“SYSTEM PROTECTION SCHEMES (SPS)” IMPLEMENTED IN ASSAM TRANSMISSION SYSTEM (AEGCL)

REVISION NO: 5

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O/o The Chief General Manager, State Load Despatch Center (SLDC),
KAHILIPARA, GUWAHATI-19
Phone: 95312 06854, 6003327418 (Control Room/Operations)
Email: cgm.sldc@aegcl.co.in, sldcassam@aegcl.co.in, Website: www.assamsldc.in
ASSAM ELECTRICITY GRID CORPORATION LIMITED

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INTRODUCTION

The Electrical Power System has grown from a small stand-alone system to a large integrated and complex combination of generating units and transmission networks covering larger geographical areas beyond national boundaries. The stability and reliability of the transmission system is of prime importance as it plays the most important role in supply of power to consumers through vital link between the generation stations and distribution systems.

For stability of the grid, the load and generation balance is to be maintained at every instant of time. As the transmission system is prone to disturbances (faults), it is of utmost importance to minimize the losses (discomfort of customers, power supply failure to critical facilities and economic losses) and restore the system at the earliest. As a precautionary measure and to mitigate the possibilities of wide area disturbances/blackouts, periodic analysis of the transmission system is carried out and "System Protection Schemes or SPS" are designed. The SPS has proved to an important tool when utilized in the transmission grid during rare contingencies. The SPS is often employed as "Secondary Protection Functions". The Primary Protection Functions (used in relays) are used to protect against the actual grid disturbances, whereas SPS helps to maintain the stability and reliability of the transmission system post the actual fault scenario.

SYSTEM PROTECTION SCHEME

SPS is defined as a "protection scheme that is designed to detect a particular system condition which may cause unusual stress to the power system and therefore, take a predetermined action to counteract the observed condition in a controlled manner". During contingency, SPS can be used as a tool for maintaining overall satisfactory operation of the power system. SPS can be installed to maintain frequency deviation during post contingency which is referred as Frequency Control SPS or preventing the system from voltage collapse or overloading of thermal limit and it is referred to as Network Control SPS

In certain cases, SPSs' can be designed for the detection of system condition which results in overloading of a transmission line leading to voltage collapse and instability. To counteract against such scenarios, it may require disconnection of single or multiple lines, generator trippings, increased HVDC power transfer capacity, premeditated load shedding or other planned actions. SPS initiates corrective actions in mitigating the consequences of abnormal conditions without involving the isolation of faulted elements (Isolation of the faulty element is carried out by primary protection functions). SPS is therefore a protection employed to the capability of the power system instead of specific equipment.

WHY AND HOW IS SPS IMPLEMENTED IN AEGCL

WHY?

I. To maintain Load-Generation Balance.
II. To prevent large scale blackouts.
III. To increase the reliability and stability of the transmission system

HOW?

I. STAGE 1: Based on field studies and simulation studies, the need of an SPS is either proposed by the Regional Load Despatch Centre (NERLDC), Regional Power Committee (NERPC) or by AEGCL (T&C and SLDC)
II. STAGE 2: The preliminary logic and plan of action are discussed and formulated in the PCC and OCC Meetings (Held by NERPC). The final logic is designed and laboratory simulation tests are carried out by AEGCL to ensure the correctness of the logics. The final logics are then forwarded to NERLC and NERPC for verification
III. STAGE 3: Upon successful verification and approval of the same, the logic is then implemented at field level. (SPS is implemented via Relay Soft Logics, Protection Functions, Communication signals via PLCC or OPGW), hardware contact multiplier circuits and auxiliary relays. The SPS is also integrated in the "Disturbance Recorder System" of the IEDs to analyze the event (post SPS operation)

The SPS logics are periodically revisited (with respect to the changing dynamics of the transmission system). If any changes are administered in the logic, the approval of the same is taken from the Regional Power Committee.

REGULATORY REQUIREMENT

As per Clause 5.2 (O) of IEGC

All Users, STU/SLDC, CTU/RLDC and NLDC shall also facilitate identification, installation and commissioning of System Protection Schemes (SPS) (including inter-tripping and run-back) in the power system to operate the transmission system closer to their limits and to protect against situations such as voltage collapse and cascade tripping, tripping of important corridors/flow-gates etc. Such schemes would be finalized by the concerned RPC forum and shall always be kept in service. If any SPS is to be taken out of service, permission of RLDC shall be obtained indicating reason and duration of anticipated outage from service.

As per Clause 4.1 of planning criteria

After suffering single contingency (N-1), grid is still vulnerable to experience secondary contingency, though less probable (N-1-1), wherein some equipment may be loaded upto their emergency limits

To bring the system parameters back within their normal limits, load shedding/re-scheduling of generation may have to be applied either manually or through automatic System Protection Schemes (SPS). Such measures shall generally be applied within one and half hours after the disturbance.

As per Clause 3.5 (f) of IEGC

Suitable System Protection Scheme may be planned by NLDC/RLDC in consultation with CEA, CTU, RPC and the Regional Entities, either for enhancing transfer capability or to take care of contingencies beyond that indicated as mentioned in Clause a (i)

Clause a (i)

As general rule, the ISTS shall be capable of withstanding and be secured against the following contingency outages

I. Without necessitating load shedding or re-scheduling of generating during Steady State Operation
II. Outage of a 132kV D/C line or Outage of a 220kV D/C line
III. Outage of a 400kV S/C line or Outage of a single Interconnecting Transformer or Outage of one pole of HVDC Bi-pole line or one pole of HVDC back-to-back station or Outage of 765kV S/C line

MONITORING THE HEALTHINESS OF THE SPS

DEFINITION OF SPS MIS-OPERATION

I. Failure to Operate: Any Failure of a SPS to perform its intended function within the designed time when system conditions intended to trigger the SPS
II. Failure to Arm: Any failure of a SPS to automatically arm itself for system conditions that are intended to result in the SPS being automatically armed
III. Unnecessary Operation: Any operation of a SPS that occurs without the occurrence of the intended system trigger condition(s)
IV. Unnecessary Arming: Any automatic arming of a SPS that occurs without the occurrence of the intended arming system condition(s) and
V. Failure to Reset: Any failure of a SPS to automatically reset following return of normal system conditions if that is the system design intent

OBJECTIVES

I. Reporting of all SPS Mis-operations
II. Analysis of all SPS Mis-operations and/or
III. Mitigation of all SPS Mis-operations

REQUIREMENT

1. System Operational Personnel and System Protection Personnel of the Transmission Licensee and Generator Company shall analyze all SPS operations. System Operational Personnel and System Protection Personnel shall report and review all SPS operations to RPCs/RLDCs/NLDC to identify apparent Mis-operations within 24 hours.

   System Protection Personnel shall analyze all operations of SPS within seven working days for correctness to characterize whether a Mis-operation has occurred that may not have been identified by them.

2. Transmission Licensee and Generator Company shall perform the following actions for each Mis-operation of the SPS. If SPS actions that appear to be entirely reasonable and correct at the time of occurrence and associated system

performance is fully compliant with IEGC/CEA Standards the following requirements shall not be applicable. If the Transmission Licensee or Generator Company later finds the SPS operation to be incorrect through their analysis, the following requirements become applicable at the time the Transmission Licensee or Generator Company identifies the Mis-operation

If there is an SPS Mis-operation, the Transmission Licensee and Generator Company shall repair and place back in service within 24 hours of the SPS that mis-operated. If this cannot be done, then

- Transmission Licensee or Generator Company shall report to respective SLDC/RLDC
- SLDC/RLDC/NLDC shall give instructions to concerned utilities to operate the facilities within permissible limits
- Transmission Licensee and Generation Company shall perform the instructions of SLDC/RLDC/NLDC as soon as they receive and report back to respective SLDC/RLDC/NLDC for the implementation of the same

3. Transmission Licensee and Generation Company shall submit Mis-operation incident reports to NLDC/RLDCs/RPCs within seven working days for the following:
    - Identification of Mis-operation of a SPS
    - Completion of repair or the replacement of SPS that mis-opearted
4. SPS shall be reviewed at least 1 (once) in a year or whenever there is any change/modification in network

SYSTEM PROTECTION SCHEMES IMPLEMENTED IN ASSAM TRANSMISSION GRID

The summary of the System Protection Schemes (SPS) for both intra/inter regional transmission networks implemented by AEGCL are detailed below:

TABLE 1: STATUS OF SPS IN AEGCL

REGION	TOTAL NO. OF SPS IN AEGCL	NO. OF SPS IN SERVICE	NO. OF SCHEMES YET TO BE OPERATIONALIZED *
ASSAM	9	8	1

SPS no IX- SPS BTPS ICT yet to be operationalized.

SUMMARY OF THE IMPLEMENTED SPS

I. **SPS SALAKATI:** When the current flow in either of the 220kV Salakati – Salakati (PG) circuits I & II crosses 600A, a signal would be sent from Salakati to Agia which would trip the circuit breakers of 220kV Boko and 220kV Mirza feeder at 220kV Agia GSS (**Note: The 220kV Salakati – Salakati (PG) lines I & II have been upgraded with HTLS conductors. The SPS is kept inactive at present)**

II. **SPS RANGIA:** Upon loss of 220kV Salakati – Rangia Ckt I & II, the following feeders are tripped to prevent overloading of 132kV Motonga line (international line) and blackout of Rangia Grid. 132kV Nalbari, 132kV Barnagar, 132kV Sipajhar, 132kV Tangla, 132kV Kamalpur ckt I & II. 132kV Rangia-Motonga TL keeps feeding the local load of Rangia during the operation of this SPS.

III. **SPS KAHILIPARA:** Upon loss of any circuit (during peak load hours) of the 132kV Sarusajai – Kahilipara ckt II, III and IV (Note: Ckt I is kept bypassed at Kahilipara and connects Sarusajai to Kamakhya directly), the other two circuits are overloaded. The loss of the three circuits would heavily affect the critical area and critical loads of Guwahati. As per the designed logic, if any among the three circuit crosses 400A (for 5 seconds), 132kV Kahilipara – AIIMS feeder is tripped. **(NOTE: The above SPS scheme will be updated soon. SPS Kahilipara was proposed by SLDC, AEGCL)**

IV. **SPS SARUSAJAI:** Upon loss of 220kV Sarusajai – Mirza Ckt I & II, the only major power source for Guwahati Capital Region is 220kV Samaguri GSS (via Sonapur and Jawaharnagar). (*Generation from KLHEP is considered minimum*). This would create an under-voltage scenario at Guwahati Capital area which will lead to potential mass scale blackouts. Hence, to maintain load – generation balance, a curtailment of **160MW** is achieved by tripping the following feeders: 132kV Sarusajai – Kamakhya, 132kV AIIMS – Amingaon, selected 33kV Feeders (non-critical and approved by APDCL) at Sarusajai and Kahilipara GSS. (The signal exchange of the overall SPS Sarusajai is based on OPGW network).

V. **SPS SAMAGURI:** Upon loss of 220kV Samaguri – Misa Ckt I & II, the only major power source to Samaguri is Sarusajai GSS (via Sonapur and Jwaharnagar). To prevent under-voltage scenario at Samaguri, a total curtailment of **80MW** is achieved by tripping the following elements: 132kV Samaguri – SD Nagar Line I & II

VI. **SPS MIRZA:** If there is reverse power flow in the 315MVA ICTs at Mirza (>7% of Rated Power), the ICT is tripped. This is done to prevent reverse flow of power from 220kV System to 400kV System and improve system stability. **Note: Presently the SPS is kept inactive**

VII. <u>SPS SONABIL:</u>

Criteria 1: When loading of any one circuit of the 220kV Sonabil – Balipara D/C line surpasses 630A, the CBs of 220kV Sonabil – Samaguri Line I & II will be tripped.

Criteria 2: When both 220kV Sonabil – Balipara D/C line trips, a total controlled load shedding of 90MW (in case of loss of Sonabil – Balipara D/C line) would be implemented to safeguard the Sonabil transmission network.

VIII. <u>SPS CHAPAKHOWA:</u>

Criteria 1: If the current in either of the 132kV Tinsukia – Rupai or 132kV Tinsukia – Margherita circuits cross 300A (during peak load condition when one circuit is lost), a signal will be sent to 132kV Chapakhowa GSS which would open the circuit breakers of 132kV Chapakhowa – Roing Lines I & II. Further, an automated controlled load shedding of 8 – 10MW will be actuated at Rupai GSS if current in the healthy circuit does not fall below 300A after operation of the first logic of SPS

Criteria 2: On event of loss of 132kV Ranganadi – Ziro line in the Arunachal Pradesh System, to mitigate the overloading of 132kV Tinsukia – Rupai line, an automatic load shedding of 8 – 10MW will be carried out at Rupai end, if the current in the 132kV Tinsukia – Rupai line exceeds 300A

IX. <u>SPS BTPS ICT:</u>

The 2X160MVA ICTs at 220/132/33kV BTPS GSS AEGCL are not fulfilling N-1 contingency criteria. As per system studies (conducted by NERLDC and SLDC), a total load shedding of 140 MW (instantaneous) is required to preserve the stability of the system in case of loss of one ICT during peak load condition.

