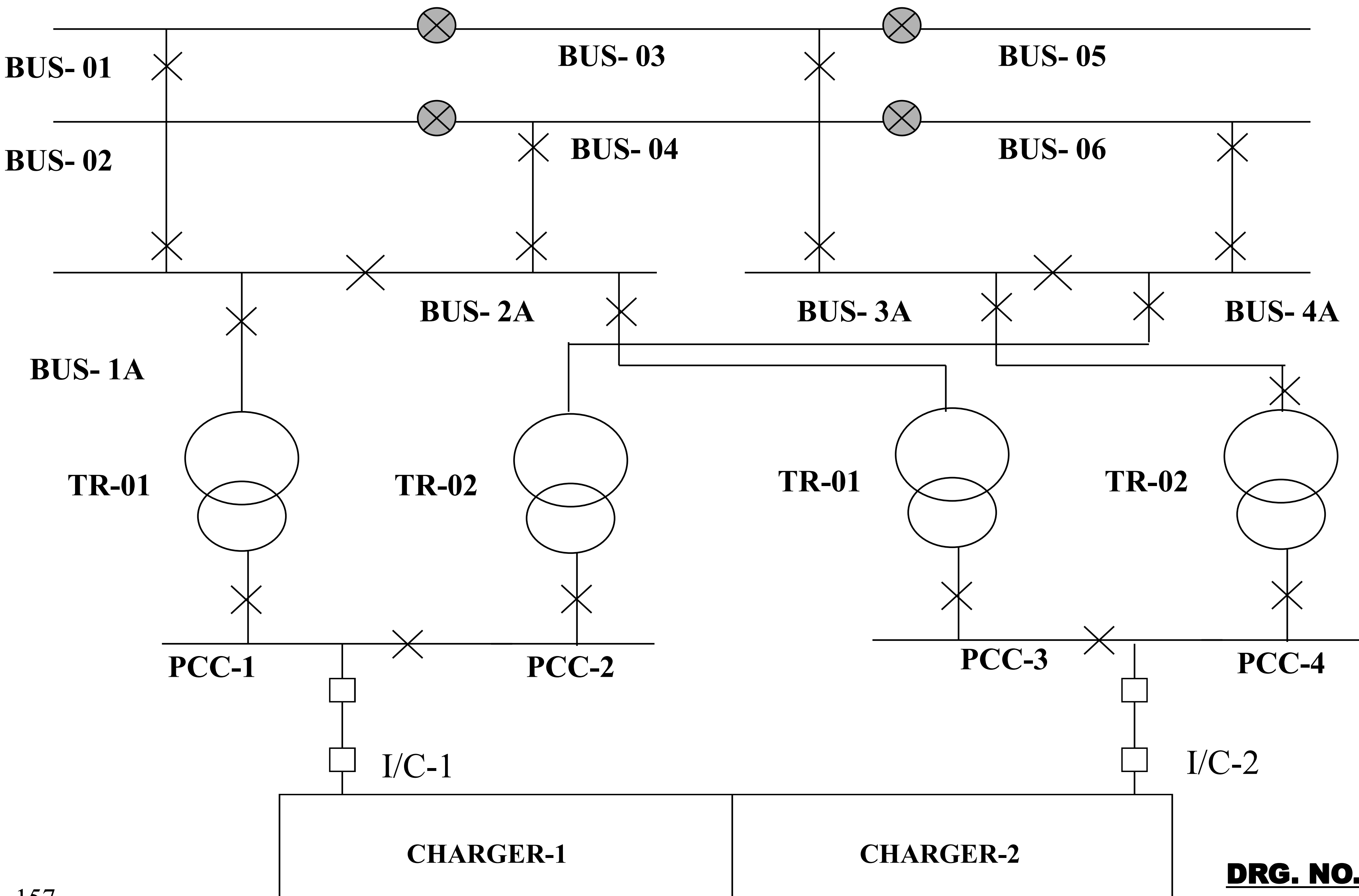
	relay with alarming in the control room. Also a milliamp meter is to be provided which shall show the leakage current flowing in the circuit thus the extent of leakage current in the system may be monitored continuously.
6.11	This shall help in maintaining reliable control supply without unwarranted failure due to wrong fuse coordination.
6.12	Labeling of fuse rating shall help the operator in providing correct fuse rating during replacements. The use of overall DC diagram with fuse ratings will mainly help in; • Source identification • Overall fuse coordination for entire DC system in a sub station • Verification of fuse rating, in case of doubt by operator. • Fuse inventory management.
6.14	In order to protect the damage of battery bank due to inadvertent prolong boost charging, it is recommended to provide a boost charging alarm of the chargers at the manned location / control room
6.16	To ensure reliable operation of the charger and to ensure healthiness of the components, it is recommended to periodically measure the ripple contents in the charger output supply & output and battery AC ripple current component. The ripple content should be less than 2% of the rated voltage.
6.18	Faults on the DC emergency lighting system are inevitable due to day to day field maintenance. It is not desirable to risk the Instrumentation DC system due on account of such voltage dips as plant operation is affected by voltage dips in the Instrument control supply. It is therefore desirable to have separate DC system for Instrumentation and Emergency lighting.
6.23	Copper cables are preferred over aluminium due to lower resistivity of copper leading to reduced voltage drop.
6.24	It shall be possible to take shutdown of complete set of Battery Charger & Battery Bank through paralleling of both chargers by closing DCDB B/C and complete on line load transfer to other charger without affecting plant operation for PM/Load testing of Battery charger & Battery Bank.

To be modified



BATTERY CHARGER CONFIGURATION WITH DUAL BANK

DRG. NO. 6C.1



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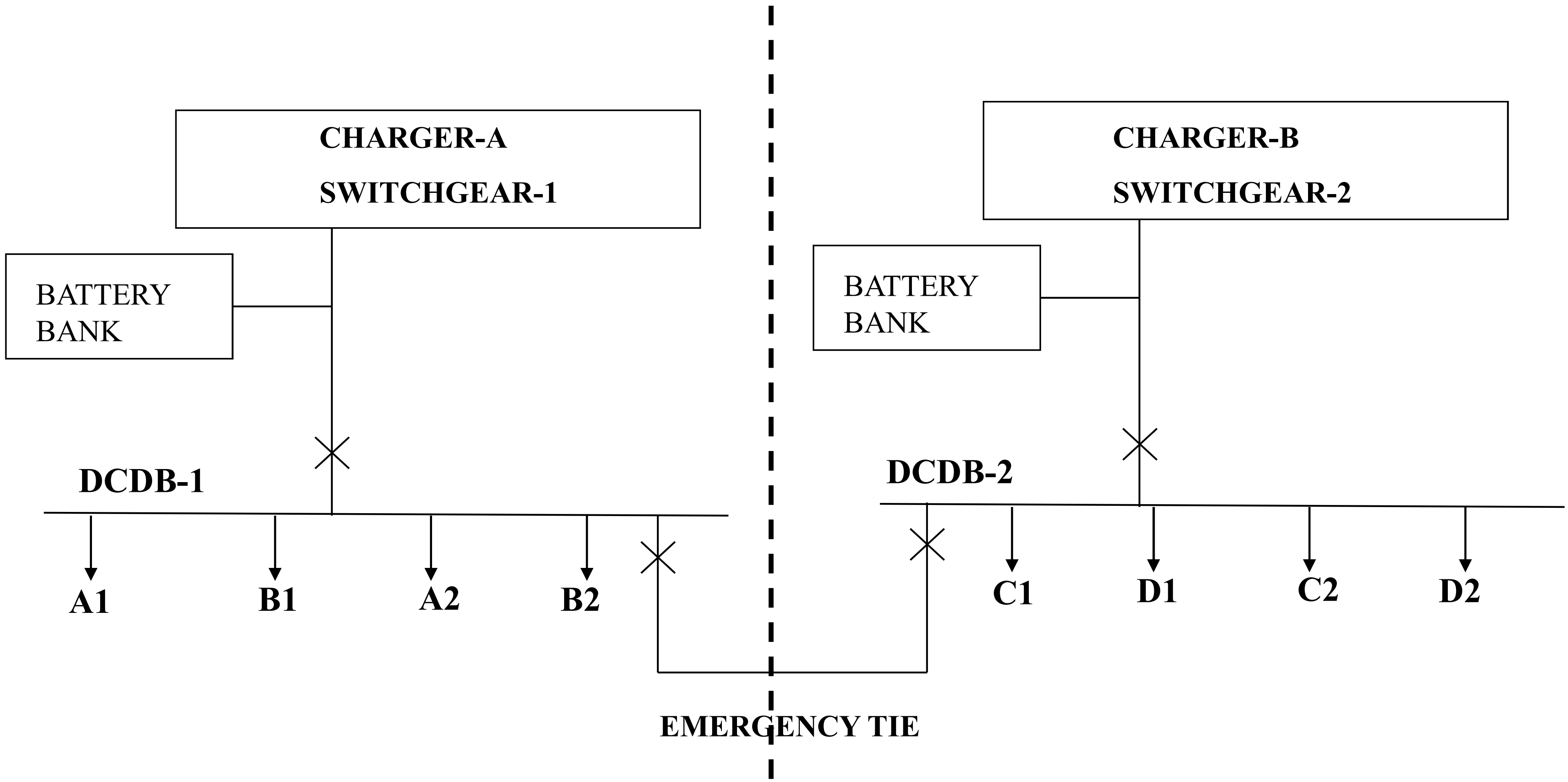
BATTERY CHARGER SUPPLY ARRANGEMENT WITH GEN. BUS SECTIONALIZING



BATTERY CHARGER CONFIGURATION WITH EMERGENCY TIE

DRG. NO. 6C.3

Check List 6E.1

Chapter -6 DC SYSTEM

Area/ Location:- (to be filled)

Note:- Gaps in the existing system and actions to be taken are to be indicated by ***BOLD ITALICS in RED COLOUR***

S.No.	Recomm. Ref.		**Area/ Sub Station →** **Switch Board No. →** ↓ **Reliability check point**									
1	**6.1**		Provision of separate DC Charger system for each HT substation.	Yes / No								
2	**6.2**		Battery chargers are redundant with paralleling or changeover facility	Yes / No								
3	**6.3**		The incoming power supply sources shall not fall on the same primary Generation / distribution source at 11 kV level	OK / Not OK								
4	**6.4**		Incoming power supply to chargers is from SFUs / MCB's and not from contactors	SFU / MCB/ Contactors								
5	**6.5**		Provision in battery charger to come into service automatically after voltage dips or after plant restoration.	Available / Not Available								
6	**6.6**		DCDB provided with dual section with a bus coupler switch.	Yes / No								
7	**6.7**		Single battery charger is feeding to large no. of units,	Yes / No								
8	**6.7**		Feasibility of installation of dual battery banks or separate chargers	Feasible / Not Feasible								
9	**6.8**		Availability of redundant DC supply f or Critical DC loads.	Available / Not Available								
10	**6.9**		Availability of emergency interconnection between DC systems to facilitate battery maintenance.	Available / Not Available								
11	**6.9**		If not available , Feasibility of emergency interconnection between DC systems to facilitate battery maintenance.	Feasible / Not Feasible								
12	**6.10**		Provision of DC ground fault alarm for all DC systems (220 / 125 / 110 V etc)	Available / Not Available								
13	**6.11**		Review of the DC distribution system upto downstream level for proper fuse coordination	Available / Not Available								
14	**6.12**		Marking of fuse ratings above fuse base inside the panels.	Available / Not Available								

S.No.	Recomm. Ref.		**Area/ Sub Station** →									
			Switch Board No. → ↓ **Reliability check point**									
15	**6.12**		Availability and display of DC systems diagram for the sub station	Displayed / Not Displayed								
16	**6.13**		Redundant DC control supply to each HT bus is available	Available / Not Available								
17	**6.14**		Provision of boost charging alarm at the manned location / control room	Available / Not Available								
18	**6.15**		Provision of critical battery charger alarms at the manned location / control room	Available / Not Available								
19	**6.16**		Provision of Alarm / MIS for ripple measurement in output supply of battery charger.	Available / Not Available								
20	**6.17**		Confirmation regarding healthiness of battery bank based on last discharging.	Healthy / Unhealthy								
21	**6.17**		Date of last discharging to be furnished.	Date								
22	**6.17**		Maintaining record of Auto / Manual boost charging of battery bank	Available / Not Available								
23	**6.18**		Provision of Separate battery bank for emergency lighting and process units instrumentation supply.	Available / Not Available								
24	**6.19**		Measurement on DC system shall be done with floating signal probe	Yes/No								
25	**6.20**		Replacement of critical components as per OEM guideline	Yes/No								
26	**6.21**		Use of VRLA batteries	Yes/No								
27	**6.22**	**New project**	Electronic cards shall comply ISA-G3 compliant	Yes/No								
28	**6.23**	**New project**	Use of copper cables in DC distribution	Yes/No								
29	**6.24**	**New project**	Complete DC redundent system as per Point 6.24	Yes/No								
			REMARKS									

Chapter-7

UNINTERRUPTED POWER SUPPLY SYSTEMS

7 A RECOMMENDATIONS

Following actions are desirable for safe and reliable operation of UPS Systems. Detailed explanation to these recommendations marked as (◀) has been enclosed at Section 7B of this chapter.