ANNEXURE I: SYSTEM PROTECTION SCHEME (SPS) LOGIC IMPLEMENTED AT 220kV SALAKATI GSS AGAINST TRIPPING OF 220kV SALAKATI (AS) – SALAKATI (PGCIL) D/C TL.

Description: In case of loss of one circuit among the 220kV Salakati – Salakati (PG) double circuit lines, if the other healthy circuit has a load of >600A, the SPS is initiated and a signal is sent from Salakati to Agia. Upon receiving the "SPS Operate" signal at Agia, the Circuit Breakers of 220kV Boko and 220kV Mirza feeders are tripped. This is achieved to restrict the overloading of the 220kV Salakati – Salakati (PG) Lines I & II

The implemented logic is as shown below:

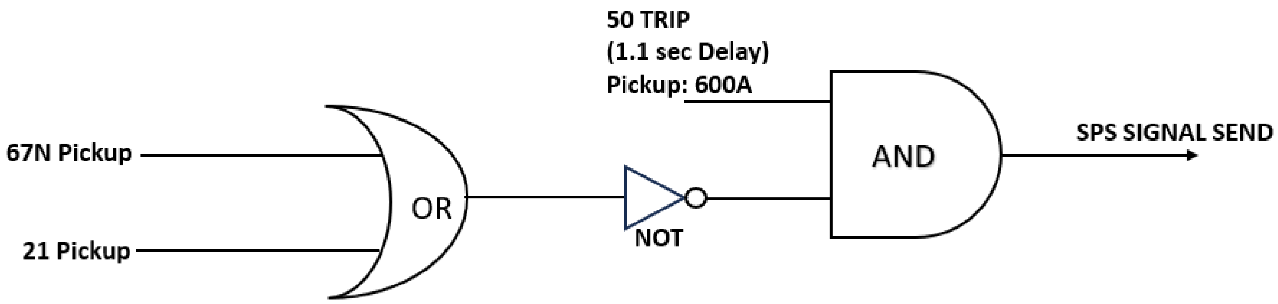

Fig 1: Logic diagram of SPS Salakati

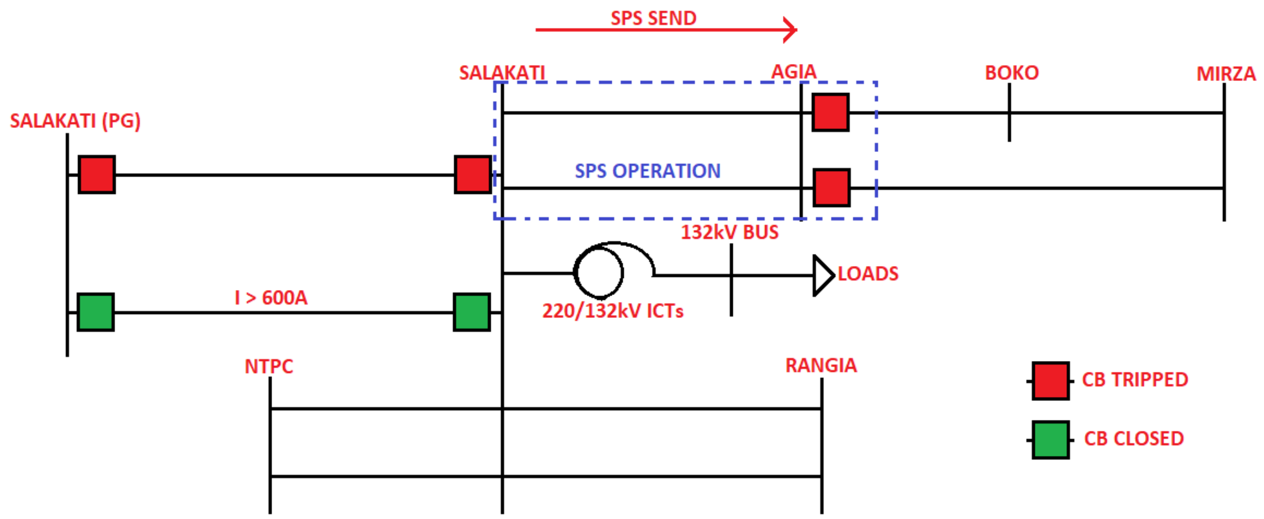

Fig 2: The interconnected grid at Salakati GSS during SPS operation

Logic definition: A "Definite Time Non – Directional Overcurrent Protection" has been used (50) with a time delay of 1.1s and pickup of 600A. The SPS will be blocked in case of pickup of Dir. Earth fault protection (67N) and start of Zones of Distance Protection (21).

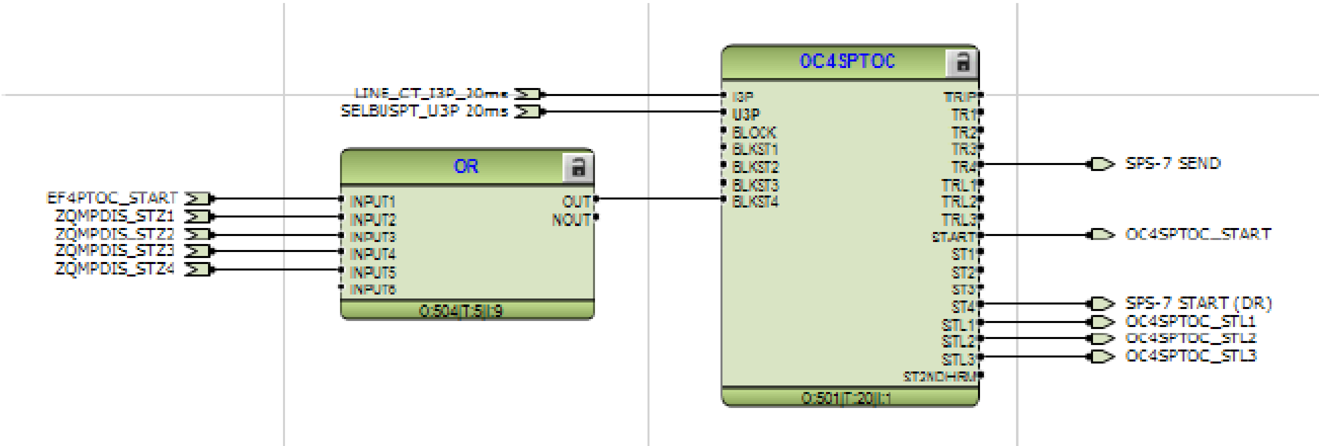

Fig 3: The SPS logic implemented in the ABB make REL 650 relay

SPS hard wiring scheme at Salakati GSS

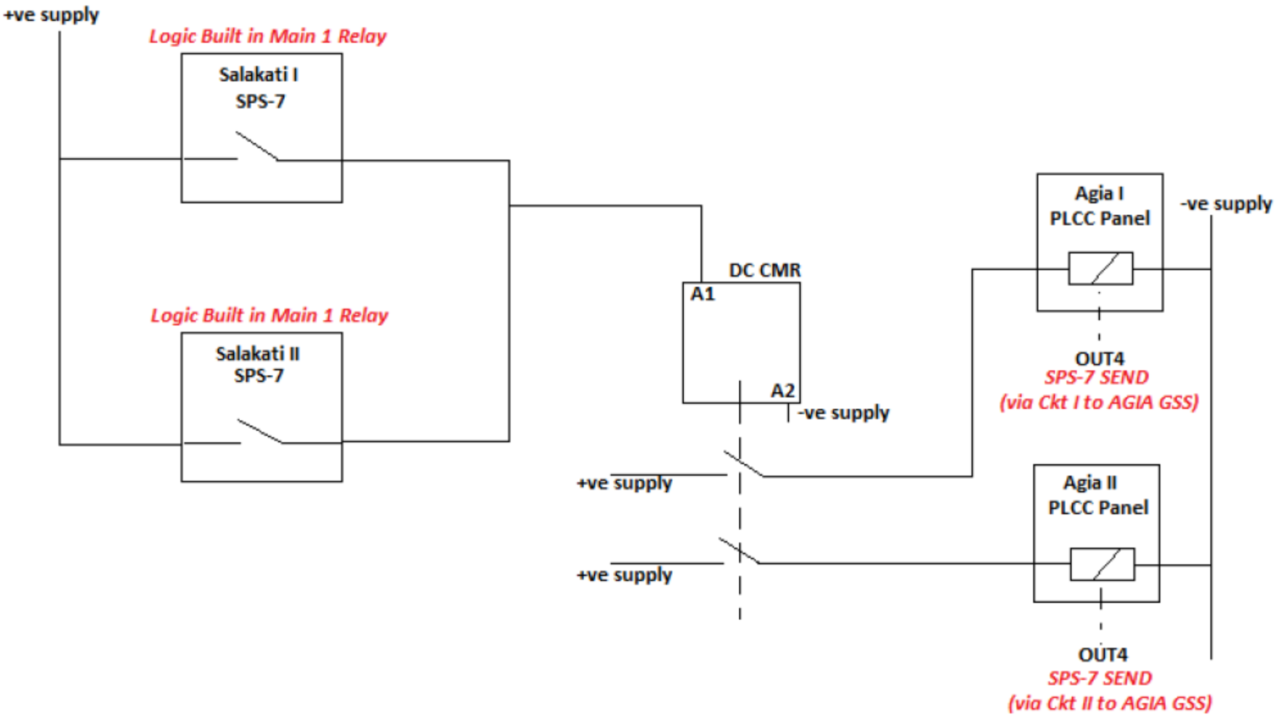

Fig 4: SPS connection diagram at Salakati GSS

SPS hardwiring scheme at Agia GSS

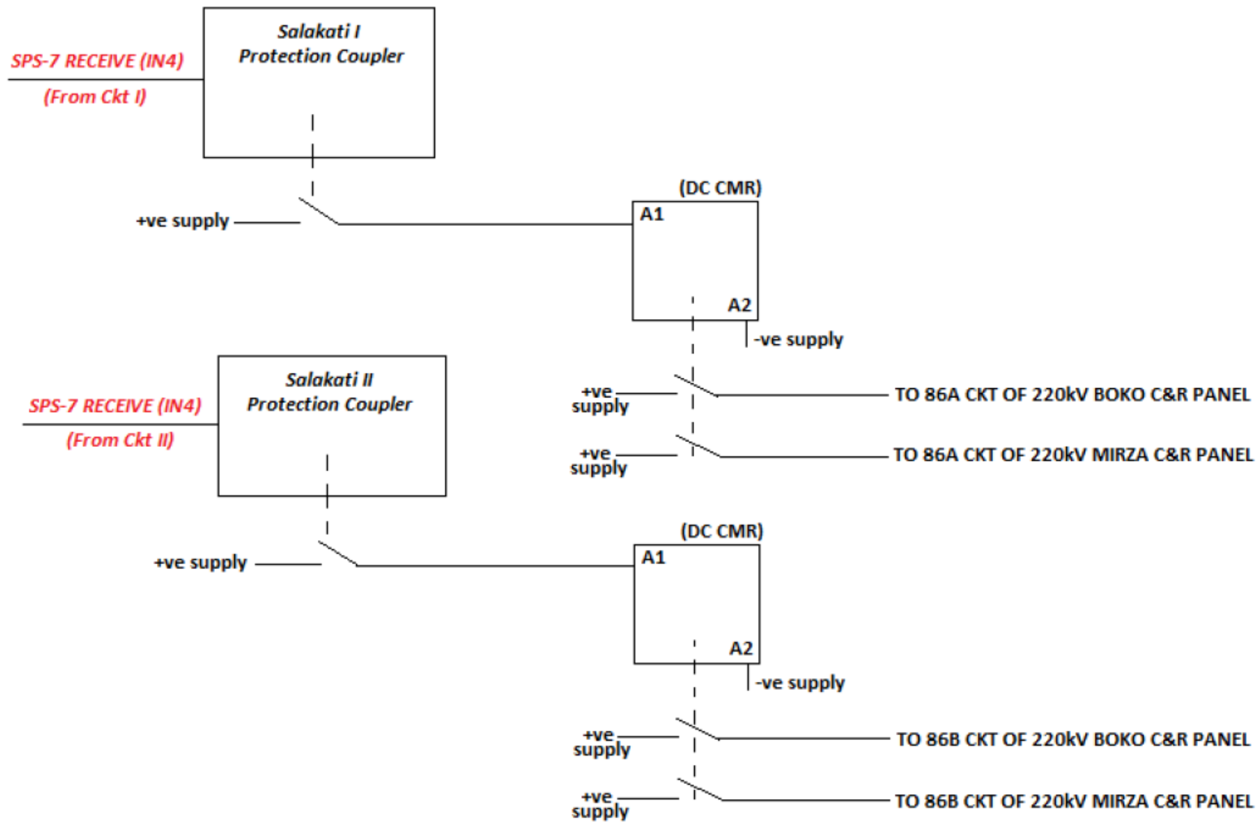

Fig 5: SPS connection diagram at Agia GSS

RESTORATION OF THE SYSTEM POST OPERATION OF THE SYSTEM PROTECTION SCHEME (SPS)

For restoration of the lines the following cases may be applicable:

Case I: If both the lines are restored within the stipulated time but the lines are still subjected to higher loading, the loading may be reduced by reducing the load of the downstream lines by shifting of load. For instance, load of Barpeta may be shifted to Nalbari. If after reducing the load the loading of 220kV BTPS (As)- Salakati D/C is still higher than the permissible limit, Agia and Boko feeder will be kept in open condition. Likewise, if the loading of the lines is within the limit the lines may be restored normally.

Case II: if only one of the 220kV lines is restored, then accordingly loading may be reduced and both Azara and Boko feeders may be kept open.

Case III: If both the lines are not restored within the stipulated time, both Azara and Boko feeders may be kept in open condition.

However, all switching operations as mentioned above are subjected to real time grid condition and situations best known to the system operator.

ANNEXURE- II: SYSTEM PROTECTION SCHEME (SPS) LOGIC IMPLEMENTED AT 220/132kV RANGIA GSS AND 132/33kV RANGIA GSS TO PREVENT BLACKOUT OF RANGIA AREA IN CASE OF LOSS OF 220kV RANGIA – SALAKATI LINE D/C TL

Description of the scheme: 220/132kV Rangia GSS and 132/33kV Rangia GSS are inter-connected by two short lines. The power sources for Rangia and adjacent areas are ***220kV Salakati – Rangia Line I&II*** via 220/132kV Rangia GSS and ***132kV Motonga Line*** via 132/33kV Rangia GSS. It has been observed during many instances that, in case of loss of 220kV Salakati double circuit line, the 132kV Motonga Line is tripped at Remote end (Bhutan) on Overcurrent protection (due to overload) which results in blackout of 132/33kV Rangia GSS.

The SLD of Rangia area is as below:

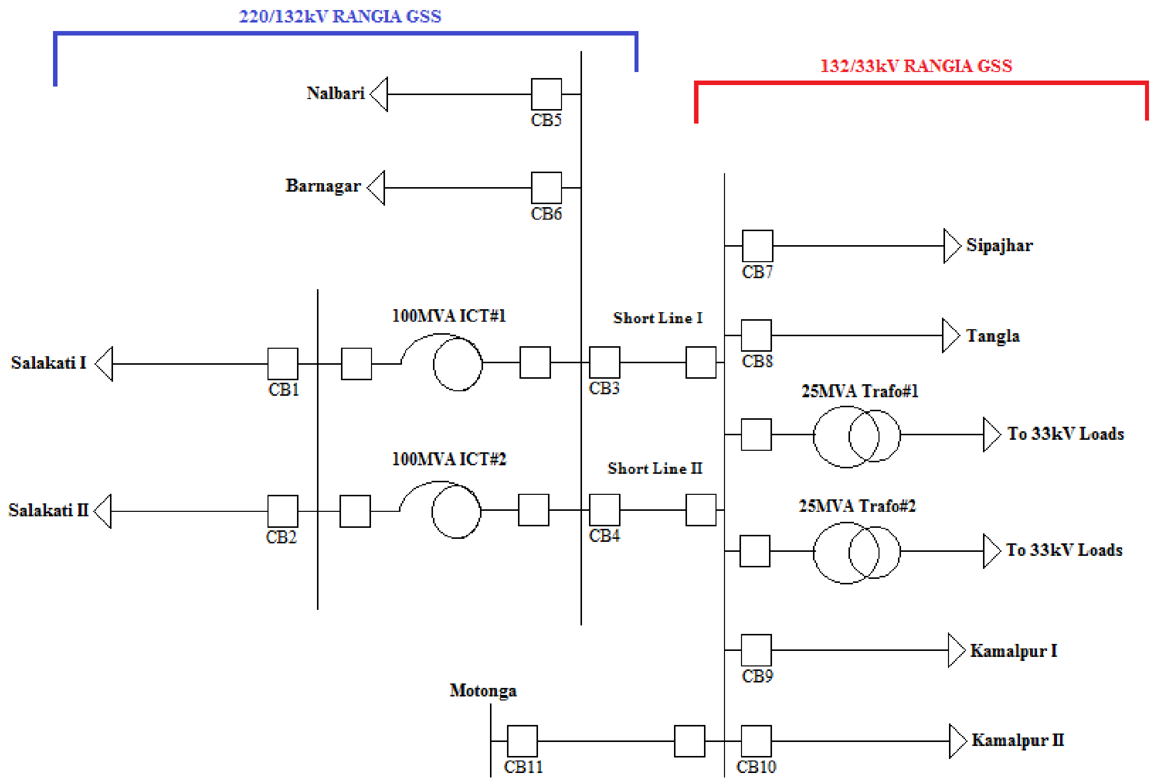

Fig 6: Interconnected grid elements at 220kV Rangia GSS and 132kV Rangia GSS

Grid Configuration Description:

a. The bus at 132kV Barnagar GSS is segregated into two sections. One section is fed from Dhaligaon whereas the other section is fed from Rangia
b. 132kV Nalbari is fed radially from Rangia
c. 132kV Kamalpur I & II lines are in ideal charged condition (CB for Rangia ckt is kept open at Kamalpur end) and Kamalpur is connected to Kahilipara and Sishugram. The transmission link between Rangia via Kamalpur to Kahilipara is to be kept disconnected as per instruction of SLDC
d. 132kV Sipajhar is fed radially from Rangia as 132kV Rowta line is normally kept in ideal charged condition from Sipajhar
e. 132k Tangla line is normally radially fed from either Rangia or Rowta. 132kV Tangla is a LILO substation between previously 132kV Rangia – Rowta Line.

TABLE 2: Load (Active Power) recorded in the year 2021-22 for 132/33kV Rangia GSS

NAME OF FEEDER	MAXIMUM LOAD RECORDED IN YEAR 2021-22 (MW)	AVERAGE LOAD RECORDED IN YEAR 2021-22 (MW)
132kV RANGIA – SIPAJHAR	38.8	15
132kV RANGIA – TANGLA	45.4	12
132kV RANGIA – KAMALPUR I	61.1	18
132kV RANGIA – KAMALPUR II	61.2	18
132kV RANGIA – MOTONGA	66.4	35
33kV FEEDERS	48.6	28

**132kV Rangia – Tangla was previously 132kV Rangia - Rowta*

As per the above table 1, the average generation of Motonga (incase of loss of Salakati I&II) can be balanced out (approximately) if the 33kV Feeders are kept in operation and all other feeders are tripped.

- Maximum Load drawn by 33kV Feeders = 48.6MW
- Average import by of 132kV Rangia – Motonga Line = 35MW

Note: "***Maximum Load"*** *of 33kV Feeders* is considered for worst case scenario. As Motonga is also interconnected with Bhutan grid, a difference of a few MWs may be balanced.

The logic for the SPS is designed as below:

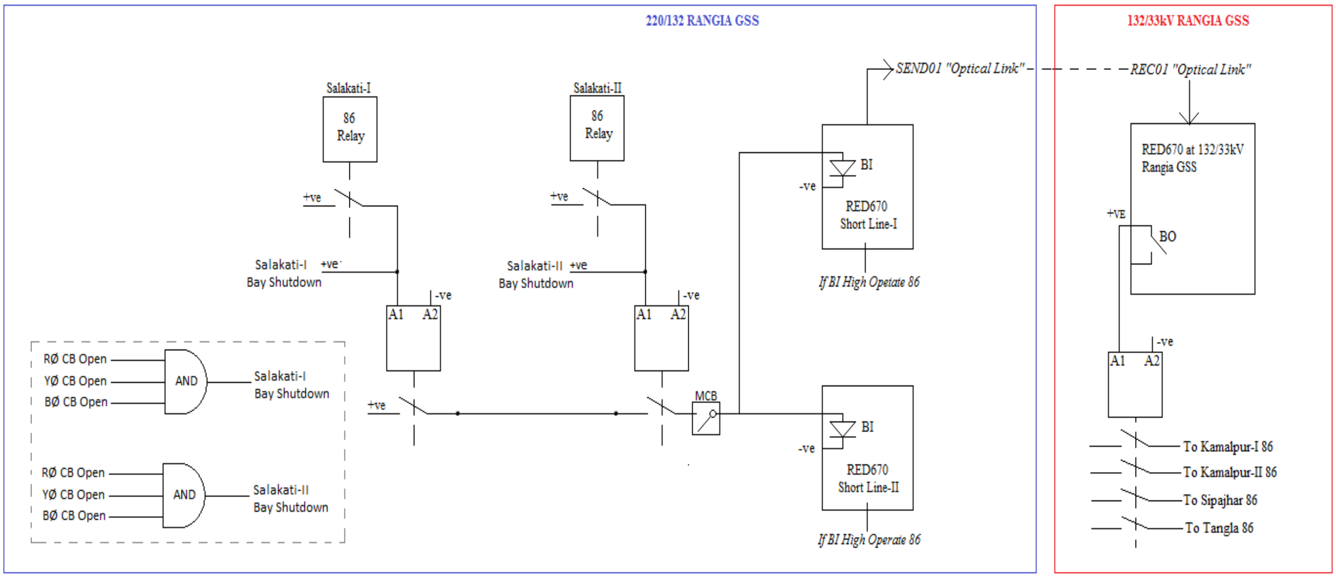

Fig 7: SPS logic to be implemented at 220kV Rangia and 132kV Rangia GSS

LOGIC designed for implementation at 220/132kV Rangia GSS

i) "Potential free NO contacts" from 86 relays of Salakati Line I & II are separately connected to the energization point (A1) of two individual Contact Multiplier relays (CMR)

ii) The CB Open status (of each pole) is received through Binary Inputs by the REL670 Distance Protection relay. A soft logic is to be configured in the REL670 relay with "each pole open status" as inputs to the **AND** logic. The output from the **AND** gate when "*High*" would indicate the CB to be in open state.

iii) The **AND** gate output signal is to be linked with a spare Binary Output of the REL670 relay which would be externally wired to the energization point (A1) of the CMR.

The same is to be done separately for each circuit.

As per the above points, each CMR would pickup (continuously latch) for the following two cases:

a) When the Circuit has tripped due to fault (86 Operate Status)
b) When the Circuit is under shutdown (CB Open Status)

iv) An **AND** logic is further implemented by connected the NO contacts of each CMR in series which is extended to a configured Binary Input (BI) in both the local end line differential relays (RED670) for 132kV Short Line I & II. The BI's in the RED670 relay when "High" would trip the 86 relay of individual short line.

The following condition is achieved with the above logic:

a) In case of loss of both the circuits (**CB1 and CB2**) due to a tripping event, both the CMRs would pickup (Continuously latch)
b) In case of one circuit being under shutdown (its concerned CMR would be continuously latched), if the other charged circuit is lost due to a tripping event, the state of both the CMRs in pickup condition would be achieved.

Hence, both the above cases (*a,b*) would make the BI's high in the two RED670 relays which would in turn trip the circuit breakers (**CB3 and CB4**) of the short line I & II respectively.

v) "***Dedicated Digital Signals***" can be sent between local and remote end line differential relays which completely depend on the Optical fibre link. As these signals are transmitted over dedicated end-to-end optical link (which is independent of LAN network), there is negligible chance of loss of signal.

vi) When configured Binary Input (BI) in RED670 of Short Line-I is "true", the RED670 relay would trip its 86 relay and also send a signal "**SEND01**" via the optical link to the remote end RED670 relay located at 132/33kV Rangia GSS.