7.1 It is advisable to have a separate dedicated UPS system for each process unit (associated units). In the existing system, it may be adopted wherever feasible. ◀ ***(New Facilities/ Projects)***

7.2 All the 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. ◀ (Refer drg. no. 7.C1)

7.3 UPS systems shall be Parallel redundant types with each UPS capable of feeding 100% plant load. It is desirable to have UPS with Dual ACDB configuration.(Refer drg. no. 7.C2) (New Facilities/ Projects)

7.4 It is desirable to install separate battery banks for each UPS section, in order to provide sufficient back up during emergencies. ◀ (New Facilities/ Projects)

The battery bank provided with the UPS should be in healthy condition & adequate to provide sufficient backup in case of power failure. The schedule and history of record of testing of battery should be maintained for each UPS.

7.5 All the input supplies to the UPS shall be provided from SFU's & not from the contactor controlled modules. ◀

7.6 It is UPS supply Protection coordination need to be jointly examined by identified team of electrical and instrumentation, from UPS ACDB level to the downstream distribution level (in the instrumentation panels) is to be ensured to avoid complete outage of supply due to coordination mismatch. ◀

7.7 It is recommended to provide all UPS alarms at the manned location / control room. If required single summary (Group) fault contact alarm may be provided.

7.8 Every UPS system is provided with internal cooling fans, it is recommended to ensure the healthiness of these fans & sufficient inventory to be maintained for timely replacement.

7.9 It is recommended to place all UPS systems in only dust free air-conditioned atmosphere.

7.10 **UPS supply shall not be used for external auxiliary requirements like lighting, fans, space heater etc.**

7.11 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).

7.12 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 / ES Schemes).

7.13 Based on the OEM recommendations of life cycle of critical components like capacitors, cooling fans etc. replacement plan shall be made to enable initiate timely procurement action. A typical guideline is enclosed at the end of the chapter.

7.14 Use of VRLA batteries shall be avoided.

7.15 **Preferably copper cables shall be used in UPS ACDB & ACDB to downstream distribution systems.**

7.16 **Contactor change over schemes shall not be provided in the UPS output supply.**

7.17 **Electronic cards of system like UPS, battery charger, VFD, SCADA, Heater control system shall be ISA-G3 compliant as per Std. S.71.04. (For new projects/New procurements)**

7.18 **UPS ACDB shall be dual redundant fed from independent UPS systems and two feeders (one from each ACDB) shall feed the parallel redundant load of instrumentation for reliability. For single load service, automatic transfer switch (ATS) may be used.(New projects) as shown in Diagram. 7C.3**

In order to facilitate full implementation of above recommendations by identifying GAPs and preparing action plan, a check list has been developed for reference and is given at Section 7E of this chapter.

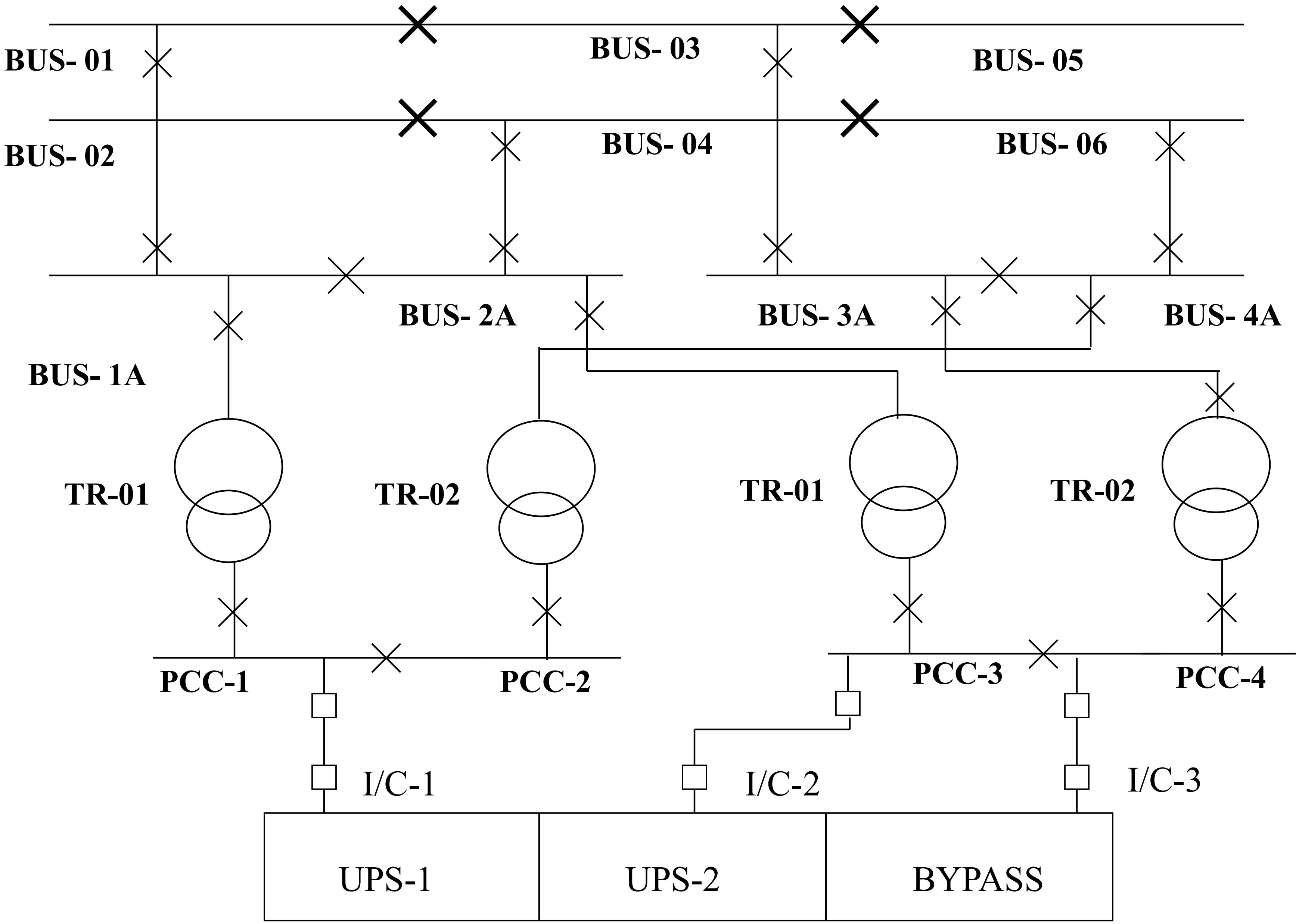
Chapter-7

UNINTERRUPTED POWER SUPPLY SYSTEMS

7B - EXPLANATION TO RECOMMENDATIONS

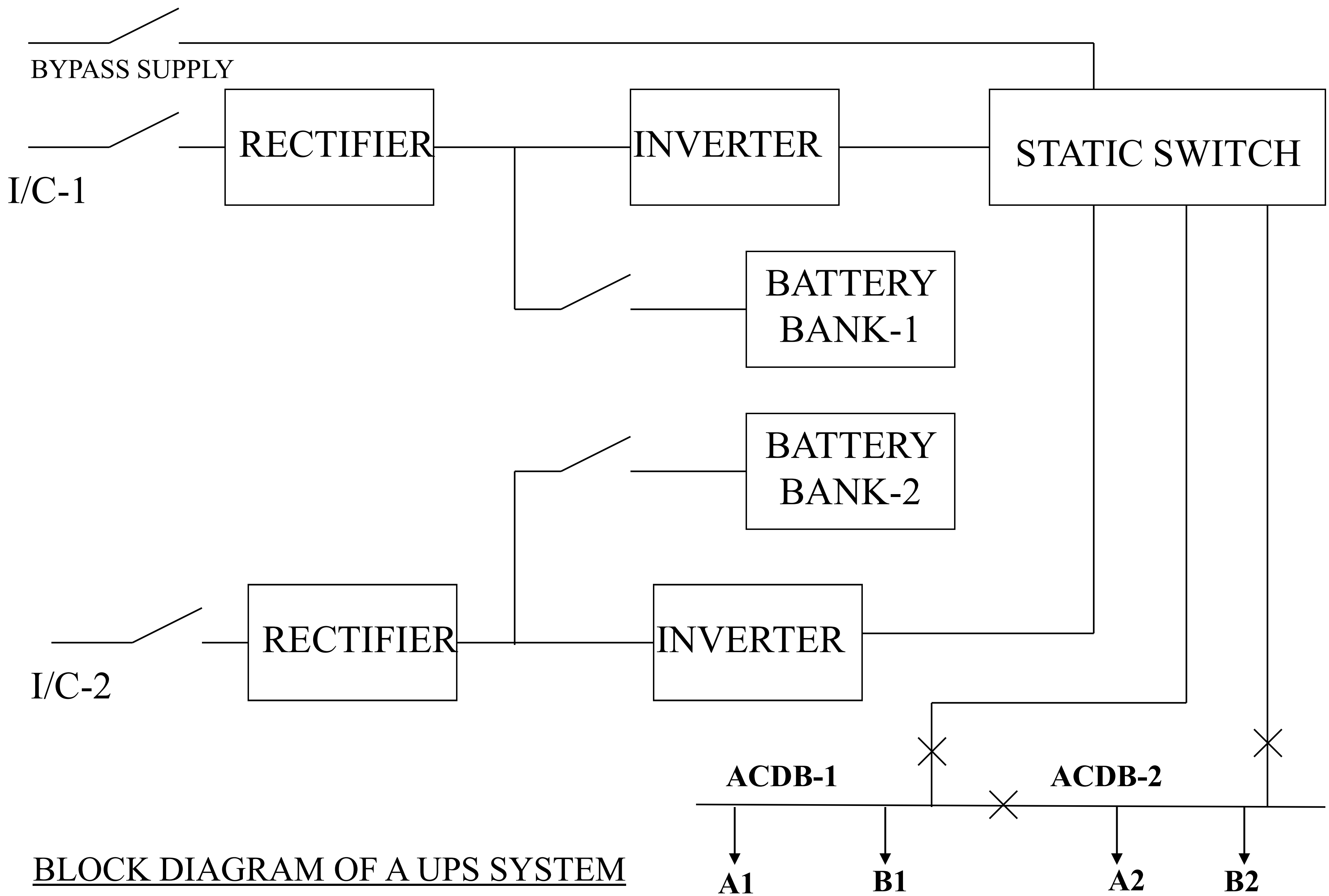
Reference	***EXPLANATION***
7.1	The same shall facilitate the individual UPS shutdown along with the shutdown of each Process Units. Also in case of UPS interruption, the affect shall be limited to a particular process unit.
7.2	The reliability of the incoming power supply sources is to be ensured in order to prevent the simultaneous tripping of both the sources. The power supply sources shall not fall on the same primary Generation / distribution source at 11 kV level. Also it is desired to feed bypass supply from different sub station to ensure the availability of UPS in case of complete loss of supply to a particular substation.
7.4	The separate battery bank for each section of UPS may be provided with the existing systems wherever feasible, in consultation with OEMs. This will facilitate the improved reliability and facilitate timely checking of battery health with out waiting for plant shutdowns.
7.5	Since remote control operation of UPS main supply is not provided therefore technically it is not required to provide incoming supply from the contactor type module. Also inherent problems related to contactor may be avoided e.g. coil burning, contactor dropping during under voltage etc. Hence it is desirable to have MCB / SFU type feeder for UPS mains supply.
7.6	Proper coordination is to be achieved in the UPS supply distribution network to avoid any maloperation. The UPS distribution network is constituted of several type of fault clearing devices e.g. HRC fuse, MCB's, Semi conductor fuse, Glass fuse etc.hence proper care is to be taken while reviewing the system based on the current characteristics of each device. It is also to be ensured that the protection coordination is available for the entire current range of various type of fault clearing devices i.e. for both low and high fault current range.
7.8	UPS systems are provided with fans for venting out the internally generated heat. In case any faults in these fans remain unnoticed for longer durations, the same may be harmful for the health of the UPS components.

7.10	If the auxiliary equipments are fed from UPS supply, any failure of the auxiliary equipment e.g. choke burning / fan burning / short circuit etc. may result in the interruption of UPS output supply.
7.15	Copper cables are preferred over aluminium due to lower resistivity of copper leading to reduced voltage drop.
7.16	Whenever changeover of contactor will happen, the UPS supply to ACDB/loads shall get momentarily interrupted.
7.18	Failure of any one UPS system or ACDB section shall not initiate tripping of process unit or any equipment. It shall be possible to take shutdown & carry out preventive maintenance of any one of the UPS at a time or any one ACDB section in plant running condition without affecting the reliability of the overall UPS system & plant operation.