LOGIC designed for implementation at 132/33kV Rangia GSS

i) The RED670 relay would receive the signal **"SEND01"** sent from remote end through **"REC01"** input.
ii) If "REC01" is "true/high", a separate Binary Output would be configured to excite a Contact multiplier relay (CMR) which would trip the 86 relays of Kamalpur I&II, Sipajhar and Tangla lines. (**CB7**, **CB8**, **CB9** and **CB10**)

If the above scheme is operated successfully, the power drawn from Motonga would be used to supply the **33kV Local** at 132/33kV Rangia GSS. Thus the blackout of Rangia can be avoided.

Note:

i) As the scheme is dependent on the 86 operate status of Salakati I & II at 220/132kV Rangia GSS, it is utmost necessary that the CB1 and CB2 are opened during the fault event. In certain cases, both circuits may trip at Salakati end whereas only one circuit may be tripped only at Rangia end. In that case, both circuits are lost but the SPS would not operate.
ii) To counteract against the undesired situation, a "**Direct Trip**" signal should be sent from Salakati to 220kV Rangia GSS when 86 relay of the line operates at Salakati. When DT signal is received from Salakati end, the 86 would operate at Rangia and SPS can be fulfilled.

On event of successful operation of the System Protection Scheme, the restoration procedure should be as such:

- "The CB's of the 220kV Line should be closed at first (CB1 and CB2) followed by the charging of the remaining 132kV lines in both the substations as CB open status (CB1 and CB2) would continuously send a tripping command to the 132kV system."
- "For switching off the SPS scheme, the "MCB" as shown in fig 2 should be cut off"

RESTORATION OF THE SYSTEM POST OPERATION OF THE SYSTEM PROTECTION SCHEME (SPS)

For restoration of the lines, the following cases may be applicable:

- Case I: if both the circuits are restored within the stipulated time period all the 132kV feeders will be charged normally one by one (the feeders with lowest load in the antecedent condition will be attempted first).
- Case II: If only one of the 220kV line is restored, keeping into account the loading, all the 132kV lines may be charged with some load restrictions.
- Case III: If both the 220kV lines are not restored, alternate power sources to the feeders may be arranged such as Barnagar may be fed from Dhaligaon end, Sipajhar & Tangla may be fed from Rowta end, Nalbari fed from Barpeta end, Kamalpur may be fed from Amingaon end with load restrictions being imposed as per real time grid condition.

However, all switching operations as mentioned above are subjected to real time grid condition and situations best known to the system operator.

ANNEXURE-III: SYSTEM PROTECTION SCHEME (SPS) LOGIC IMPLEMENTED AT 132/33kV KAHILIPARA GSS TO PREVENT OVERLOADING & BALANCE 33kV LOADS IN CASE OF LOSS OF EITHER OF 132kV SARUSAJAI LINES II, III & IV DURING PEAK LOAD CONDITION

Description: If the combined load of the three feeders Sarusajai II, III & IV is above 800A, the (n-1) contingency in case of the three lines is not achieved. The loss of one feeder would overload the other two healthy feeders. To prevent this undesirable situation which may lead to cascaded tripping effect, reduction in load at 33kV level is required to avoid overloading of the remaining two circuits of 132kV Kahilipara – Sarusajai.

As per the letter from CGM, SLDC dated 11.07.2022, a system protection scheme is to be designed at Kahilipara which would prevent overloading of the Sarusajai circuits by tripping the 33kV feeder Ulubari – III in case of loss of one circuit of Sarusajai during peak load condition (load >=800A)

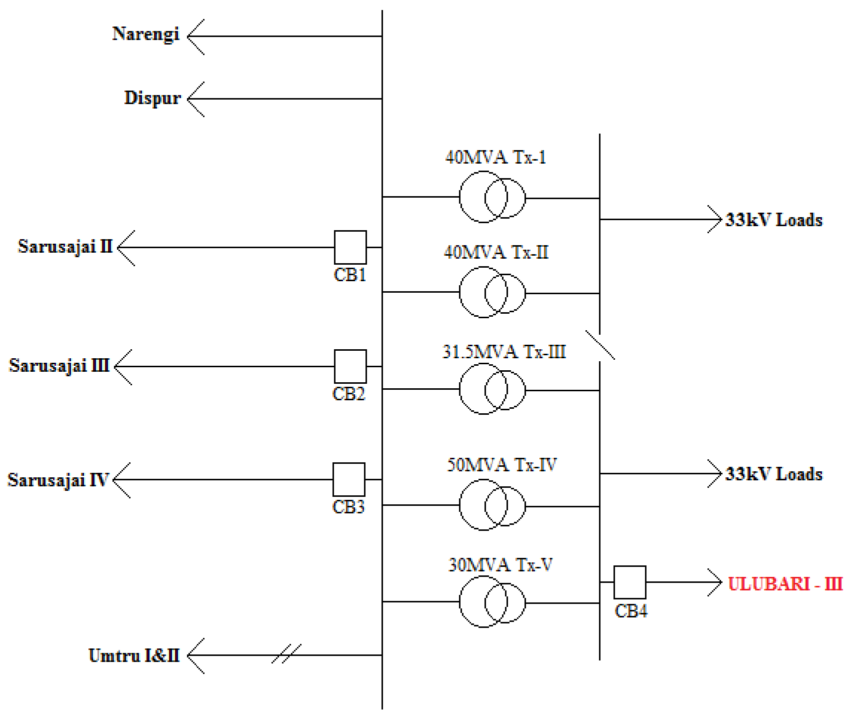

Fig 8: Grid Diagram at 132/33kV Kahilipara GSS and associated feeders

Note: Sarusajai-I is by passed at Kahilipara and is routed to 132kV Kamakhya GIS, thus forming the 132kV Sarusajai – Kamakhya circuit. 132kV Kamakhya feeder at Kahilipara GSS is kept idle.

DESIGN OF SPS LOGIC:

1. As 800A is kept as the limit for SPS activation, on loss of one of the Sarusajai circuits, the total load of 800A would be shared by the remaining two active circuits. Hence, **400A should be the deciding factor/pickup limit for SPS activation**.

2. A "Non-tripping Overcurrent Stage-IV" is to be configured in the REL650 relays of Sarusajai line feeders at Kahilipara GSS with the following settings:
   - Directional Mode: Non-Directional
   - Characteristics Curve: IEC Definite Time
   - Pickup: 400A
   - Operate time: 5 second

   Considering high ROT of OC protection during resistive faults and downstream faults (bi-directional), an operate time of 5 seconds to sense overload condition would suffice and mitigate the chances of false operation due to actual weak infeed line faults.

3. Logic Diagram of SPS

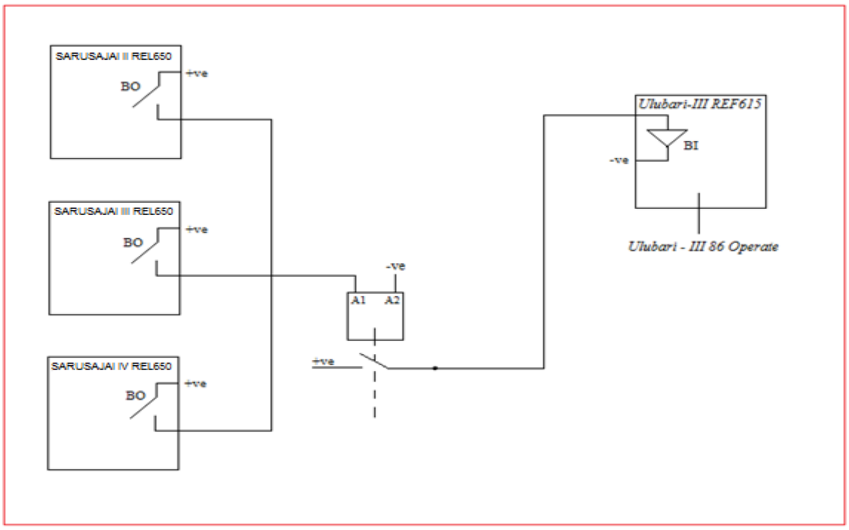

Fig 9: SPS logic to be implemented at 132/33kV Kahilipara GSS

a. A Binary Output (BO) would be configured in the REL650 relays (Sarusajai II, III and IV) which would pickup if Overcurrent Stage IV operates after a delay of 5 seconds on overload condition.
b. As load current is maintained strictly at 800A among the three circuits during healthy condition, a loss of any of the circuits would necessary increase the current to **>400A** (during peak load condition) in the other two circuits. Hence, the "*86 operate status*" or "*Protection trip status*" to represent the <u>loss of any of the circuit is not required to be implemented in the SPS logic.</u>
c. On pickup of OC Stage-IV by any of the circuits, the BO is operated which extends the positive to a contact multiplier relay (CMR). A "NO" contact of the CMR is to be hard wired to a Binary Input (BI) of the REF615 relay at 33kV Ulubari-III panel.
d. The BI of the REF615 relay would be associated with the tripping matrix, i.e. 86 would operate if BI is "*High*".

The configured BI in the REF615 relay would also useful to trigger a "Disturbance Recorder file" on operation of the SPS scheme.

OPERATION CASE: Let the loading prior to a tripping event be 820A (Three lines combined). If Sarusajai Ckt II is tripped due to fault; 820A would be then shared the Sarusajai Ckt III and Ckt IV.

<u>Condition 1</u>: If the loading is equally shared, both the REL650 relays would operate on OC Stage IV after a delay of 5 seconds, whereas

<u>Condition 2</u>: If the loading is unequally shared, at least one of the lines among Sarusajai III and IV would operate on OC Stage IV after a delay of 5 seconds.

Any of the above conditions if met, would lead to the pickup of the CMR.

Pickup of CMR would make the Binary Input of the 33kV Ulubari-III feeder to be "High". Hence, the 33kV Ulubari-III would be tripped on SPS operation and a SPS DR would be triggered for reference.

Note: *As per line maintenance at Kahilipara, the transmission line can be loaded till 400A. However, long time loading at 400A is not desirable. Upon SPS operation, the load would be reduced. If further reduction is necessary, the same can be achieved by manual load adjustment with APDCL substations.*

In the above SPS Logic, "33kV Ulubari-III" was later replaced by "132kV Kamalpur Line" as per discussion with APDCL and value of final load curtailment. However, 132kV AIIMS GSS is introduced in the previously 132kV Kahilipara – Kamalpur Network, hence the above SPS logic is presently under revision stage. The same will be updated with respect to present grid connectivity and critical loads in due course of time

RESTORATION OF THE SYSTEM POST OPERATION OF THE SYSTEM PROTECTION SCHEME (SPS)

For restoration of the lines, the following cases may be applicable:

- Case I: Attempt will be made first for restoration of the 132kV Kahilipara-Sarusajai feeder which has tripped, if the issue of overloading still persists some of the 33kV feeders may be shifted to other GSS, such as Fancy Bazar feeder of Kahilipara may be shifted to Kamakhya, Paltan Bazar feeder of Kahilipara may be shifted to Sarusajai and so on. Again to further decease the loading 132kV Kahilpara-Narengi may be opened and under extreme condition Kahilipara-Dispur may be opened. Following this Kahilipara-AIIMS may be restored.
- Case II: If charging of the line is not possible, then 132kV Kamalpur-Amingaon D/C is closed and likewise power may be fed to AIIMS.

However, all switching operations as mentioned above are subjected to real time grid condition and situations best known to the system operator.

ANNEXURE-IV: SYSTEM PROTECTION SCHEME (SPS) LOGIC IMPLEMENTED AT 220kV SARUSAJAI GSS AGINST TRIPPING OF 220kV SARUSAJAI-MIRZA D/C TL

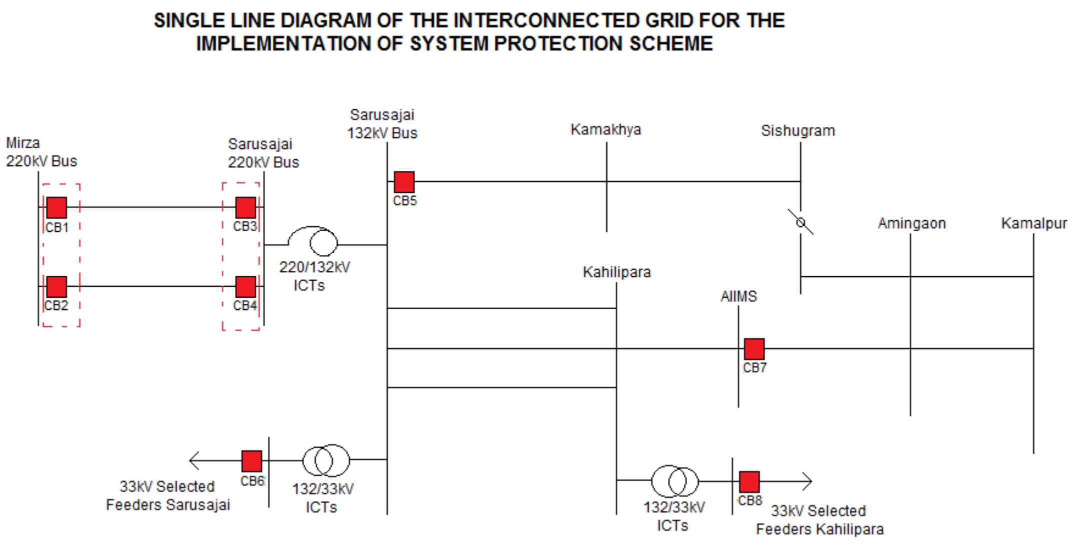

Fig 10: Interconnected Grid with Sarusajai GSS and operation of SPS

A. SPS Operation Logic Details:

On the event of loss of the **220k Mirza – Sarusajai Line I & II**, the following elements are to be tripped (CB Opened) to prevent under-voltage scenario at Guwahati area:

a. 132kV Sarusajai – Kamakhya Line (CB5)
b. 132kV AIIMS – Amingaon Line (CB7)
c. Selected 33kV Feeders at Sarusajai GSS
d. Selected 33kV Feeders at Kahilipara GSS

The 132kV Bus at Sishugram is segregated into two sections, one being fed from Kamakhya while the other being linked to Amingaon. The connectivity at Kamalpur is such that, it is connected either to Kahilipara Grid or to the Rangia Grid. A through LILO between Kahilipara – Kamalpur – Rangia is not present.

Hence, disconnecting the circuits of 132kV Sarusajai – Kamakhya (CB5) and 132kV AIIMS – Amingaon (CB7) would be effective. (The same was verified by Simulation studies by NERLDC). The later margin of load to be disconnected was decided to be achieved by tripping of selected 33kV Feeders at Sarusajai and Kahilipara (As per consent from APDCL)

The loss of 220kV Mirza – Sarusajai Lines I & II should initiate the "Operation of SPS". Two major potential events were taken into consideration while designing the SPS.

CASE A: Both CB's tripped at Sarusajai end

CASE B: AR successful at Sarusajai end, but both CB's tripped at Mirza end

As per CASE A and CASE B, it is observed that the "SPS OPERATE LOGIC" is to be configured both at Mirza end and Sarusajai end.

B. LOGIC DEFINITION: (<u>AT SARUSAJAI END</u>)

1. The "CB Open status" is readily available to the BCU and the distance relays via CB auxiliary contact wirings to the BI (Binary Inputs) of the IED.
2. A separate Binary Output (BO) will be configured in each BCU of Line I and Line II, which will be latched (closed) when CB Open status (of each CB pole) is high.
3. As, both the CB's of Ckt I and Ckt II are to be opened for initiation of the SPS logic, an **AND logic** is achieved by hardwiring the two BO's in series which is then terminated to the operating coil of Contact Multiplier Relay circuits (CMR).
4. When the "SPS Operate" signal will be high, the 132kV Sarusajai – Kamakhya feeder (CB5) and 33kV Feeders at Sarusajai will be opened via the CMR circuit.
5. At the same time a "SPS OPERATE SIGNAL" (utilized by a spare DT circuit) will be send to Kahilipara GSS. At Kahilipara, when the "SPS OPERATE SIGNAL" would be received, the selected 33kV Feeders would be opened via a CMR circuit and at the same time, a "SPS OPERATE SIGNAL" would be send to AIIMS GSS via a spare DT circuit.
6. When the "SPS OPERATE SIGNAL" is received at AIIMS GSS, it would trip the 132kV AIIMS – Kamalpur Line (CB7).
7. Hence, all the tripping operation related to the SPS is achieved.

C. LOGIC DIAGRAM OF SPS

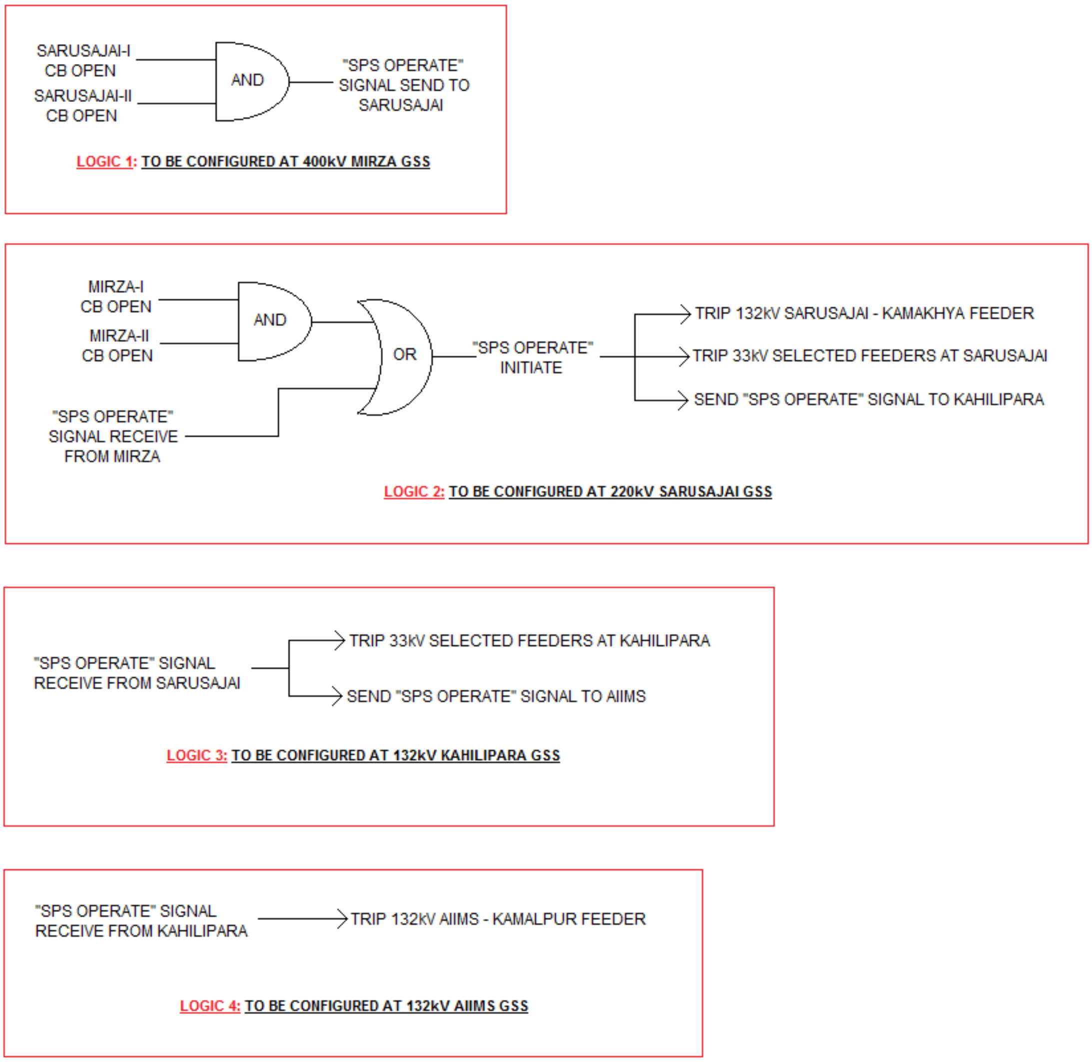

Fig 11: The SPS Sarusajai implemented logics

As per the above figure, "SPS Operate" signal will also be sent from Mirza end, if both CB's are opened at Mirza. Sarusajai upon receiving the signal from Mirza would proceed further with the logic described in Section B.

D. WIRING DIAGRAM AT MIRZA

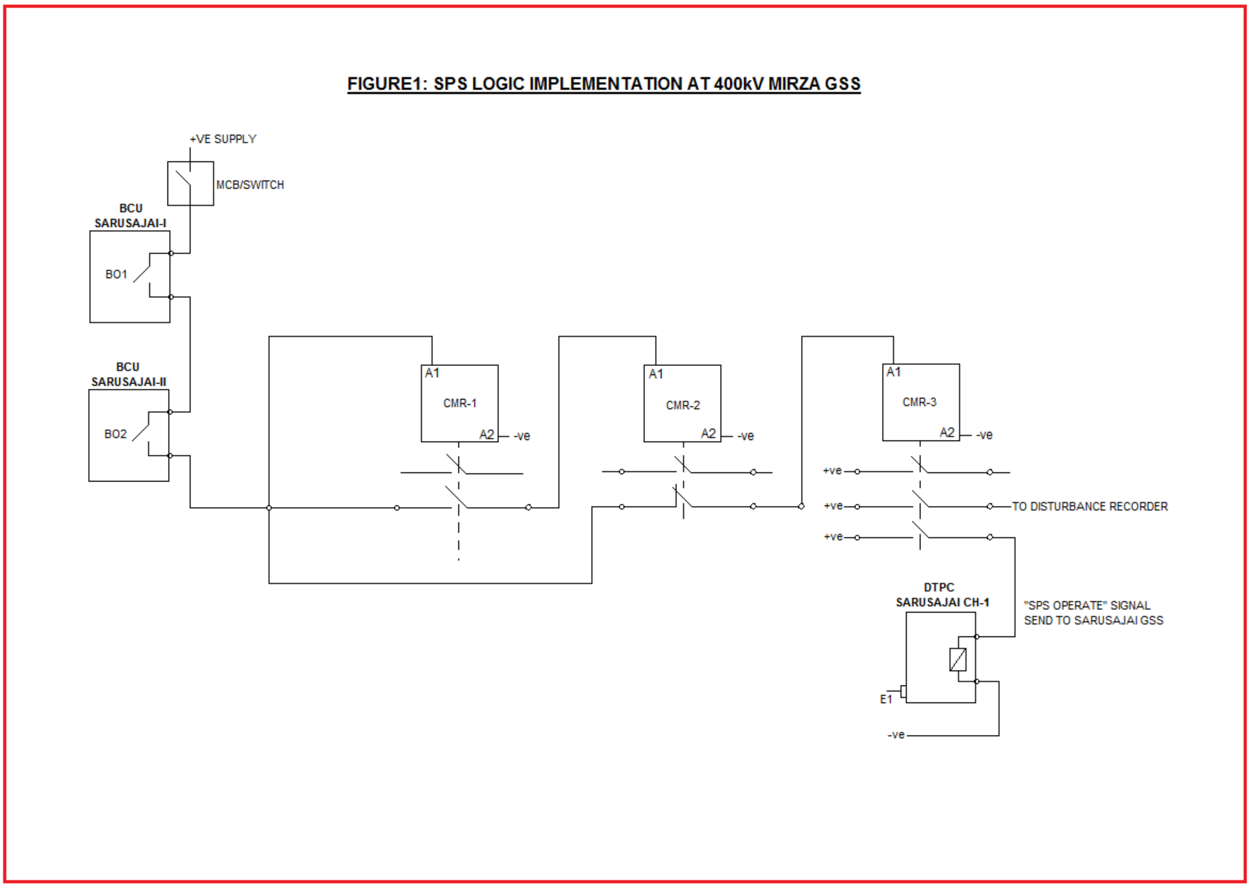

Fig 12: Hardwiring diagram of SPS logic at Mirza GSS

Definition:

i) BO's of the BCUs of two lines are wired in series (forming an AND logic), which in turn is used to pick up a group of CMRs. (Refer **Section F** for CMR circuit definition)

ii) The Pickup of CMR's would initiate DR recording (to register the SPS operation) and the same circuit is linked with the PLCC panel for sending the "SPS operate" signal to Sarusajai.