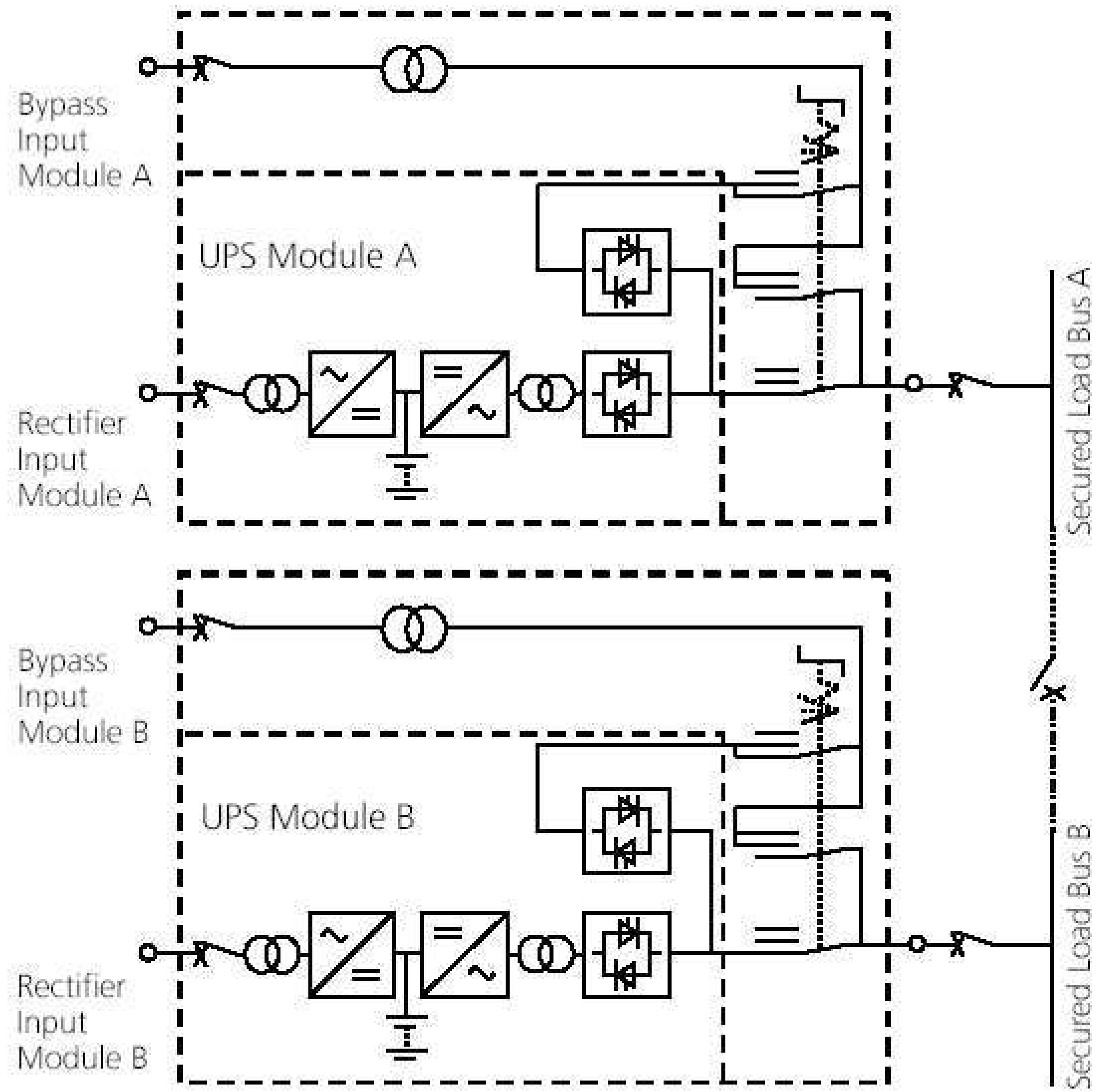
<u>TYPICAL UPS INCOMING SUPPLY ARRANGEMENT</u>

DRG. NO. 7C.1



BLOCK DIAGRAM OF A UPS SYSTEM

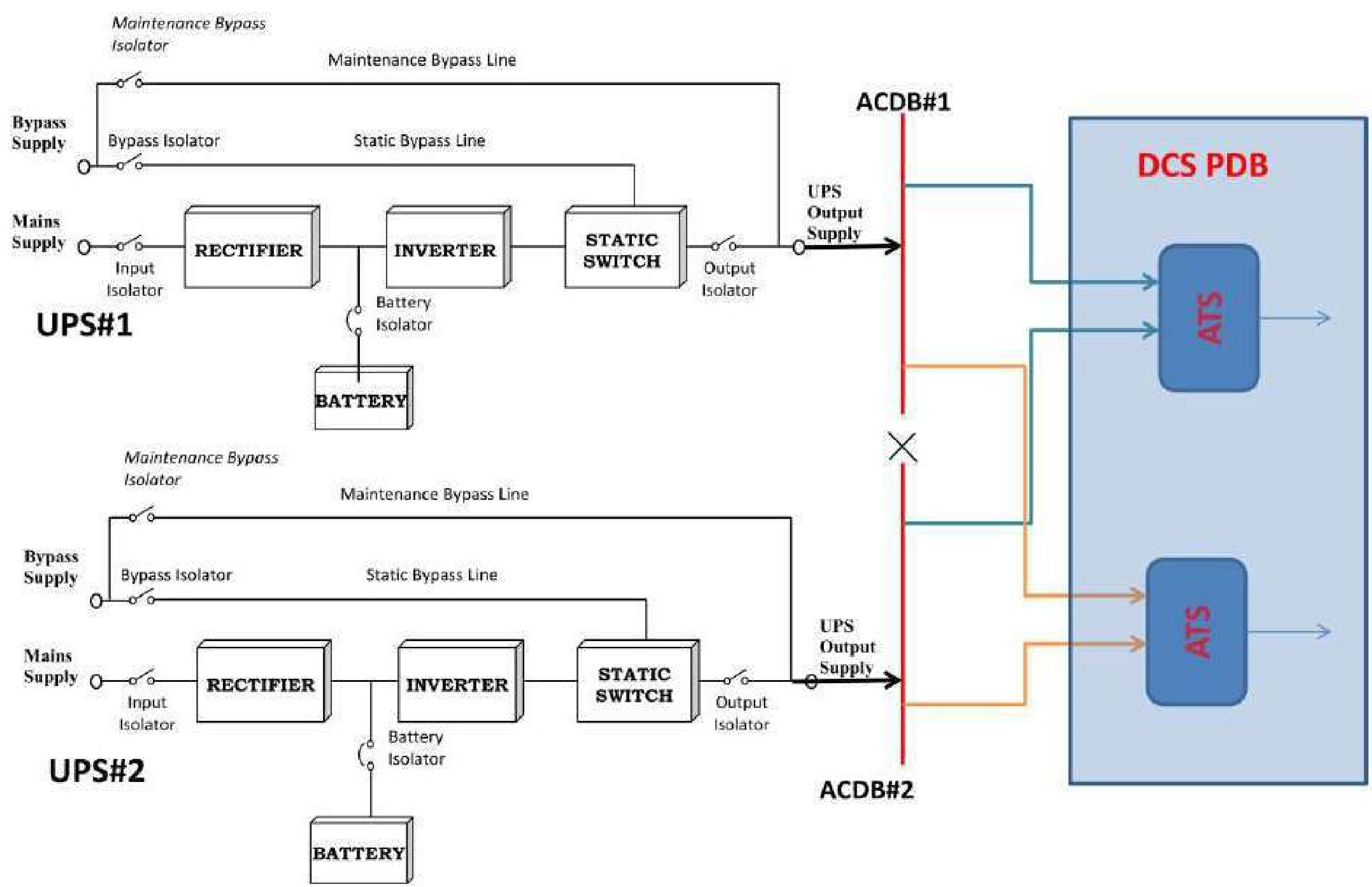
DRG. NO. 7C.2A



BLOCK DIAGRAM OF A UPS SYSTEM

DRG. NO. 7C.2B

Block Diagram of UPS system



DRG. NO. 7C.3

Check List 7E.1

Chapter -7 UPS

Area/ Location:- (to be filled)

Note:- Gaps in the existing system and actions to be taken are to be indicated by ***BOLD ITALICS in RED COLOUR***

S.No.	Recomm. Ref.		**Area/ Sub Station →** **Switch Board No. →** ↓ **Reliability check point**									
1	**7.1**	**New project**	Provision of separate UPS system for group of associated process units.	Available / Not Available								
2	**7.2**		The incoming power supply sources shall not fall on the same primary Generation / distribution source at 11 kV level	OK / Not OK								
3	**7.3**	**New project**	UPS systems are parallel redundant type.	Yes / No								
4	**7.4**	**New project**	In case single UPS is feeding to large no. of units, feasibility of installation of two battery banks may be explored. – New projects	Possible / Not possible								
5	**7.4**		Confirmation regarding healthiness of battery bank based on last discharging.	Healthy / Unhealthy								
6	**7.4**		Date of last discharging to be furnished.	Date								
7	**7.4**		Is the schedule and history record of battery testing available	Available / Not Available								
8	**7.5**		Type of power supply module for input feeders to the UPS	SFU / Contactor								
9	**7.6**		Fuse coordination to be reviewed from ACDB to downstream distribution level	OK / Not OK								
10	**7.7**		Provision of critical UPS alarms at the manned location / control room	Available / Not Available								
11	**7.8**		Internal cooling fans are healthy	Healthy / Unhealthy								
12	**7.8**		Adequate inventory of Internal cooling fans available	Available / Not Available								

S.No.	Recomm. Ref.		Area/ Sub Station → Switch Board No. → ↓ Reliability check point									
13	**7.9**		UPS systems are installed in dust free air conditioned atmosphere.	AC / Non AC								
14	**7.10**		The power supply to auxiliary equipments e.g. tube light, fans, space heater etc. shall be provided form the normal plant supply	Non UPS / UPS								
15	**7.11**	**New project**	Provision of redundent configuration with static switch	Yes/No								
16	**7.12**	**New project**	UPS systems selection shall be based on standard ratings									
17	**7.13**		Replacement of critical components as per OEM guideline	Yes/No								
18	**7.14**		Use of VRLA batteries	Yes/No								
19	**7.15**	**New project**	use of copper cables in UPS distribution	Yes/No								
20	**7.16**		Usage of contactor change over schemes in UPS output supply	Yes/No								
21	**7.17**	**New project**	Electronic cards shall comply ISA-G3 compliant	Yes/No								
22	**7.18**	**New project**	Complete DC redundent system as per Point 6.24	Yes/No								
			REMARKS									

Chapter-8

VARIABLE SPEED DRIVES

The incidences of failure of VSD's, which are associated with the process unit operation, invariably lead to the tripping of the process unit. There are multi-dimensional factors such as ambience, reliability of electronic components / cards used in VSD's, limitation on the length of the power cable, control supply problems which lead to failure of VSDs. In spite of various corrective measures undertaken by the refineries to improve upon the performance of VSD, the incident of failures of VSD still continues. This has been a major concern area in all the refinery units irrespective of the make of VSD.

8 A RECOMMENDATIONS

Following actions are desirable to overcome the problems in **critical VSDs /** Soft Starters which may affect the process unit operations. Detailed explanation to these recommendations marked as (◀) has been enclosed at Section 8B of this chapter.

8.1 In view of reliability getting more concern over the energy conservation (in case when there is single equipment used for a particular service and tripping of which may result in tripping of process unit) use of VSDs shall be avoided . *(New Facilities/ Projects)*

"OR"

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. (New Facilities/ Projects)

"OR"

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. ◀

8.2 Distance between the drive and the motor should be minimum possible and should be within the recommended distance for a particular model by OEM. ◀

8.3 It is recommended to install drive panels in the dust free and air-conditioned environment with humidity control in order to protect the electronic components / PCB's of drives panels from dust & heat.

8.4 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. ***(New Facilities/ Projects)***

8.5 It is desirable to provide Drives with PLC based logic in view of the inherent problems observed in the relay based scheme due to the frequent problems observed with the coils / contacts etc. ***(New Facilities/ Projects)***

8.6 Drives must be provided with "Power Off Ride Through feature" to maintain drive operation during voltage dips. ◀

8.7 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)

8.8 Only reputed make of relays with PTR for similar application shall be used for process interlock tripping. ◀

8.9 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.***

8.10 For the latched type start / stop commands of the drives, It is desirable that 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. To achieve this, an additional holding contactor may be installed in the drive panel depending upon the scheme requirement. ***(instrument interface)***

8.11 The earthing requirement for the VSD's & motor should be strictly adhered as per OEM recommendations.

8.12 It is desirable to have insulated bearing installed in VSD applications for HT motors. ***(New Projects)***

8.13 Only screened type signal cables are desirable in VSD applications. The cables should be properly laid away from power cable to prevent interference. ◀

8.14 Normally drives shall be without ventilating fans. If system demands, provision of ventilation with redundant fans and fan fail alarm may be explored & provided. VFD internal cooling Fans shall be fed from its internal supply only.

8.15 To minimize damage to cards / components from the environmental effects, the Conformal coating of cards used in VSD's is desirable.

8.16 For effective troubleshooting, it is desirable to have trending of VSD parameters & alarm logging through a dedicated PC/ DCS. ◀

8.17 It is desirable to have separate control cable used for different voltage level of control supplies.

8.18 It is desirable that the critical power supply units (Cards) installed inside the drive panel should be redundant. ◀

8.19 Based on the OEM recommendations of life cycle of critical components like capacitors, cooling fans, cards etc. replacement plan shall be made to enable initiate timely procurement action and replacement.