E. WIRING DIAGRAM AT SARUSAJAI

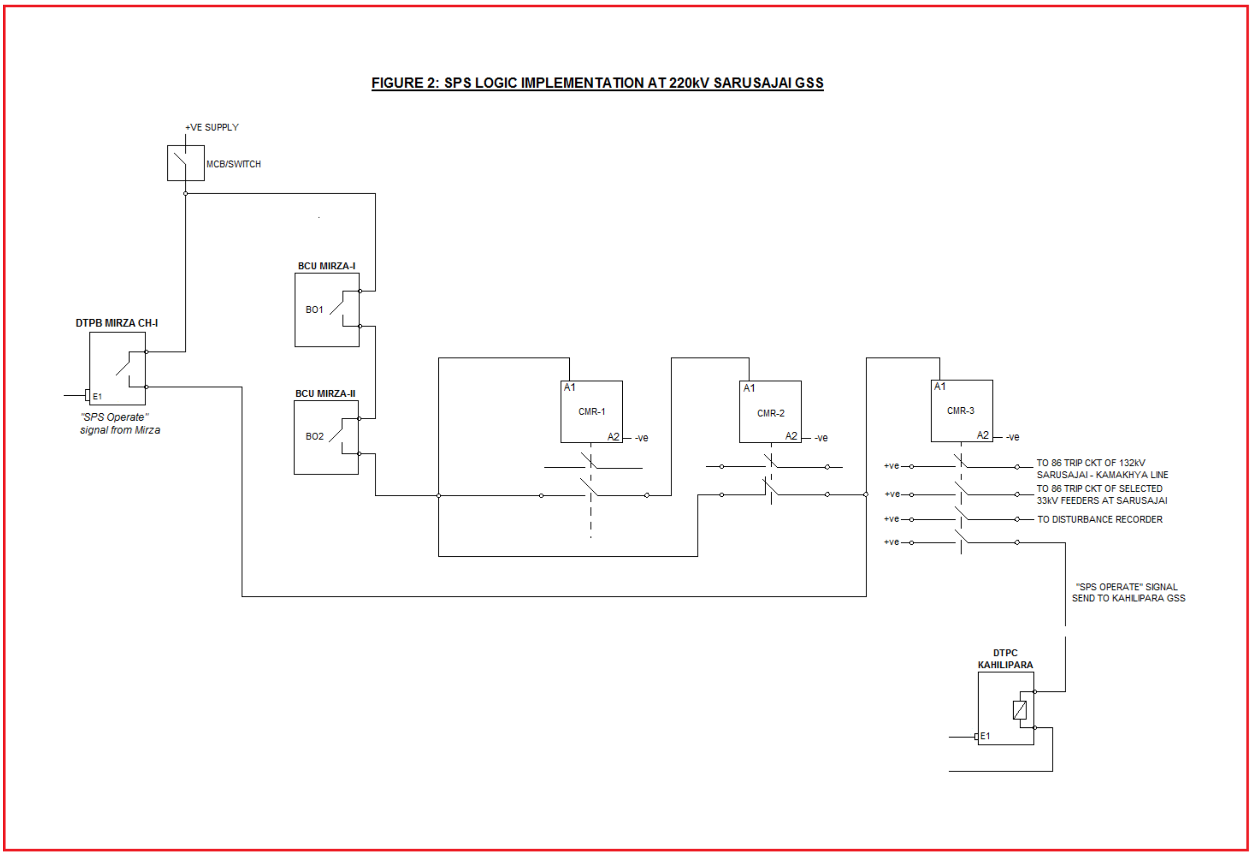

Fig 13: Hardwiring diagram of SPS logic at Sarusajai GSS

Definition:

i) Here, the operation of the CMR's is linked with "SPS OPERATE RECEIVE" signal from Mirza and "both circuit CB open" status via the BCUs

ii) Operation of the CMRs would trip the 132kV Sarusajai – Kamakhya line, selected 33kV feeders, register the event in the DR and send "SPS OPERATE SIGNAL" to Kahilipara

iii) As per approval of APDCL, the 33kV feeders to be tripped during SPS operation at Sarusajai are: 33kV Bhetapara, 33kV Gorchuk, 33kV Fatasil and 33kV Garbhanga

F. Use of Contact Multiplier Relays (CMR) in "SPS OPERATE CIRCUIT"

a. The CB open status will be continuously high. As "SPS OPERATE" is utilized via a "DT send circuit" which is based on CB Open status of both lines at Sarusajai end, so a self reset mechanism should be adopted to send a DT as prolonged DT send signal will damage the Protection Coupler equipment.

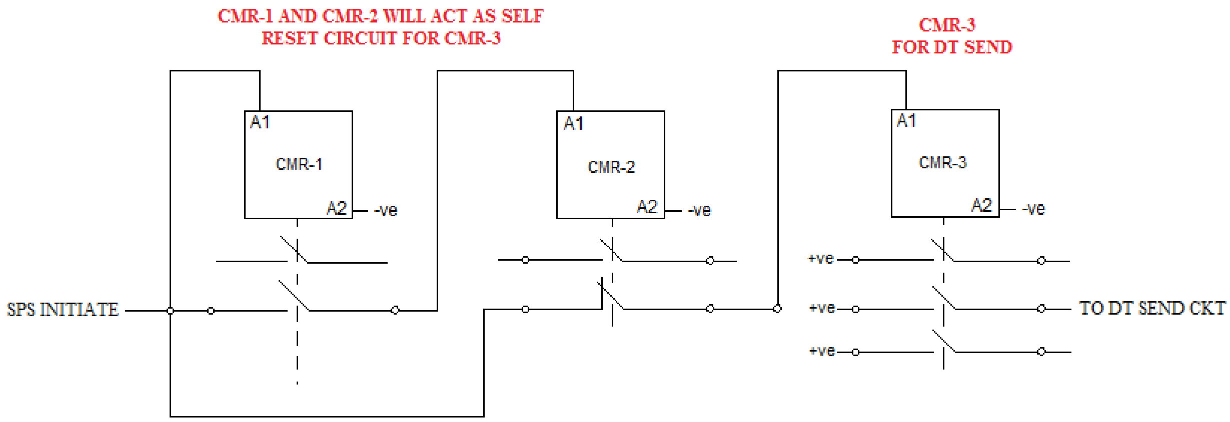

Fig 14: Self re-latching contact design used for SPS

Upon Activation of the SPS Initiate signal, CMR-1 and CMR-3 will pickup spontaneously. The path of pickup coil of CMR-3 is through a NC contact of CMR-2. It can be observed that, the pickup coil of CMR-2 is through an NO contact of CMR-1. Hence, the sequence of the operation will be as such:

a. CMR-1 picks up. At the same time the signal is extended to CMR-3 through NC contact of unpicked CMR-2 and CMR-3 picks up.
b. Upon Pickup of CMR-1, the NO contact will be closed and CMR-2 will be picked up.
c. Upon Pickup of CMR-2, the NC contact will be opened and pick up of CMR-3 will be dropped off.
d. The DT send signal is hence high for a short period of time. On practical realization of the circuit and simulation of the same, the DT send circuit was high for 18ms which is in safe limit of the Protection Coupler circuit.

Note: The CMR circuit is necessary because a the SPS is based on signal send from one station to another. Keeping Sarusajai in view, the loss of circuits can also be sensed by status of 86 relays (for all protection functions except Zone 1 operation). However, 86 relays are not a self reset equipment. Hence, to include all events of tripping the "CB Open Status" can be considered an effective signal. As these signals (unlike proteciton signals) are continuously high, hence, a DT self reset hard wired circuit is required to prevent the healthiness of the Protection Coupler Equipment.

G. WIRING DIAGRAM AT KAHILIPARA

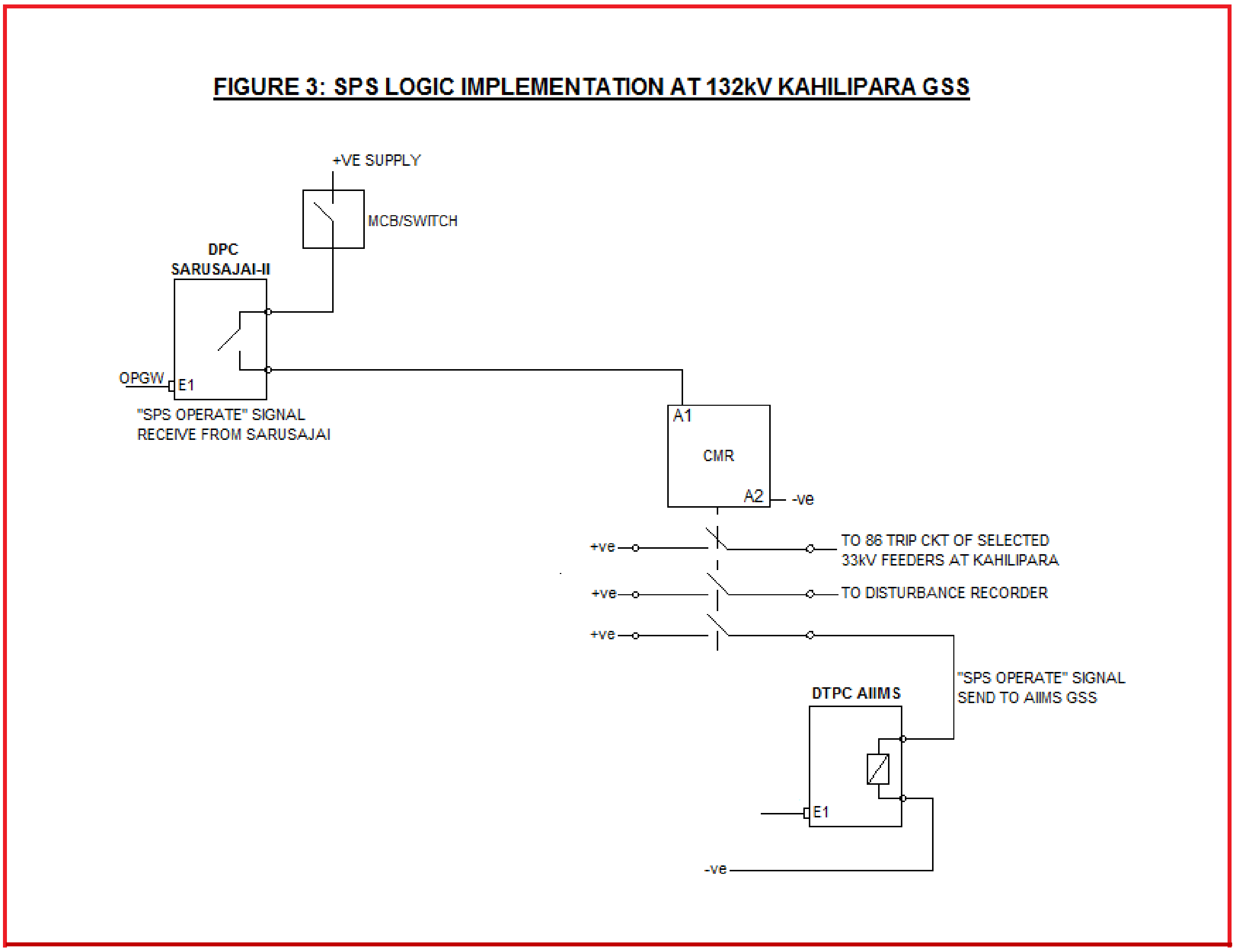

Fig 15: Hardwiring diagram for SPS logic at Kahilipara GSS

As per approval of APDCL, the 33kV Feeders to be tripped upon receiving of SPS operate signal at Kahilipara are: 33kV Ulubari-III, 33kV Jalukbari, 33kV Old Kahilipara and 33kV Borbari

H. WIRING DIAGRAM AT AIIMS

FIGURE 4: SPS LOGIC IMPLEMENTATION AT 132kV AIIMS GSS

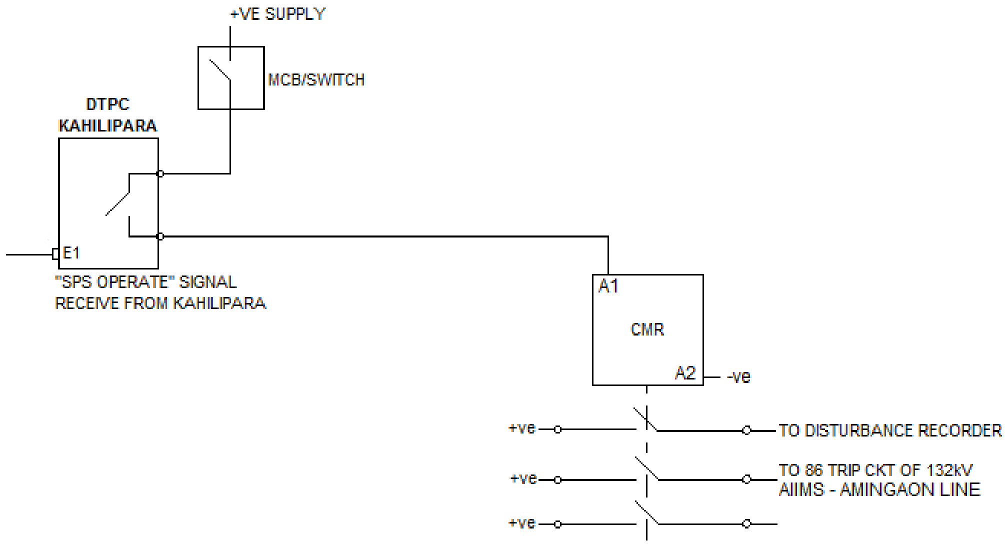

Fig 16: Hardwiring diagram of SPS logic at AIIMS GSS

NOTE: The communication network used for exchange of signals for SPS is based on Optical Fibre Network

<u>FINAL UPDATED LIST OF FEEDERS TO BE TRIPPED DURING SPS OPERATION:</u>

"The tripping of selected non-critical loads in 33kV Feeders has the approval of APDCL"

i) 132kV Sarusajai – Kamakhya Line
ii) 132kV AIIMS – Amingaon Line
iii) 33kV Ulubari-III Feeder
iv) 33kV Jalukbari Feeder
v) 33kV NABARD (Old Kahilipara) Feeder
vi) 33kV Borbari (Narengi) Feeder

(iii)–(vi): At Kahilipara GSS

vii) 33kV Bhetapara Feeder
viii) 33kV Gorchuk Feeder
ix) 33kV Fatasil Feeder
x) 33kV Garbhanga Feeder

(vii)–(x): At Sarusajai GSS

RESTORATION OF THE SYSTEM POST OPERATION OF THE SYSTEM PROTECTION SCHEME (SPS)

For restoration of the lines the following cases may be applicable:

- Case I: if there is delay in charging of the 220kV lines 132kV Amingaon-Kamalpur D/C may be closed in order to restore power to Sishugram and Kamakhya with some amount of load constraint.
- Case II: If there is no delay in the restoration of 220kV Mirza-Sarusajai D/C, then the 132kV lines may be charged normally and monitoring the load the rest of the 33kV lines may also be charged accordingly.