8.20 Redundancy of drive run signal to DCS shall be provided for critical VFD applications. (New Projects)

8.21 **Joints in VFD output cables (VFD to Motor) are to be avoided as far as possible (New Projects/ old cable replacement).** ◀

8.22 **Electronic cards of system like UPS, battery charger, VFD, SCADA, Heater control system shall be ISA-G3 compliant as per Std. S.71.04.(For new projects/New procurements)**

8.23 **Minimum Speed (VFD frequency) limiter settings shall be done in VFDs to avoid over-heating of VFD motor on low speed**

8.24 **VFDs shall be provided with provision of Bypass (DOL) mode wherever possible with motor capacity. (new projects/ New procurements)**

8.25 **For DM water cooled VFDs, proper quality water is to be kept in ready stock for topping up with defined shelf-life to meet any exigency.**

In order to facilitate full implementation of above recommendations by identifying GAPs and preparing action plan, a check list has been developed for reference and is given at Section 8E of this chapter.

Chapter-8

VARIABLE SPEED DRIVES

8B - EXPLANATION TO RECOMMENDATIONS

Reference	Explanation
8.1	It is advisable not to use VSD in the case when there is single equipment used for a particular service and tripping of which may result in tripping of process unit. Steam drives may be used for such cases. It is recommended to have configuration to run two motors with VSD's in parallel, at 50% load on each, for critical applications. Each motor shall be driven by a separate drive so that in the event of interruption of one drive, other shall take the full load thereby preventing the plant interruption. In cases where two separate motors have been considered operating on 50% load, it is to be ensured suitable damper / isolation arrangement exists to prevent reverse rotation of the idle unit. Reverse rotation may lead to the tripping of motor during starting If it is not feasible to use two equipments running in parallel, then the single running equipment must be provided with redundant VSDs, both kept in service simultaneously as hot standby so that the failure on either do not stop the equipment. It is to be ensured that process trip is not operated during the changeover period. However, in such a case provision is to be made to isolate the defective VSD and carry out maintenance without stopping the equipment
8.2	Distance between the drive and motor should be as low as possible in order to prevent capacitive phenomenon due to long cable. The larger lengths of cable may be used by using suitable chokes, but the reliability of the system suffers with the use of additional hardware due to possibility of component failure. Moreover the problem of excessive heating due to installation of choke is another area of concern
8.6	In order to ensure uninterrupted operation of the drives during power system voltage dips or bus coupler changeover phenomenon, drives must be provided with "Power Off Ride Through feature" to maintain drive operation during voltage dips.
8.8	In order to prevent spurious tripping of drives due to maloperation of process relays, only reliable relays e.g. Alstom make VAJ relay etc. should be used for process interlock tripping.

8.13	There have been instances of mal operation of VSD due to interference signal with the adjacent power cables hence it is desirable to use only screened cables to avoid such problems.
8.16	It is recommended to performing trending & alarm logging of the drive through a dedicated PC to facilitate failure analysis. Since it is not possible to carry out logging of all alarms through DCS / PLC hence in case of faults, when the number of alarm generation is very high, if dedicated logging is not carried out then effective fault analysis shall not be possible. A single PC may be used for the purpose of logging of more than one drive. Also it is desirable to provide trending of critical drive parameters in DCS so that in the event of tripping or plant disturbances, drive parameters may be easily compared with the process parameters for troubleshooting purpose without facing the problems related to the time synchronization etc.
8.18	Power supply units are installed in the drive panels to meet the internal power requirement of the drive for various purposes. It has been observed that due to trouble / failure of the power supply unit installed in the VSD, complete units gets tripped and leading to the process unit interruption. It is desirable to install redundant Power supply units (in line with AVR's configuration) to prevent VSD from tripping in the event of failure of single power supply unit.
8.21	IGBT based VFD driven motors and cables are subject to reflected waves (due to impedance mismatch between motor and cable) and unbalanced voltage which is the common-mode voltage source. Common mode voltage gives rise to common mode current. This current flows to earth through all the system components leading to heating. Joints being a weak link of the cable system are usually the first to fail during over-voltage or heating. Hence long cable length and cable joints are to be avoided in VFD driven motors.

Check List 8E.1

Chapter -8 Variable Speed Drives

Area/ Location:- (to be filled)

Note:- Gaps in the existing system and actions to be taken are to be indicated by ***BOLD ITALICS in RED COLOUR***

S.No.	Recomm. Ref.		Area/ Sub Station →								
			Switch Board No. →								
			↓ Reliability check point								
1	**8.1**	**New project**	Run two motors with VSD's in parallel, at 50% load on each, for critical applications	Yes / No							
2	**8.1**	**New project**	Ensure that suitable damper / isolation arrangement exists between the parallel running drives to prevent reverse rotation during idle condition	Yes / No							
3	**8.1**		In case of single critical drive operation, VSD's to be provided with hot standby facility mode	Available / Not Available							
4	**8.2**		Is the length of the power cable from drive to motor is suitable as per vendor reccomandations.	Yes / No							
5	**8.3**		Confirm drive panels are installed in the dust free and air-conditioned environment with humidity control	Yes / No							
6	**8.4**		IP42 enclosure for Fan Cooled drives	Yes / No							
7	**8.4**		IP52 enclosure for self ventilated drives	Yes / No							
8	**8.4**		If panel enclosure ingress protection is not as mentioned above, whether adequate protections atken to prevent the ingress of dust.								
9	**8.5**		Use of PLC based logic in drives instead of relays/ contactors logic.	Yes / No							
10	**8.6**		Drives are provided with "Power Off Ride Through feature" / Re -accelaration feature to maintain operation during voltage dips	Yes / No							

S.No.	Recomm. Ref.		Area/ Sub Station → / Switch Board No. → / ↓ Reliability check point									
11	**8.7**		The auxiliary / Control supply of the drive panel shall be provided from reliable source e.g. UPS / DC	UPS / DC / Plant Supply								
12	**8.8**		Reliable make of relays used for process interlock	Yes / No								
13	**8.9**		Both Drive run & Drive fault signal given to PLC for monitoring the status of the drives.	Yes / No								
14	**8.9**		Drive run signal may be used in logic along with the process parameters	Yes / No								
15	**8.9**		Analog signals are provided through screened cable	Yes / No								
16	**8.10**		latching of Start / stop command, if required, has been done in the drive panel	Yes / No								
17	**8.11**		Earthing of Drive panel & Motor done as per OEM reccomandations.	Yes / No								
18	**8.12**		Insulated Bearing provided in HT motors with VSD applications.	Yes / No								
19	**8.13**		Screened type signal cables provided for VSD applications	Yes / No								
20	**8.14**		Provision of redundant ventilating fans in case of forced ventilating system, if feasible.	Yes / No								
21	**8.15**		The cards used in VSDs are provided with conformal coating	Yes / No								
22	**8.16**		Continuous trending of VSD critical parameters & alarm logging is available	Yes / No								
23	**8.17**		Separate control cables used for different voltage level of control supplies	Yes / No								
24	**8.18**		Redundant power supply units available for drives	Yes / No								
25	**8.19**		Replacement of critical components as per OEM guideline	Yes / No								
26	**8.20**	**New project**	Redundancy of drive run signal to DCS shall be provided for critical VFD applications	Yes / No								
27	**8.21**	**New project**	Joints in VFD cables	Yes / No								
28	**8.22**	**New project**	Electronic cards shall comply ISA-G3 compliant	Yes / No								

S.No.	Recomm. Ref.		Area/ Sub Station →								
			Switch Board No. → ↓ Reliability check point								
29	**8.23**		Provision of minimum speed setting in VFD	Yes / No							
30	**8.24**	**New project**	Bypass (DOL) option in VFD	Yes / No							
31	**8.25**		Availability of proper qualit of water for DM water colled VFDs	Yes / No							
			REMARKS								

Chapter-9

LOAD SHEDDING SCHEME *(Power And Steam)*

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.

9 A ***RECOMMENDATIONS***

Following are some of the key aspects for ensuring effectiveness of the load shedding scheme. Detailed explanation to these recommendations marked as (◀) has been enclosed at Section 9B of this chapter.

9.1 ***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 smallest capacity machine.*** ◀

9.2 ***Load shedding scheme shall be adequate to take care of the simultaneous tripping of the largest power and steam generation sets.*** ◀

9.3 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. ◀

9.4 ***System Disturbances / transient phenomenon shall not cause nuisance tripping of the scheme.*** ◀

9.5 ***The Power Load Shedding Schemes shall actuate "Automatically" and shall always be kept in "Auto" mode. It is also desirable to have "Automatic" Steam load shedding scheme.*** ◀

9.6 Additional provision of Manual load shedding form TPS control room may additionally be provided for non-critical load / units as a backup for manual intervention.

9.7 ***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.*** ◀

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

9.9 ***In view of the change in criticality of process units, increase in plant load, augmentation of power source, the load shedding scheme is required to be upgraded / reviewed after any expansion in the refinery.***

9.10 ***It is desirable that command from two redundant outputs / relays shall be used to trip a particular step of load shedding scheme.***

9.11 ***Scheme shall be provided with reliable & redundant control supply so that scheme shall remain operational in case of failure of one control supply.***

9.12 ***Critical loads like UPS, battery chargers and critical process equipments should not be covered under the load shedding scheme to the extent possible.***

9.13 **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. For new projects, HT PTs shall be provided with tertiary winding loaded with suitable resistance.**
- **It is recommended to block Frequency Based load shedding during under voltage conditions.**

9.14 ***It is recommended to install self-reset contact and hand reset flag type relays for actuating load shedding to achieve faster normalization of the system.***

9.15 ***All alarm / annunciation/ indications related to healthiness and operation of load shedding should be made available in the power plant control room or nearly manned sub station.***

9.16 ***Alarm / Indication for load shedding operation may also be provided in the Process control room for immediate information.***

9.17 Adequacy of steam and power load shedding shall be reviewed by multi disciplinary group on annual basis. The approved updated copy of the load shedding priority table to be made available in TPS / CGP.

In order to facilitate full implementation of above recommendations by identifying GAPs and preparing action plan, a check list has been developed for reference and is given at Section 9E of this chapter.

Chapter-9

Load Shedding Scheme

9B - <u>EXPLANATION TO RECOMMENDATIONS</u>

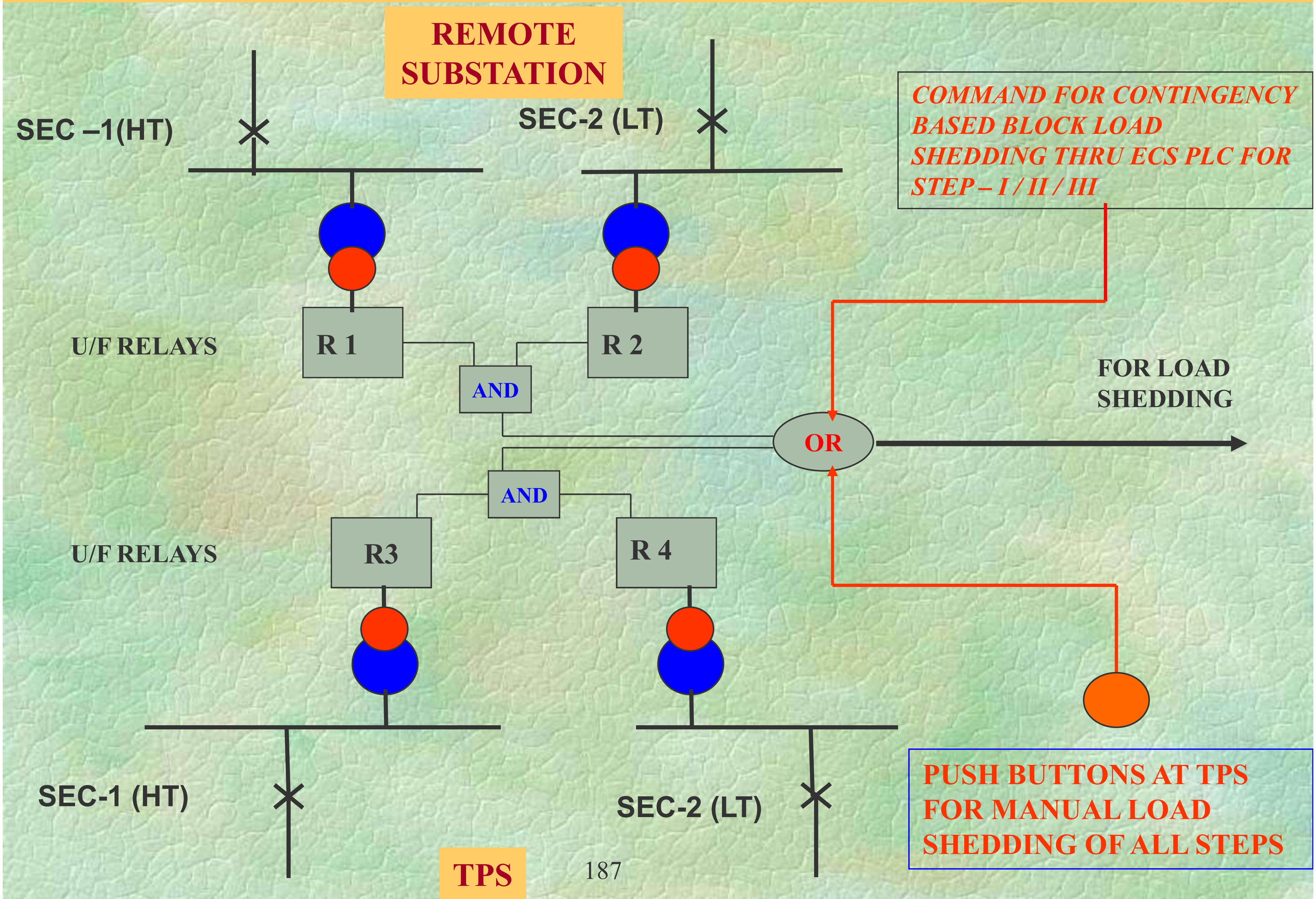
Reference	Explanation
9.1	The adequacy of load shedding shall be such that in the event of cascaded tripping of multiple generating units, at least the smallest capacity unit should continuously be available to avoid the total power failure and enable quick normalization of the process units. Hence load shedding scheme shall be adequate to take care the single smallest running machine always remain operation during system disturbances. (System Maximum Load - Total Load considered in Load Shedding Scheme) < Capacity of Smallest installed machine
9.2	In the event of simultaneous tripping of the largest power & steam generation sets, the load shedding adequacy to ensure stable operation of the balance plant with other generating units.
9.3	Load shedding scheme shall be designed in such a way so that it should be able to take care any unforeseen condition arising due to deviation in machine behavior on account of climatic impact or due to any sudden problem in machine components. • Phenomenon of variation in machine performance (GT loading etc) due to climatic impact i.e. actual permissible loading to be considered in the scheme at any instant of time. • Sudden problems encountered in the machine behavior during emergency conditions causing loading constraints i.e. governor response problem, IGV or flow divider response problem, jamming of any steam valve etc. shall not lead to mal-operation of the load shedding scheme.
9.4	Load shedding should not maloperate at the time of system disturbance. Since the load shedding scheme is largely dependant on the relays and transducers. These relays / transducers are used for the sensing of system power or frequency using voltage input. Any voltage dip shall cause hunting in these parameters due to fluctuation in voltage sensed through Bus PT's. In view of the above, relays / transducers getting fed through voltage signal shall show erratic values. Hence load shedding scheme shall be engineered so that it should not maloperate during system disturbances.

9.5	The power load shedding scheme will be designed / reengineered in such a manner that it should actuate automatically whenever required by identifying the gap between load demand and generation.
9.7	It is necessary to have an under frequency based load shedding scheme in back up of other type of load shedding scheme as any loss of generating source or any unforeseen problems related to loading of any individual machine during emergency condition is always followed by decay in frequency. Normally the logic of ECS or PLC based schemes are based on the master relay contacts of the generators therefore the scheme will actuate only after the tripping of machine however the climatic or machine response related problems can be “Automatically” taken care only by a frequency based backup scheme whereas logic based scheme shall have to be operated manually.
9.10	In order to take care of hardware / wiring problems, scheme shall be provided with sufficient redundancy for the actuation of each step.
9.13	In case of under frequency based load shedding schemes, phenomenon occurring due to lightly loaded PT’s on account of Ferromagnetism may lead to mal-operation of the scheme. In such schemes, following actions are recommended: - • Loading of PT’s through external resistances to be done which comes into picture only during under voltage conditions say V<95%. The value of resistances shall be suitable to load the PT’s to around 50% of the rated VA. Proper rating wire wound variable stabilising resistances (Alstom make) are suitable to serve the short time requirement. • Taking series contact of two relays, one relay installed in HT system & other relay installed in LT system. Load shedding shall take place on the actuation of both the relays. The voltage input for the relay installed in LT system may be taken directly from the LT Bus without using any PT with necessary isolations. The selection of HT & LT Bus for providing relays should be done in such a manner so that both should not fall on the same primary / secondary distribution system.
9.13	The frequency signal to the under frequency relay is provided through PTs (Voltage signal). In the event of under voltage dips due to system faults, there are possibilities of the erratic behavior. It is, therefore, recommended to block Frequency Based load shedding during under voltage condition (V < 80%) to avoid spurious tripping due to erratic transient reading of transducers / associated frequency relays.

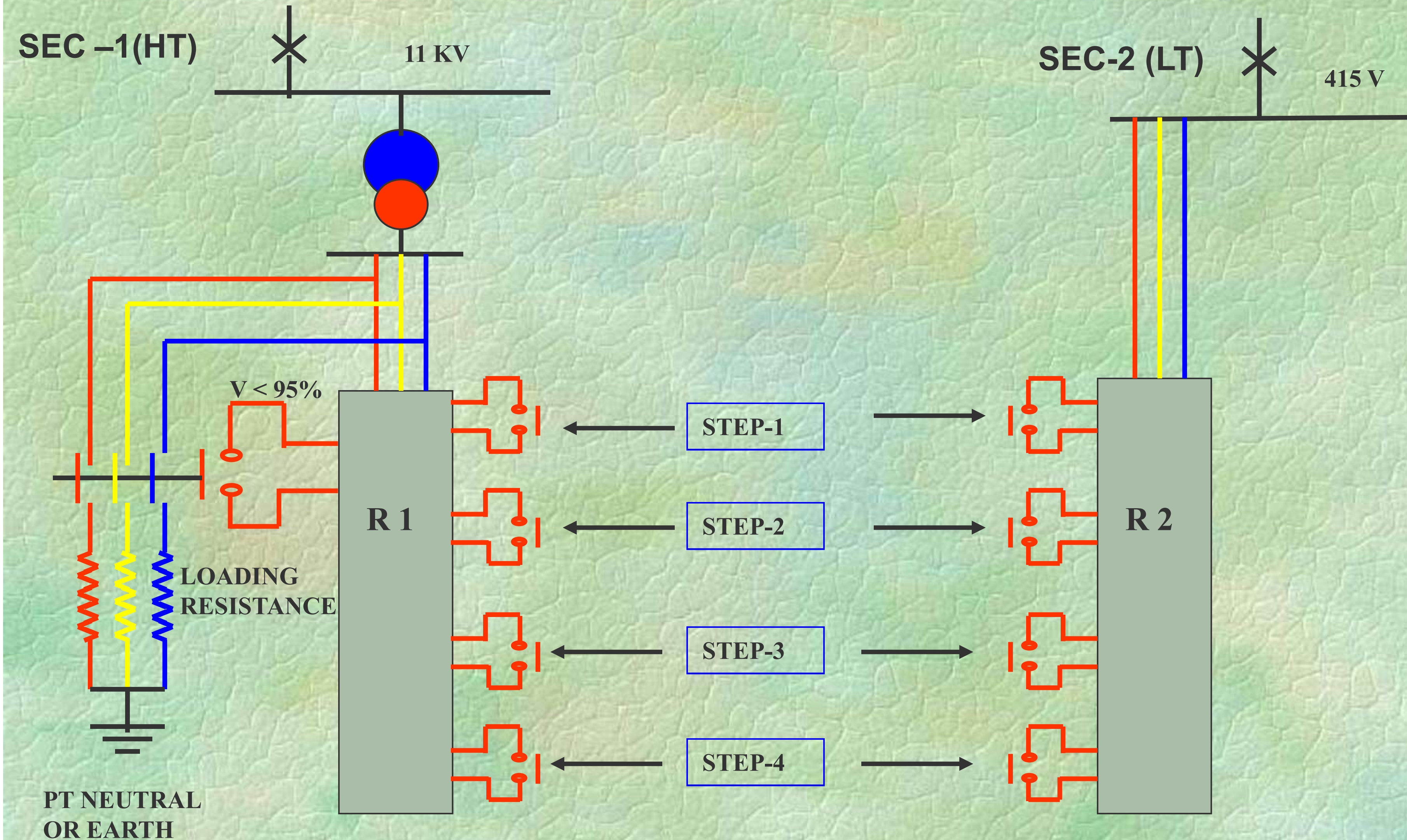
POWER LOAD SHEDDING SCHEME
OF
MATHURA REFINERY

ANNEXURE 9D.1

LOGIC DIAGRAM FOR U/F LOAD SHEDDING SCHEME

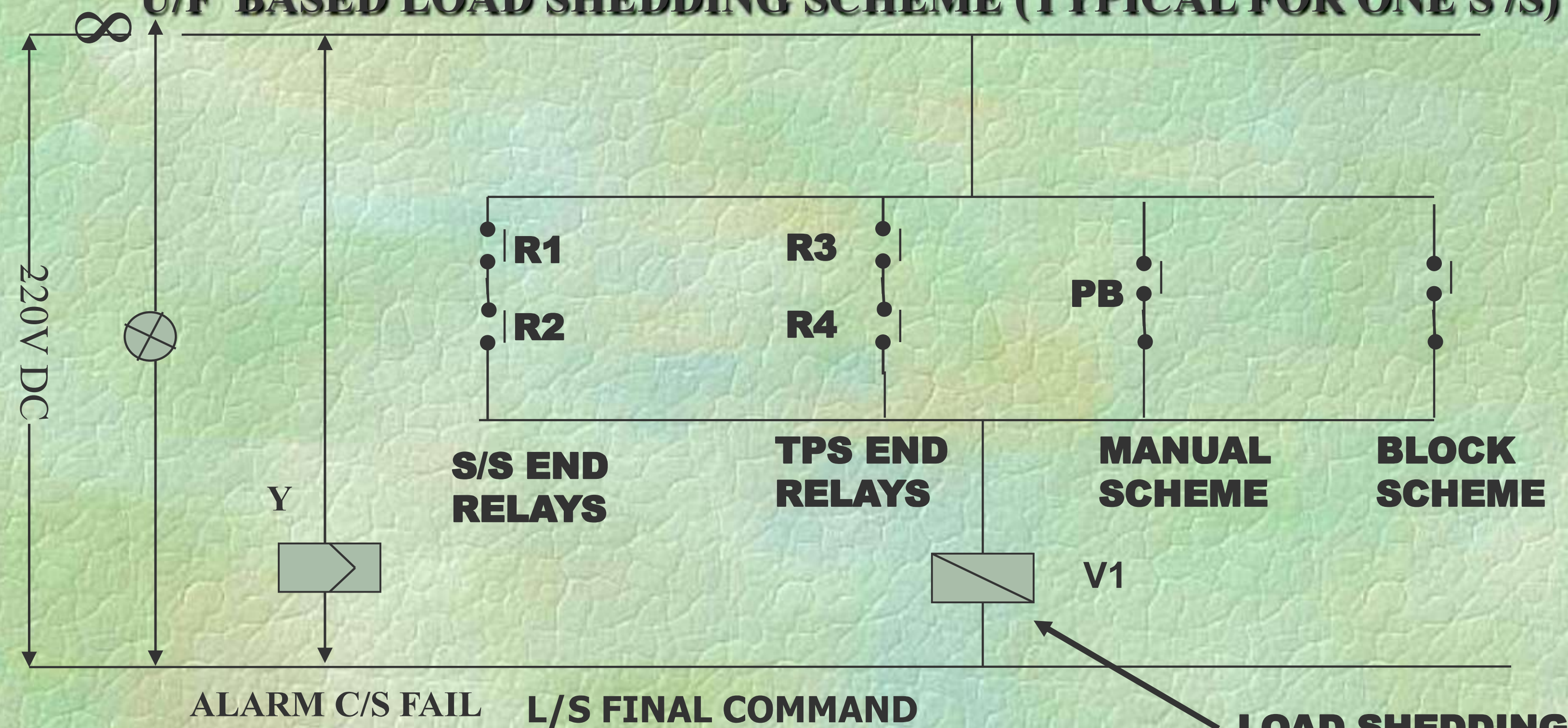


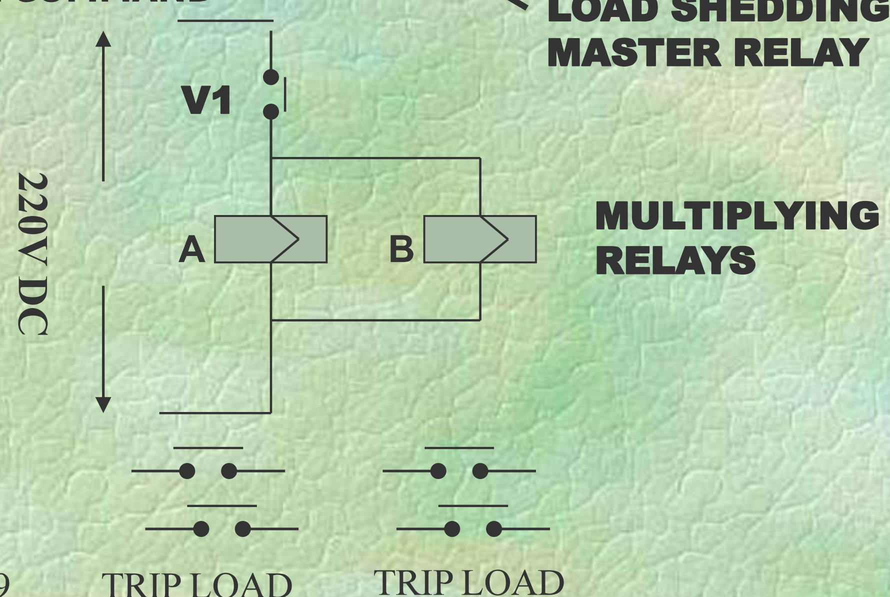
TYPICAL CONNECTION DIG.