However, all switching operations as mentioned above are subjected to real time grid condition and situations best known to the system operator.

ANNEXURE -V: SYSTEM PROTECTION SCHEME (SPS) LOGIC IMPLEMENTED AT 220kV SAMAGURI GSS AGAINST TRIPPING OF 220kV SAMAGURI-MISA D/C TL

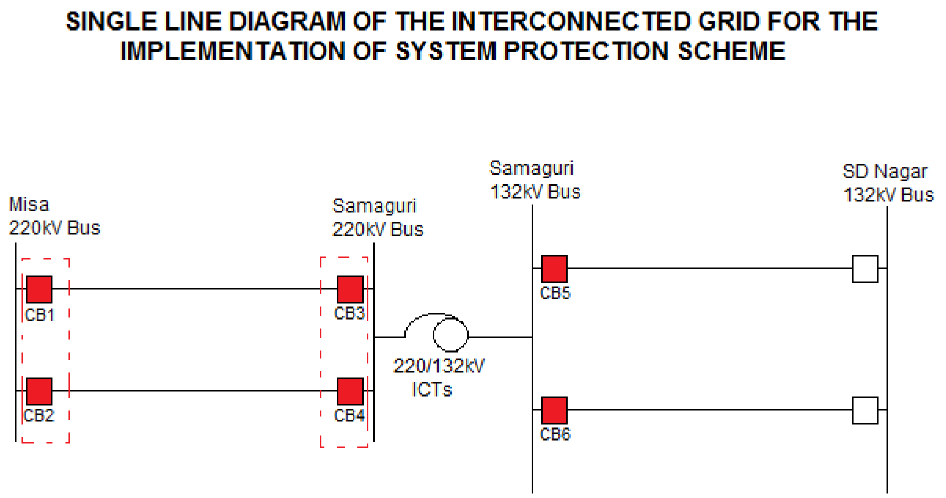

Fig 17: Elements included in SPS Samaguri

A. SPS OPERATION LOGIC DETAILS

On the event of loss of 220kV Samaguri – Misa Line I & II, the following elements are to be tripped to prevent under-voltage scenario in Samaguri area:

a. 132kV Samaguri – SD Nagar Line I
b. 132kV Samaguri – SD Nagar Line II

The loss of 220kV Samaguri – Misa Line I & II should initiate the "Operation of SPS". Two major potential events were taken into consideration while designing the SPS.

CASE A: Both CB's tripped at Samaguri end

CASE B: AR successful at Samaguri end, but both CB's tripped at Misa end

As per CASE A and CASE B, it is observed that the "SPS OPERATE LOGIC" is to be configured both at Samaguri end and Misa end.

B. LOGIC DIAGRAM OF SPS

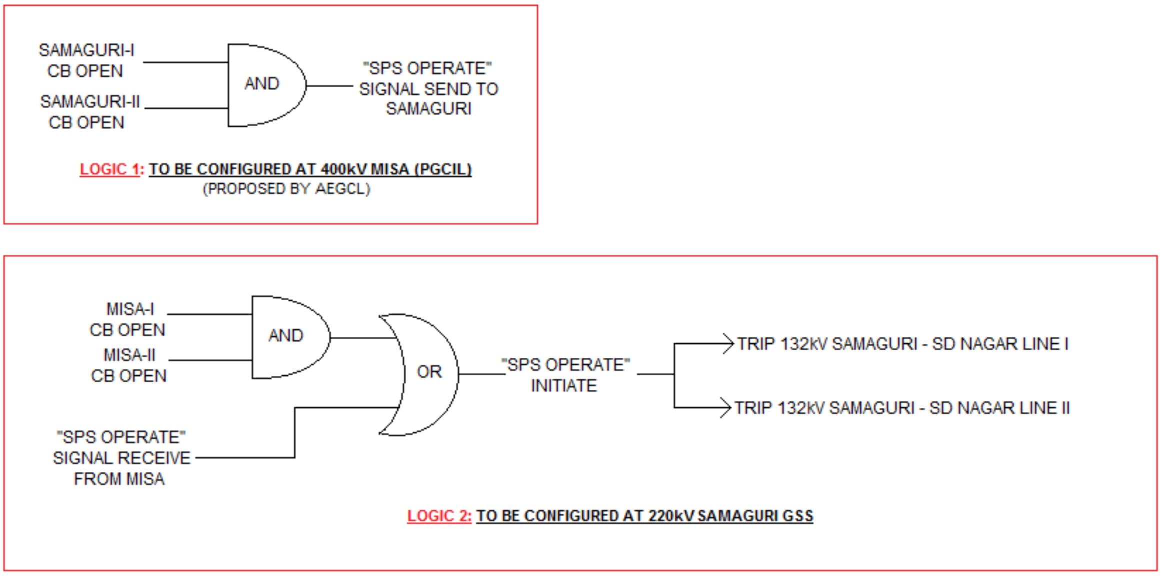

Fig 18: Logic diagram for SPS Samaguri

C. WIRING DIAGRAM AT SAMAGURI

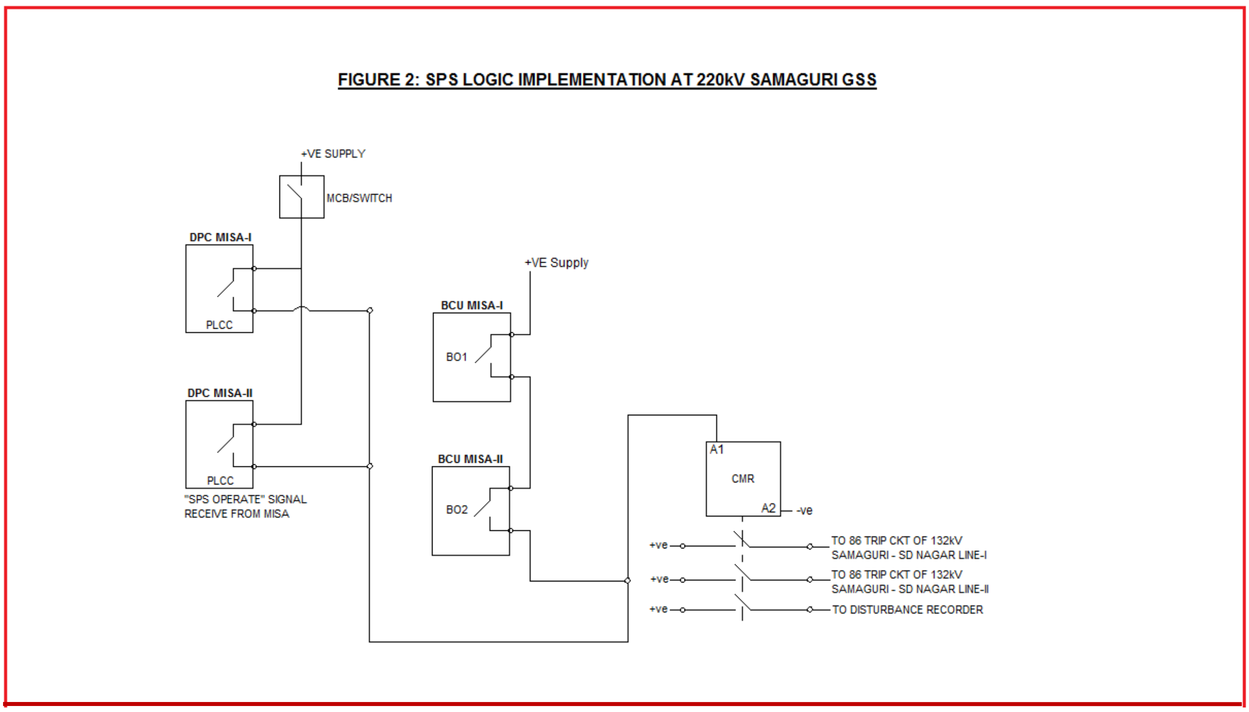

Fig 19: Hardwiring diagram for SPS Logic at Samaguri

D. LOGIC CONFIGURATION AT MISA (PGCIL)

AT PGCIL END: "CB Open" status of both Samaguri ckt I & II are fed to the relay via Binary Inputs. A soft logic (using AND gate) is designed in the PSL "Programmable Sequential Logic" in the MiCOM relay. The output of the AND gate is linked to a Binary Output (BO) which is connected with the PLCC protection coupler. The drop-off time of the Binary Output when the AND logic is high is kept at 50ms. If both the CB's of Samaguri Line I & II are detected in OPEN State, the Logic is fulfilled and a "DT signal" is sent to Samaguri for initiating the SPS operation.

RESTORATION OF THE SYSTEM POST OPERATION OF THE SYSTEM PROTECTION SCHEME (SPS)

For restoration of the lines the following cases may be applicable:

- Case I: If both the lines are restored within the stipulated time 132kV Samaguri- Sankardevnagar I&II will be charged normally.
- Case II: If only one of the 220kV line is restored charging of 132kV Samaguri- Sankardevnagar may be done keeping into account the real time loading, also Load of the Diphu feeder may be shifted to Bokajan and Morigaon feeder which is generally fed from Khaloigaon may be shifted to Baghjap which would help in reducing the line load.
- Case III: If both the 220kV lines are not restored, then until the lines are charged, the load of Diphu feeder may be shifted to Bokajan, load of Morigaon feeder may be shifted to Baghjap and load of Lumding feeder may be shifted to Diphu.

However, all switching operations as mentioned above are subjected to real time grid condition and situations best known to the system operator.

ANNXEXURE - VI: SYSTEM PROTECTION SCHEME (SPS) IMPLEMENTED AT 400/220/132/33kV MIRZA GSS AGAINST REVERSE POWER FLOW IN 2X 315 MVA ICTs.