- Contacts of Relay R1 & R2 have been used in series for each step
- Two Such Configurations provided for each step with final output command in parallel

U/F BASED LOAD SHEDDING SCHEME (TYPICAL FOR ONE S /S)





R1,R2, – U/f Relays S/S end

R3,R4, - U/f Relays TPS end

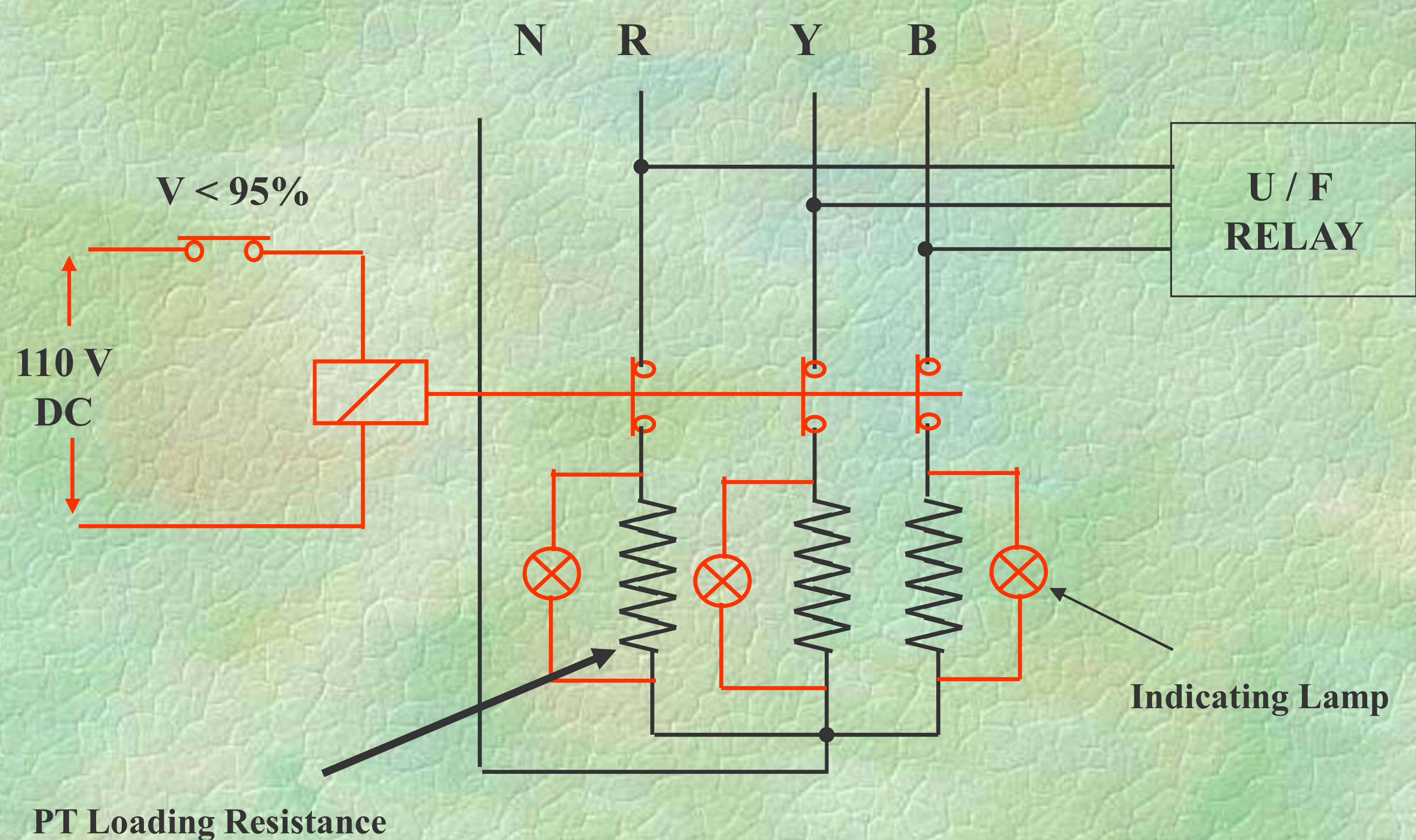
V1 – Tripping Relays

A, B,,Y – Auxiliary Relays

PB – Manual Push Button

BL - Block Load Shedding from ECS

TYPICAL CONNECTION DIG.



UNDER FREQ. BASED POWER LOAD SHEDDING SCHEME

NEW STEP	DESCRIPTION	FREQ.	TIME	LOAD SHEDDING STEP	LOAD SHEDDING CUMMLATIVE	BALANCE LOAD BASE = 42 MW
1	TOWNSHIP/ KOYALA / ADM / S/S -13 / S/S-1 / MJPL / MTPL / IOTL / S/S-2 & S/S - 8 (PART)	49.5	0.5	5.3	5.3	36.7
2	OMS-1 / TANKAGE / PRU / CW PUMP (PCT)	49.25	0.5	2.65	7.95	34.05
3	7-KM-3 (OHCU) / 6-KM-5 (HGU)	49	0.5	2.3	10.25	31.75
4	AVU + CW PUMP (PCT) + S/S-10 + S/S-11 (PART)	48.75	0.5	4.8	15.05	26.95
5	NSU + BBU (S/S-8)	48.5	0.5	1.5	16.55	25.45
6	DHDS	48.3	0.5	1.5	18.05	23.95
7	OHCU	48.1	0.5	8.8	26.85	15.15
8	CRU	47.9	0.7	2.6	29.45	12.55
9	HGU	47.7	0.7	2.7	32.15	9.85
10	FCCU + SWSU + SRU + ARU + VBU	47.6	0.7	2.9	35.05	6.95

■ Completed ■ To be done

Prioritisation of units furnished by TS.

LOADING RESISTANCE CALCULATIOS

PT RATED VA		**200**	VA	
PT SEC. VOLTAGE (Phase)	**V**	63.51	VOLTS	
REQUIRED LOADING OF PT	**VA**	50	%	
I.e.		100	VA	
LOADING CURRENT (VA / V)	**I**	1.57	AMPS	
LOADING RESISTANCE (V / I)		40.34	OHMS	
	SAY	40	OHMS	
VOLTAGE FOR LOADING OF PT		95	%	(UNDER VOLTAGE)

ALL THE THREE SINGLE PHASE PT'S SHALL BE LOADED BY SEPATRATE RESISTANCES

LOADING HAS BEEN CONSIDERED BASED ON RATED VOLTAGE THEREFORE BURDEN MAY REDUCE DURING VOLTAGE DIP AS PER THE VOLTAGE DROP

BLOCK LOAD SHEDDING SCHEME

SALIENT FEATURES

- AT EACH S/S, TWO U/F RELAYS HAVE BEEN CONSIDERED FOR THE OPERATION OF EACH STEP. CONTACTS OF BOTH U/F RELAYS HAVE BEEN TAKEN IN SERIES i.e. 2 OUT OF 2 OPERATION.
- INPUT PT SUPPLY OF ONE RELAY HAS BEEN TAKEN FROM HT SECTION & OTHER HAS BEEN TAKEN FROM LT SECTION. AS FAR AS POSSIBLE, LT SUPPLY TO RELAY HAS BEEN TAKEN DIRECTLY FROM THE PCC i.e. 415 V
- LOADING RESISTANCES HAVE BEEN PROVIDED FOR PT LOADING. RESISTANCES COMES INTO SERVICE AT $V < 95\%$ TO LOAD PT'S AROUND 50% OF RATED BURDEN.
- RELAYS OF DIFFERENT MAKE HAS BEEN INSTALLED TO PROVIDE SERIES CONTACTS FOR EACH STEP AS FAR AS POSSIBLE TO PREVENT MAL OPERATION OF SCHEME DURING SYSTEM TRANSIENTS.
- UNDER VOLTAGE BLOCKING OF U/F SCHEME HAS BEEN PROVIDED AT VOLTAGE LESS THAN 70%.
- DC / UPS CONTROL SUPPLY HAS BEEN USED FOR THE SCHEME

Check List 9E.1

Chapter -9 LOAD SHEDDING SCHEME

Area/ Location:- (to be filled)

Note:- Gaps in the existing system and actions to be taken are to be indicated by ***BOLD ITALICS in RED COLOUR***

S.No.	Recomm. Ref.	Description										
1	**9.1**	Amount of left out load from load shedding scheme is less than the capacity of smallest capacity machine	Yes / No									
2	**9.2**	Load shedding scheme is adequate to take care of the simultaneous tripping of the largest power and steam generation sets	Yes / No									
3	**9.3**	Phenomenon of variation in machine performance (GT loading etc) due to climatic impact has been taken care	Yes / No									
4	**9.3**	Problems encountered in the machine behavior causing loading constraints i.e. governor problems etc. taken care	Yes / No									
5	**9.4**	Transient phenomenon (Voltage dips) shall not cause nuisance tripping of the scheme	Yes / No									
6	**9.5**	Automatic Load Shedding Schemes for Power & Steam) provided	Yes / No									
7	**9.5**	Load Shedding is normally kept in "Auto" mode by default.	Yes / No									
8	**9.6**	Provision Manual load shedding at TPS control room exists	Yes / No									
9	**9.7**	Logic / ECS based schemes are provided with back up Under frequency-based load shedding scheme	Yes / No									
10	**9.8**	Load-shedding scheme is having predefined order for the various steps	Yes / No									
11	**9.9**	The load shedding scheme is upgraded / reviewed after any expansion in the refinery.	Yes / No									
12	**9.10**	Command from two separate outputs / relays is used to trip a particular step of load shedding scheme	Yes / No									

S.No.	Recomm. Ref.	Description									
13	**9.11**	Scheme provided with reliable & redundant control supply	Yes / No								
14	**9.12**	Critical loads like UPS, battery chargers and critical process equipments are not covered under the load shedding scheme	Yes / No								
15	**9.13**	HT system PT loading feature through external resistances provided in case of under frequency based load-shedding schemes.	Yes / No								
16	**9.13**	Blocking of Frequency Based load shedding provided during under voltage	Yes / No								
17	**9.13**	Self-reset contact and hand reset flag type relays provided for actuacting load shedding in unmanned substations	Yes / No								
18	**9.14**	All alarm / annunciation/ indications related to healthiness and operation of load shedding scheme available at manned location/ TPS Control room	Yes / No								
19	**9.15**	Alarm of load shedding operated available in the Process control room	Yes / No								
		REMARKS									

CHAPTER 10

OPERATIONAL/ MAINTENANCE PRACTICES, DOCUMENTATION AND FAILURE ANALYSIS

The reliability of the P&U system, at large, gets addressed by implementing the improvement measures as discussed in previous sections, which are mainly focused on strengthening the system hardware/ configuring. Apart form above, the health and correct operation of the plant and equipment are essential for reliability of the system so that failures of the plant and equipment can be minimized. Some of the identified failure which result out the inadequate health and condition of the equipment / system component are:

- Flashovers in panels and breakers
- Failure of end terminations
- Flashovers in motor terminals
- Cable failures

All electrical equipment are subject to operating stress and as a result of interaction of the stresses with various components in the equipment, there is a progressive degradation, weakening and loosening ultimately leading to failure. At times external factors (Dust, Humidity, Rodent) also lead to failures. For improving the reliability and availability of the equipment, it is therefore important to operate the plant and equipment with utmost care as per the prescribed procedures, maintain, them in perfect health and monitor their health periodically to take proactive corrective measure. All these actions to be necessarily backed up by a system of retro inspection by properly analyzing the failures and reasons leading to consequential system trouble on account of these failures

As an integrated approach for building up reliability in P&U systems (Plants and equipment) by addressing all these issues, following area have been considered which need to be strengthened.

- Operating practices
- Analyzing failures and learning from mistakes
- Availability of Plant related documents, records and drawings.
- Maintenance and monitoring of system / equipment.

(A) <u>OPERATING PRACTICES</u>

Operations of power generation and distribution system are critical for ensuring reliability of the power & utility system. Operational checks should ensure effective monitoring of performance of equipment by identifying critical parameters, monitoring through alarms, physical verification and elimination of human errors. The salient recommended operational practices for improving the reliability of P&U system are as below:

(i) System to be developed for periodical review of pre-identified critical parameters by deep involvement and concern of plant operating personnel in order to bring about the focus on the performance of plant.

(ii) Structured system for review of alarms, which are prevailing for more than 24 hrs and review of corrective actions by Plant incharge.

(iii) Structured system for ensuring healthiness of performance of critical auxiliaries (their auto changeovers, re-acceleration schemes, like auto mode selection) and that of load shedding scheme at least weekly basis.

(iv) Ensuring daily recording of abnormal state of relays and other protection related indications flags of critical equipment/ feeders and reporting to shift in charge - responsibility to lie with Shift-in-charge.

(v) To ensure writing of log sheet of critical parameters or taking print out of the log from DCS/ECS for review and record.

(vi) Isolation/ shutdown procedure of each HT switchgear should be available in the switchgear room to avoid any inadvertent incidents.

(vii) Prior to giving line clearance of HT systems, it is desirable to use HT line tester prior to discharge of equipment.

(viii) Equipment tagging on the panel to be ensured in the front as well as panel rear. Layout of bus section at bus couplers/tie breakers to be ensured for preventing any inadvertent handling in charged panel.

(ix) Availability of instructions on the panel w.r.t. resetting of alarms/fault indications and emergency handling in AVR/ DAVR/UPS.

(x) Color-coding of differential CTs in HT system to be done for awareness during primary injection testing.

ALARM SYSTEM

Any sub-station, either conventional or automated type shall be designed to generate intelligent information to support the performance of substation, its connected equipment and diagnosis of the equipment. Following are the guidelines for a effective monitoring & alarm system:

(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) A structured system shall be in place for communication to the concerned person/ department and ensuring that the necessary corrective measures are carried out at the earliest.

(d) Alarms related to status, control, protection shall be available in a primary/ secondary sub-station and the alarms shall be suitably grouped. For unmanned sub-stations, all critical alarms shall be extended to a manned location and common alarm from each group shall be made available at the manned location.

(e) Remote signaling (group summary) of alarm conditions shall be classified into the categories:

- Emergency trip
- Urgent alarm
- Information

(f) In an electrical system, the various systems to be covered for monitoring & alarm are as under.

- HT primary distribution system.
- HT secondary distribution system.
- LT PCC/ MCC system.
- UPS
- DC system.
- Process related equipment like VFD and Electric heater.
- Large HT motors and its auxiliary system.
- Generation & distribution transformers.

(g) Detailed annunciation schedule shall be based on but not limited to the following:

a) HV Switchgear

- Breaker-wise fault trip alarm
- Status of Auto-changeover scheme
- Trip circuit status for breakers
- Differential relay operation alarm
- Transformer trouble alarm
- DC supply failure alarm (Bus wise)
- PT secondary MCB trip alarm for all line and but PTs.

b) MV Switchgear

- Incomer/ bus coupler fault trip alarm
- Status of Auto-changeover scheme
- Bus-wise group fault trip alarm for outgoing feeder breakers
- D.C. supply failure alarm (Bus-wise)
- PT secondary MCB trip alarm for all line & bus PTs.

c) Operating status/ fault conditions for UPS system.

d) Operating status/ fault conditions for DC supply system.

e) Operating status/ fault condition for DG sets.

(B) <u>FAILURE ANALYSIS</u>

The present failure analysis practices needs to be re-strengthened for more focused analysis of the interruption/ failures based on consequential alalysis in addition to analyzing the the root cause backed up by a structured monitoring system for implementation of the recommendations. The existing failure analysis reports put focus on the incident and its prevention but does not bring out, in general, the "System Deficiency" i.e. the underlying causes which has caused consequence losses from the incident.

a) The failure analysis should be carried out by a dedicated FA Task force involving both Operation & Maintenance Review and monitoring & liquidation of the suggested corrective measures to be periodically done by concerned HOD.

b) The focus of the failure analysis shall be on:

- Failure initiator.
- Failure contributor.

- Identifying the system requirements for taking care the consequences of the fault.
- Underlying causes of the failure i.e. root cause failure.
- Identifying areas for potential design improvement.
- System of monitoring of implementation of the recommendations in a time bound manner.

c) HOD to ensure that the failure analysis of all major incidents (TPF/ PPF) should be completed within one week of the incident and findings along with action plan (with responsibility and target) to be submitted to M&I.

d) M&I after review of the analysis to circulate the same to other units within 15 days and seek for action plan from other units, if similar deficiency also persists elsewhere.

e) System should be put in place for sharing the failure within working groups of refinery and with other units – learning from failures.

(C) SYSTEMS/ PROCEDURES / DOCUMENTATIONS

Some of the suggested improvements in the documentation and accessibility of manuals, procedures and drawings are:

a) System to be put in place to ensure timely updating of all the Operation and maintenance manuals. Designating the standard place of availability of these manuals. If possible, these manuals should be available on one for ready reference by all the users.

b) System should be put in place for maintaining the index (with revision status) and availability of the updated drawings. It is also to be ensured that all the as- built drawings of the new units are available.

c) The preventive maintenance shall also ensure potential causes of equipment failure like load changes or additions, circuit alterations, improperly set or improperly selected protective devices and changing voltage conditions.

d) All the modifications / corrections / new schemes should be implemented only after adhering to a structured Management of Change (MOC). It is desirable that all such modifications / additions should be viewed and okayed by a designated group of experts from operation and maintenance, for operational reliability and safety before it is approved by HOD for implementaion.

e) A register of distribution system "Fault Levels" including calculations, should be maintained and updated in the light of any modification.

f) For each plant, a dossier containing all relevant data for equipment should be compiled. It is to be updated and readily accessible. Dossiers should include manufacturer's handbooks, general arrangement drawings, single line and schematic drawings and CCE certification when applicable. Furthermore, for each plant a record should be maintained of the calculations and settings applied to associated protective relay systems.

g) For each circuit and/ or component part, test and inspection programmes, which include procedures outlining the extent and frequency, should be prepared. In preparing procedures, account should be taken of the guidance given in this document, history records, local environment and severity of duty.

h) Procedures need to stress the requirement for the "Safety Rules" and "Permit to Work" systems to be applied before any work is undertaken on electrical equipment.

i) A file or other suitable "permanent" record should be established for all equipment / circuits to be regularly tested/ inspected. The system should contain a "permanent" operational history including details of faults, repairs, modifications and the results of tests and inspections carried out.

j) The scope of the annual electrical audit shall also include audit of the preventive & predictive maintenance compliance and effectiveness. The objective of the audit shall ensure the following:

- To monitor the implementation of test and inspection programmes and ensure management is advised of any departures from the agreed inspection requirements/ schedules for the plant.
- To ensure deficiencies are acted upon and that serious problems are notified to management and operating authorities.
- To ensure recurring deficiencies are highlighted for redesign or upgrading considerations.

k) A schedule for application of appropriate monitoring techniques may be incorporated into the inspection and maintenance activity to reduce the requirements for unnecessary shutdown or invasive work. Specific methods, which are relevant to the operation of electrical equipment, include thermography for identifying the condition of critical electrical connections (e.g. bus bar connections, end terminations), current signature analysis for examining motor stator/ rotor condition, online partial discharge test for assessing the healthiness of motor/ switchgear.

l) Unit shutdown manual to include electrical job list along with a checklist for each equipment.

m) Compliance of schedule preventive maintenance of electrical equipment to be ensured. It is desirable to have a system of generation of MIS reports on compliance considering that maintenance of all critical equipment/ systems like protection system, earthing, switchgear and bus bar are ensured.

n) All testing found during the course of preventive maintenance should have their results recorded in such a manner to establish trends that can be used in assessing the health of the equipment like insulation of motor, predicting battery life etc.

(D) MAINTENANCE PRACTICES

The existing maintenance system based on the preventive maintenance schedule should be strictly followed for ensuring reliability of the components of the electrical system. The existing PM are successful to a large extent in maintain the good health of equipment and upkeep of system.. However, with the increase in the number of electrical equipment, it's complexity, sensitivity, state-of-the-art technology and increased availability requirement of equipment, the existing practices needs to be strengthened. The desirable strategy of routine maintenance & monitoring shall be about detecting potential abnormalities and reducing or eliminating the consequences of failure in addition to scheduled maintenance.

In addition to maintaining the health of the equipment efforts are also required to be strengthened to counter some of the fault initiators such as **Heating/Tracking/ corona/Rodent** by addressing them adequately in the maintenance plan **.** Following are some of the measures, which need to be undertaken for building up reliable and effective maintenance plan

a) Heating/ Thermal damage

Temperature even slightly above its designed levels for prolonged periods can significantly shorten the electrical life of insulating materials and lower mechanical strength. Localized heating can sometimes occur but are unnoticed because the overall temperature of the surrounding is not raised appreciably. Loose bolted connection of a bus bar joint or void spares (dead air) in a taped assembly are such examples. Some critical recommendations to minimize the heating effects in the electrical system are as under:

i. Ensuring healthiness of jaw contacts of circuit breakers specially for incomer/high rating feeders through visual examination for condition of springs, heating marks etc. Monitoring of temperature during maximum load condition using non-contact thermo-meter and infrared windows. This exercise of maximum loading on one incomer can be carried out just prior to unit shutdown.

ii. Measurement of contact resistance using digital micro ohmmeter during shutdown after ensuring isolation of the complete switchboard.

iii. Providing non-hygroscopic phase barriers should 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 should also be provided with HT paint. In case taping/sleeves are used, it is to be ensured that the insulation layer found is homogenous without any air gaps.

iv. During shutdown all bus bar joints of switchboard and bus ducts to be torqued as per OEM recommendations in the equipment manual including contact resistance measurement.

v. 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.

vi. All power cables are properly supported by clamps at the panel entry to avoid tension on cable lugs. This can cause heating and subsequent flashover. This is to be specially ensured in HT cables as in most installation glanding is not being done in view of heat shrink type end termination.

vii. Structured half yearly schedule of online temperature monitoring using infrared camera/ thermometer through infrared windows. For enabling measurement without opening of the rear panel covers modification for providing opening in the rear panel covers for installation of infrared windows may be required for enabling thermography.

viii. Use of temperature indicating crayons/markers/labels can be explored on experimental basis on joints, terminations etc. for monitoring of abnormal heating. This can be utilized during routine preventive maintenance where the color of the temperature indicating crayon/label can be monitored.

b) Tracking/ Corona

Damage caused by electrical distress will normally be evident on the surface of insulating members in the form of corona erosion or markings or tracking paths. The following are specific areas in which electrical distress is more likely to occur and should be given special attention:

i. Boundaries between two adjoining insulators
ii. Boundaries between an insulating member and the grounded metal structure.
iii. Taped or compounded splices or junctions.
iv. Bridging paths across insulating surfaces, either phase-to-phase or phase-to-ground.
v. Hidden surfaces such as the adjacent edges between the upper and lower member of split type bus supports or the edges or a slot through which a bus bar protrudes.
vi. Edges of insulation surrounding mounting hardware either grounded to the metal structure or floating within the insulating member.
vii. Effectiveness of sub-station pressurization need to be ensured for protection against dust, condensation etc. on insulators to avoid the phenomena of tracking/ corona. Structured system of maintenance of the pressurized system to be in place.
viii. The air inlet duct of the pressurization system to be suitably located to avoid entry of rainwater into the pressurization system.
ix. Cleaning of sub-stations to be done through vacuum cleaners/ mopping instead of traditional sweeping method to prevent entry of dust in the panels. In addition, all sub-station windows and doors to be properly sealed to prevent entry of dust in the sub-station.
x. Visual examination of CTs/ PTs to be ensured during preventive maintenance/ shutdown for symptoms of electrical tracking, arching and change in color due to time & temperature effect.
xi. Online detection of partial discharge in switchgears. The equipment used is based on the principle of ultrasonic air borne detection. However, the same needs to be established after demonstration.

c) Rodent entry

i. In addition to the structured rodent control system, application or rodent control chemicals in panels during shutdown to be done in line with MR.

ii. Sealing of all openings in panels, panel covers, close inspection of gaskets & replacement, if required, to be ensured. During shutdown all explosion vents also to be examined for existence of gaps. Annual electrical audit to ensure compliance of the same. During shutdowns and prior to start up, proper sealing to be ensured through light test method.

d) Motor failures

From the failure experiences, flashover in motors is attributed to failure of end terminations, heating due to loose connection, winding insulation failures. Recommended practices for minimizing motor failures are as under:

i. Monthly monitoring of body/ terminal box temperatures using a non-contact thermometer suitable for hazardous areas. By trending the temperatures, pre-mature failures related to high temperature can be avoided.

ii. Proper end termination of cables specially in HT motors by ensuring proper grade of kit, proper size of cable end box to facilitate heat shrink type end termination, cable termination with proper lugs & fasteners, condition of terminal studs etc.

iii. Monitoring & trend analysis of insulation resistance & dielectric discharge test for monitoring the insulation health. Diagnostic insulation tester having the above facility can be used.

iv. Close inspection of motor internal leads during overhauling for brittleness especially for old motors accordingly replacement action to be initiated.

v. Practice of monitoring of current in each core of cable in LT motors of high rating and having two runs of cables. Un equal distribution of current indicates loose contact due to un-equal contact resistance.

vi. Carrying out on line motor current signature analysis through external agencies for critical HT/ high rating LT motors on yearly basis for detecting rotor problems, vibrations due to mechanical/ electrical problems. This activity to be coordinated with mechanical condition monitoring group.

vii. Capital overhauling of motors to be ensured as per OEM recommendation. Considering the run length of the units is about 3-4 years, and the shutdown duration being limited, out sourcing of overhauling can be examined in line with MR.

e) Transformer Failures

Although the numbers of transformer failures are very low/ negligible, some of the maintenance practices need to be ensured, as they are critical to the electrical system.

i. Online inspection of distribution transformers w.r.t. temperature, oil level, oil leakage etc to be carried out on a regular structured basis preferably monthly and the inspection data to be available in a checklist form. Monitoring of generator transformers, tie transformers to be done on daily basis. Offline testing & inspection to be ensured during unit shutdown.

ii. Special attention is to be given to cable/bus duct termination, termination of transformer leads inside the bushing chamber, condition of bushing, provision of new gaskets for signs of leakage etc.

iii. Proper sealing of the bushing chamber to be ensured in addition to the terminal box as flash over in the bushing chamber have taken place due to moisture entry.

iv. For seismic prone locations, suitability of bucholz relay w,r,t seismic requirement to be ensured.

v. Annual BDV testing of transformer oil & DGA testing, furan analysis preferably after every three years to be carried out and liquidation plan as per the test results to be ensured.

vi. Capital overhauling, core lifting through expert external agency/ OEM to be preferably carried out once in 10-15 years based on the loading & test results.

vii. Oil conservator level to be checked & to be ensured for 60% to 70% of the tank before onset of peak winter. (To be completed by 1st December every year).

f) Cables

Failure due to cables have been observed mainly due to joint/ end termination failures and failures due to improper laying. The recommended practices for ensuring healthiness of cables are as under:

i. Proper grade of end terminations and cable jointing kits to be ensured. For example, in 6.6 KV (UE) systems, 11KV (E) Grade cable jointing kit to be used. Improper grade can result in pre-mature failures.

ii. It is desirable to have a permanent cable trenches in the Refinery to avoid mechanical damage and facilitate maintenance.

iii. Preventive maintenance of cables shall include visual inspection and electrical testing. Visual inspection shall include end terminations for signs of tracking, cable connections, physical damage, excessive tension, corroded cable supports, grounding connections etc. The same to be done during PM of motors/ feeders & during process unit shutdown maintenance.

iv. Insulation resistance testing to be carried out annually during preventive maintenance of motor/ cable with proper documentation for enabling analysis & assessment.

v. Leakage current monitoring of HT cables based on working voltage to be carried out during planned unit shutdown. Based on the trend, residual life assessment testing like tan delta, partial discharge measurement etc to be carried out through expert external agencies like CPRI, ERDA, ABB LENZOHM and accordingly corrective actions like joint replacement, cable replacement etc to be taken.

vi. Check & verify armour earthing in single core power cable's for earthing at one end only to avoid flow of induced circulating current through armour.

g) **Excitation System Failures**

Failures of the generator excitation system has been mainly experienced due to failures due to AVR and rotating diode assembly of the brush less excitation system. Following are the recommended practices for ensuring reliability.

i. Annual performance evaluation test of DVR through OEM. The guidelines of M/s BHEL, already circulated by M&I, are enclosed for reference.

ii. AVR/ DVR test points to be checked periodically and measured keeping load and power factor constant and a record should be kept. This would help in identifying card/component failure and improve operational reliability.

iii. The following general inspection and schedule may be followed for this type of exciters:

1. Monitoring of each fuse for any failure using a stroboscope daily (preferably once in each shift)

2. During minor inspection (approx. after 20, 000 hours of operation), checking of IR value of field winding, armature winding along with rotor winding (short the diodes), PMG winding and quardrature axis coils

3. During medium and major inspections (when exciter is separated from generator rotor), the following may be checked:

- Checking of IR value of field winding, armature winding (short the diodes), PMG winding and quarrature axis coils (QA coils),
- Checking of ohmic resistance of field winding, QA coils and PMG winding
- Checking of tightness of all fasteners
- Checking of journal surfaces
- Checking of condition of the bearing, babbit surface
- Checking and ensuring the locking of PMG yoke to the exciter yoke to the frame with grub screws.

4. In order to ensure proper operation of the AVR during the running condition, it is recommended to ensure that limiter settings are made as per generator capability curves (as provided by OEM) with all the limiters in service. These settings should be verified during the on line dynamic testing of the machine in line with the recommended procedure of the OEM.

5. There have been instances that DVAR was not able to cater to system requirements during HT fault/ HT motor starting due to inaccurate setting of the field current limiter (filed forcing mode). It is, therefore, desirable to ensure the proper settings of field forcing limiter in AVR for boosting the excitation during voltage dip condition upto 10 secs.

6. To prevent accidental reset of DAVR modules due to human error from the reset button provided on the cards/ modules, suitable printed inscription/ sticker should be provided on such critical reset push buttons indicating " Do Not reset-Connected to trip."
7. In order to ensure proper dynamic response of AVR / DAVR, it is desirable to perform step test (dynamic tests) of the AVR as per the instructions / procedure given by the OEM during machine M&I.

h) Cards/ Components Failures in VFD/UPS

Failure of cards/ power electronic devices has been experienced specially in VFDs. The following are some of the critical aspects, which need to ensured for minimizing card failures.

i. Dust free and air conditioned environment to be provided for VFD's of critical services especially for high rating / high voltage VFD's.

ii. For critical VFD's like ID/FD fan of Hydrogen unit, critical parameters like RPM, 4-20 ma signal, DC voltage, trouble alarm and any other critical diagnostic signals may be provided in DCS for performance monitoring. Physical monitoring for abnormal heating, noise, alarms, current, cooling fan abnormalities etc to be done on regular basis i.e. daily for critical UPS and weekly for non critical services. The facility of monitoring the internal parameters of VFD on a PC are available which can be utilized for diagnostics.

iii. It is desirable to carry out preventive maintenance & performance testing through OEM as per the recommendation of the OEM during planned unit shutdown.

iv. Replacement of critical components like cooling fan, cards etc. based on the life cycle/ OEM recommendations/ failure experiences to be ensured during planned preventive maintenance.

v. Proper failure analysis of the cards needs to be ensured by continuous follow up with the OEM to arrive at the root cause and to avoid repetitive failures.

vi. Inspection & monitoring of ventilation air filters, operation of cooling fans, alarms, parameters to be done on regular basis preferably weekly.

vii. Performance evaluation testing & maintenance through OEM of UPS shall be carried out during planned unit shutdown preferably yearly. Based on OEM recommendations and on the life cycle of components like cooling fan, capacitors, cards etc, suitable spares shall be procured for replacement during planned unit shutdown.

viii. For battery chargers inspection & monitoring shall be similar to UPS. Status of boost charging to be monitored as mal operation of auto boost selection can result in continuous boost charge and damage of the battery bank.

ix. Periodic monitoring of ripple content of battery charger to be done (shall be within 1%-2% of the output voltage) as high ripple content due to filter capacitor failure etc can damage the battery bank.

x. Instructions for critical alarms/ operations/ cautions to be available near the equipment for ready reference.

xi. Battery capacity discharge test to be ensured during planned unit shutdown. As per OEM recommendation preferably annually. During the test, battery connections to be monitored for abnormal heating using thermography.

i) Battery Bank Failure

Failures of UPS systems due to battery bank failures have taken place specially in VRLA type batteries. Some of the desirable maintenance practices for avoiding failures in battery bank are as under.

i. VRLA type batteries shall not be used in UPS systems, as it is prone to open circuit. Two such failures have occurred at HR, which have led to interruption of the process units.

ii. Tests should be performed and results recorded to establish trends that can be used in predicting battery life. In addition to the standard measurement of voltage, specific gravity and temperature, quarterly battery impedance measurement also to be carried out for monitoring the internal condition of the battery. It is desirable to use measuring equipment, which has the capability of memory storage and downloading data to a computer.

iii. A capacity test should be performed within the first 2 years of installation and every 3 to 5 years thereafter depending on the load reliability requirements and environmental conditions of the installation. The frequency of battery tests should be increased to yearly when the battery reaches 85 per cent of its service life or when it shows signs of deterioration. Once the capacity drops by 20 per cent in extended operation, however, the cell should be replaced.

j) Power Harmonics

Annual monitoring of harmonics in the power system due to the increased numbers of UPS/ VFDs being installed. The current & voltage harmonic distortion limits should be followed as per IEEE 519.

(E) <u>SHUTDOWN RELATED ISSUES</u>

a) A standard shutdown job list for electrical jobs should be prepared unit wise and made available to zonal engineers and updated periodically. This should also form the part of the Refinery shutdown manual.

b) Maintenance checklist for implementation during shutdown to be developed for each sub-station and shall be a part of the shutdown manual. Prior to start up, a system of structured verification to be ensured.

c) Replacement of critical components like cooling fan, cards etc. based on the life cycle/ OEM recommendations/ failure experiences to be ensured during planned preventive maintenance.

d) During refinery turnaround, in view of the large volume of jobs and limited availability of manpower, the following activities may be outsourced, if required.

- Earth resistance measurement
- Temporary connection, lightning etc.
- Battery bank maintenance
- Relay & panel testing
- Overhauling of motors

10. Monitoring & Documentation

10.1 A structured system of Temperature measurement of electrical equipment Motors & Switchgear panels (fortnightly), Battery bank (monthly) by zonal engineers as a walk through inspection to be carried out. For hazardous areas, suitable infrared temperature measurement meter to be used. A review of the same with regard to abnormalities observed to be discussed in the weekly planning meeting.

10.2 Sub-station monitoring based on the enclosed check list (Annexure-V) to be carried out on weekly basis to enable detection of potential abnormalities and timely corrective action. A review of critical findings to be discussed in the weekly planning meeting.

10.3 A structured second level of checking of jobs carried out during shutdown to be developed and suitable documentation (checklist) shall be made available for verification.

10.4 Skill development: A structured weekly skill development programme for executives/ non-executives to be conducted on specific topics of electrical testing, protection systems, relays etc. on continuous basis at site. The objective is to bring each and every employee to a desired level for enhanced confidence.

10.5 Spare gaskets for transformers from OEM to be kept available for ready use during maintenance. Cut gaskets are not to be used.

10.6 During maintenance of transformers the radiator valves to be checked for correct operation. Periodic temperature measurement of the radiator to be carried out for ensuring uniform heat dissipation and detection of potential abnormalities.

10.7 Base line data generation (a) for new equipments at the time of commissioning and (b) for old equipment where base line testing data not yet generated shall be established based on the last one/two years results.

10.8 A structured system of trending of test results for critical systems / equipment to be developed for periodic review.

10.9 OEM recommendations for maintenance of critical HT motors to be adhered to and assistance from OEM may be sought for supervision during major overhaul / repair. Auxiliary equipment like excitation system, lube oil motors, cooling water motors etc. also to be checked / tested along with the main motor.

10.10 Procedure of maintenance / testing activities shall be prepared for each critical equipment in line with OEM guidelines. Sample preventive maintenance checklist for switchgears is enclosed as Annexure-VIII(a) & VIII(b) for reference. Switchgear failure initiating / contributing causes are enclosed as Annexure-IX for reference during root cause analysis.

10.11 Relay setting chart, protection co-ordination graph to be made available for each sub-station. Testing section shall develop a structured system of annual review and the latest revision shall be readily available in the respective sub-station (sample format enclosed as Annexure-III(a), III(b), III(c).

10.12 Availability of drawings to be ensured in each substation for ready reference.

10.13 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-IV.

10.14 An in-house audit of the reliability recommendations shall be carried out on annual basis and a cross refinery audit shall be carried out once in two years.

10.15 Skill levels for bearing fitment & motor assembling should be continuously developed through skill development programs and on the job monitoring.

10.16 Replacement of terminal box gaskets shall be carried out once in three years during preventive maintenance of the motor. Suitable sealant to be applied on the gas kit during regular maintenance to avoid ingress of water / moisture.

10.17 Breather connection in transformer terminal box and bus ducts shall be done from the bottom only instead of side and top of the terminal box or bus duct. ◀

10.18 Second level of checking/verification is to be carried out after completion of testing activities during shutdown/major job to ensure correct relay settings without any leftover bypass arrangement if done during testing.

10.19 **For commissioning of new equipment & new hook-ups, standard check list shall be prepared and followed.**

New Points Annexure-V
Ref. Pt.10.2 of Ch.10

Sub-Station Checklist

	Substation No. :	Status
	HT Board	
1	**Alarm monitoring system is in line (Systems provided with SCADA etc.)**	
2	**Alarm monitoring system (manual) wherever automated systems are not available**	
3	**All bus differential protection are in line**	
4	**Indications related with bus differential protection scheme healthiness are in line and no abnormalities indicated**	
5	**All cable differential protection are in line, if not, the reasons thereof and whether approval obtained**	
6	**Indications related with cable differential protection scheme healthiness are in line and no abnormalities indicated**	
7	**All hi set protections other than primary differential protection are in line**	
8	**Whether two DC sources are available to the switchboard**	
9	**Indication through trip supervision relay available in all feeders and any abnormalities found**	
10	**Sticker of latest relay settings available on the panel**	
11	**Any relay healthiness LED not glowing.**	
12	**Availability of monitoring of relay healthiness LED in place**	
13	**All under frequency load shedding relays are healthy**	
14	**Load shedding is in line and if not, what is the reason**	
15	**Load shedding control supply (DC) healthy**	
16	**All Bus coupler in AUTO mode**	
17	**All relays flag reset**	
18	**All indicating lamps healthy**	
19	**All HT inter tripping are in line**	
	• **Bus diff**	
	• **Cable diff**	
	• **Master trip**	
20	**All transformer inter tripping are in line**	
21	**Ammeters of outgoing feeders working**	
22	**Voltmeters on bus and line working**	
23	**All energy meters are in working condition**	
24	**VFD AC system are working**	
25	**No ground fault in DC System**	
26	**Stickers of last test done available on relays**	
27	**Stickers of last auto changeover checking available on panel**	

	Substation No. :	Status
28	**Bus PT Healthy & secondary side MCB is ON**	
29	**Line PT Healthy & secondary side MCB is ON**	
30	**Whether all temperatures are normal and records of temperature measurements available**	
31	**Rodent control measures effective & being followed**	
32	**Whether pressurization system is in line & reason**	
33	**Absence of dust and humidity in the panel / sub-station**	
34	**System for cleaning of sub-stations in place & being followed**	
35	**System for cleaning of sub-station pressurization filters in place and being followed**	
36	**All sub-station doors & windows properly sealed**	