Description: If a situation arises when the power demand and at 400kV level is more than the generation or effective power flow availability, power may be imported in the reverse direction from 220kV Bus to the 400kV Bus (via 400/220kV, 2X315MVA, Auto-transformers I&II)

To maintain the stability of the transmission system at 220kV level, "Reverse Power Protection" feature has been enabled in the differential relay of the transformers

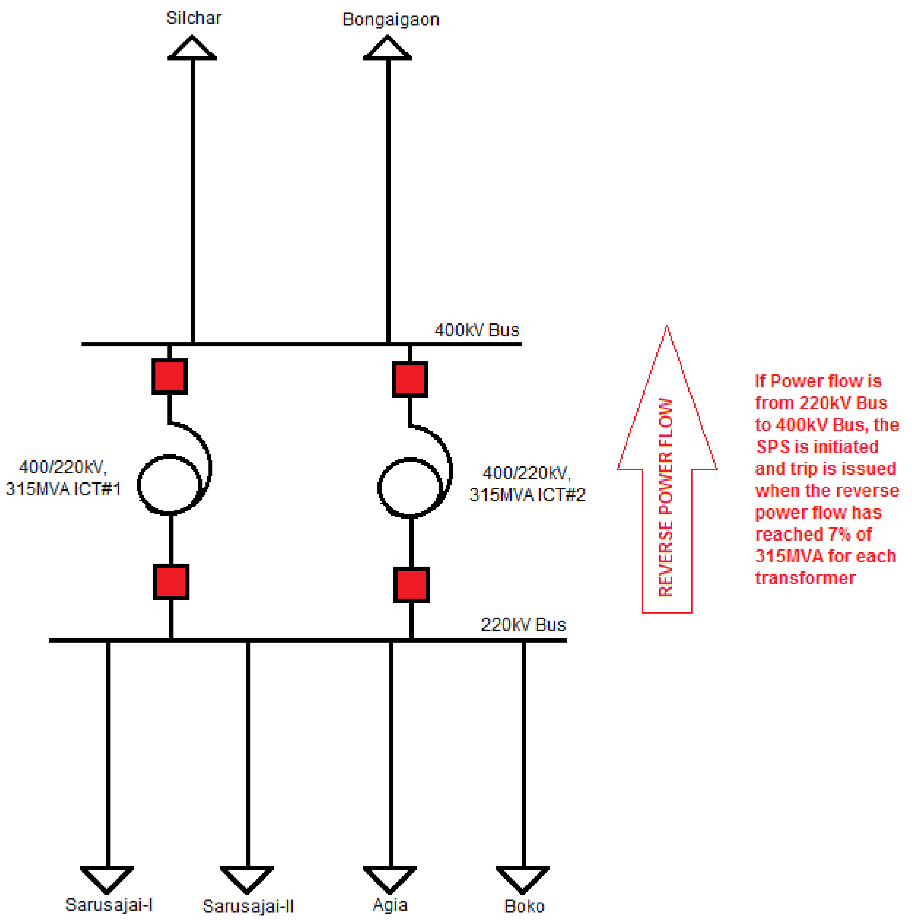

Fig 20: 400kV and 220kV Bus and connected grid elements at 400kV Mirza GSS

The SPS scheme utilizes the "Directional Over power protection function" in reverse direction

Step 1		
Setting Group1		
OpMode1	OverPower	
Power1	7.0	%SB
Angle1	180.0	Deg
TripDelay1	300.000	s
DropDelay1	0.060	s
Hysteresis1	0.5	pu
Step 2		
Setting Group1		
OpMode2	OverPower	
Power2	8.0	%SB
Angle2	180.0	Deg
TripDelay2	0.020	s
DropDelay2	0.060	s
Hysteresis2	0.5	pu

Fig 21: Settings used for "Directional Over-Power Protection"

The settings are grouped into two stages:

Stage I: An overpower protection stage is activated (Step 1). As per the settings, if the direction of power is 180 degrees apart from the direction of Reference Voltage Phasors and the value of Power is more than 7% of the Rated MVA (i.e. 22.05MVA), the Reverse Power Protection (SPS) is activated and a trip is issued (after a delay of 300 seconds) to the HV, Tie and LV Circuit Breakers of the Transformers

Stage II: The second stage is instantaneous (Step 2). As per the settings, if the reverse power flow is more than 8% of rated MVA, the HV, Tie and LV Circuit Breakers are tripped in 20ms

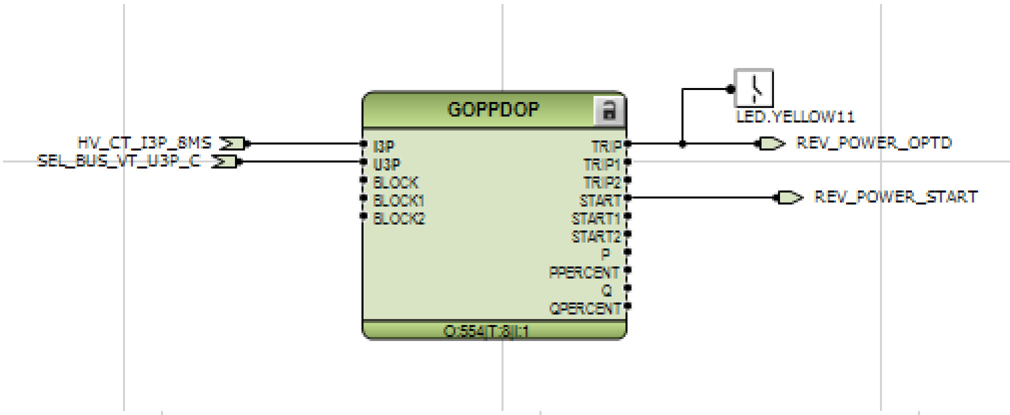

Fig 22: Logic Diagram for the SPS (Reverse Power Protection)

ANNXEXURE -VII: SYSTEM PROTECTION SCHEME (SPS) IMPLEMENTED AT 220/132kV SONABIL GSS TO PRESERVE THE SYSTEM STABILITY AGAINST OVERLOADING OR LOSS OF 220kV SONABIL – BALIPARA LINES I & II

The SPS Logic Implemented at Sonabil are based on two “Triggering Criteria”

A. TRIGGERING CRITERIA-I
(When loading of any one circuit of the 220kV Sonabil – Balipara D/C line surpasses 630A)

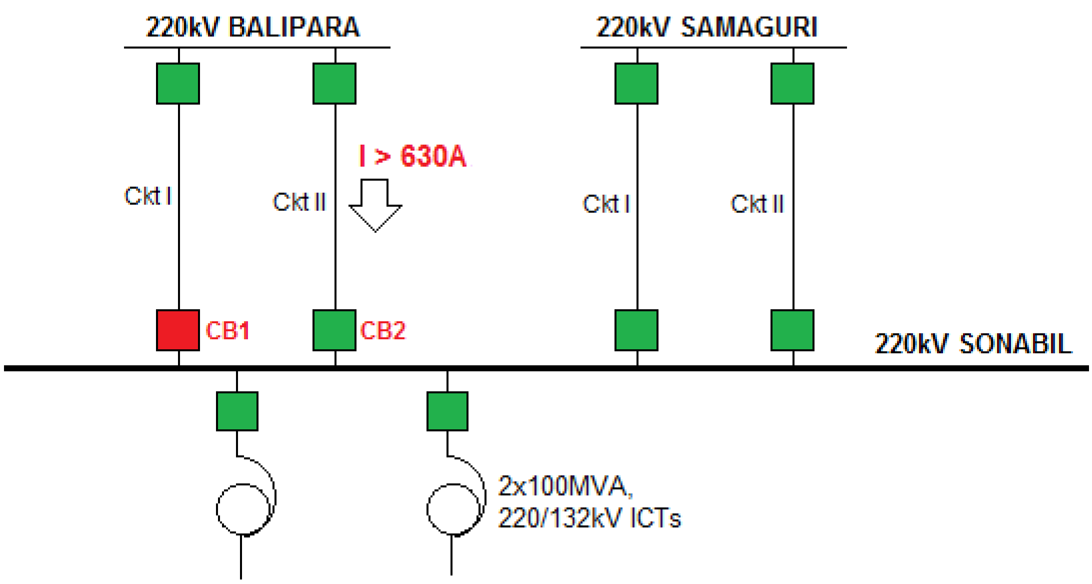

Fig 23: Loss of any ckt among the 220kV Sonabil – Balipara Double Ckt Line

As per the thermal loading limits for ACSR Zebra or equivalent conductor, it was proposed by NERLDC to restrict the loading of the 220kV Sonabil – Balipara double ckt line at 630A per circuit (worst case scenario). Such a scenario would arise when:

a. If any circuit of the double Sonabil – Balipara double ckt line is lost during peak load hours, the total load would be shifted to the other healthy circuit which would cross 630A.
b. Transient overloading (During auto-reclosure dead time) in the adjacent parallel circuit

The designed SPS logic is as below:

a. As per the present trend of loading in the lines, the current in any circuit would cross 630A, **only when** another circuit is lost during peak load hours. As such, the “TRIP STATUS” of the circuits is not incorporated in the logic.

b. A "Non-tripping" Non-Directional Definite Time Overcurrent (50) protection function will be used from the Main-1 relay (SIEMENS 7SA522) of each Balipara line. If the current read by the relay exceed 630A for a time period of 1700ms, the OC stage would be high and an "Binary Output" of the relay would be latched
<u>PROTECTION FUNCTION USED FOR SPS:</u>
    - Curve: Definite Time
    - Direction: Non-Directional
    - Pickup: 630A
    - Delay: 1700ms
c. The time delay of 1700ms is proposed as per:
    - Auto-reclosure dead time of 1 second
    - Pole Discrepancy time of the Breaker: 1.5 seconds
    - Directional Earth fault operating time of 0.9s (for maximum possible earth fault current, 3Io, depending on the resistivity of the fault, the value of 3Io may decrease)
d. The Latched Binary Output is connected to a Contact Multiplier Relay (CMR), the auxiliary NO (Normally Open) contacts of which are connected to the Master Trip relay Operating coils of 220kV Sonabil – Samaguri Line I & II
e. Hence, as per the above logic, whenever any circuit of the 220kV Sonabil – Balipara I & II crosses 630A for a time period of 1700ms, the SPS would be activated and the CBs of 220kV Sonabil – Samaguri Line I & II will be tripped

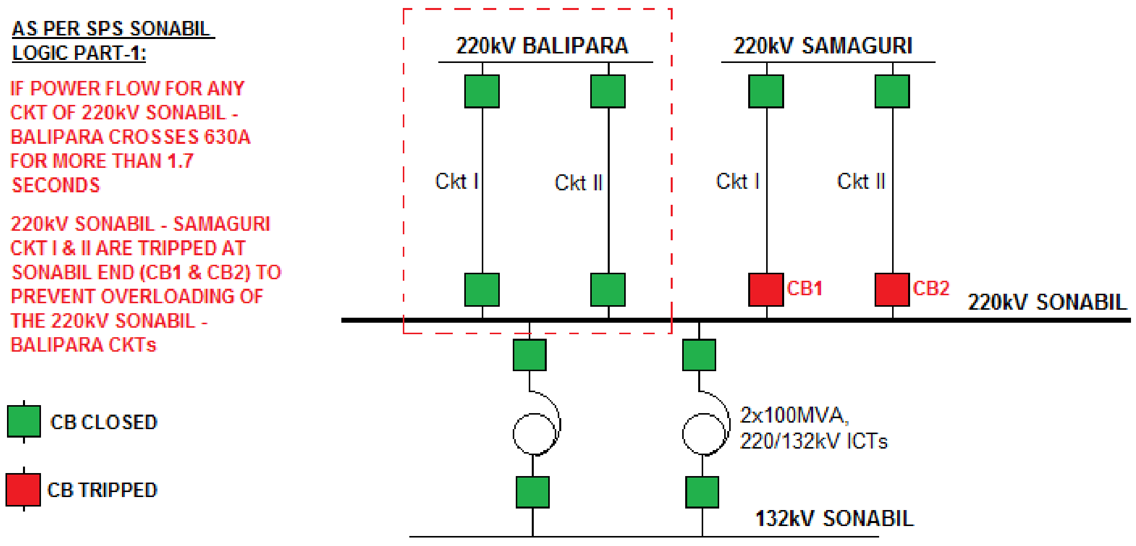

Fig 24: Tripping of 220kV Sonabil – Samaguri Line I & II as per SPS Logic

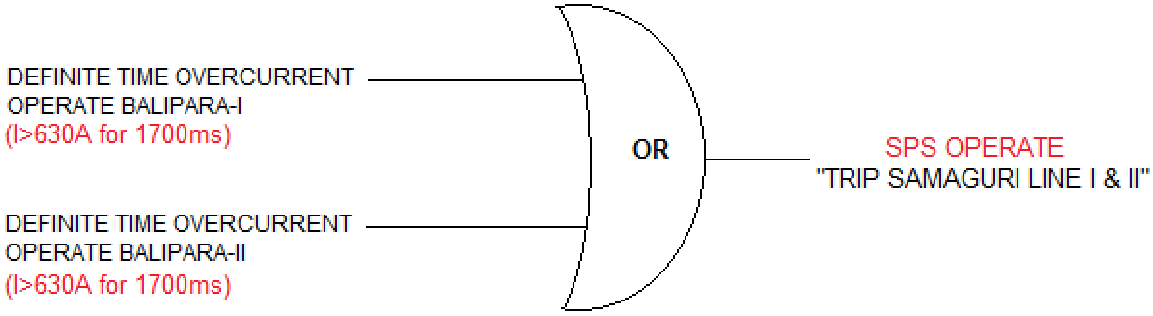

Fig 25: SPS Logic Diagram

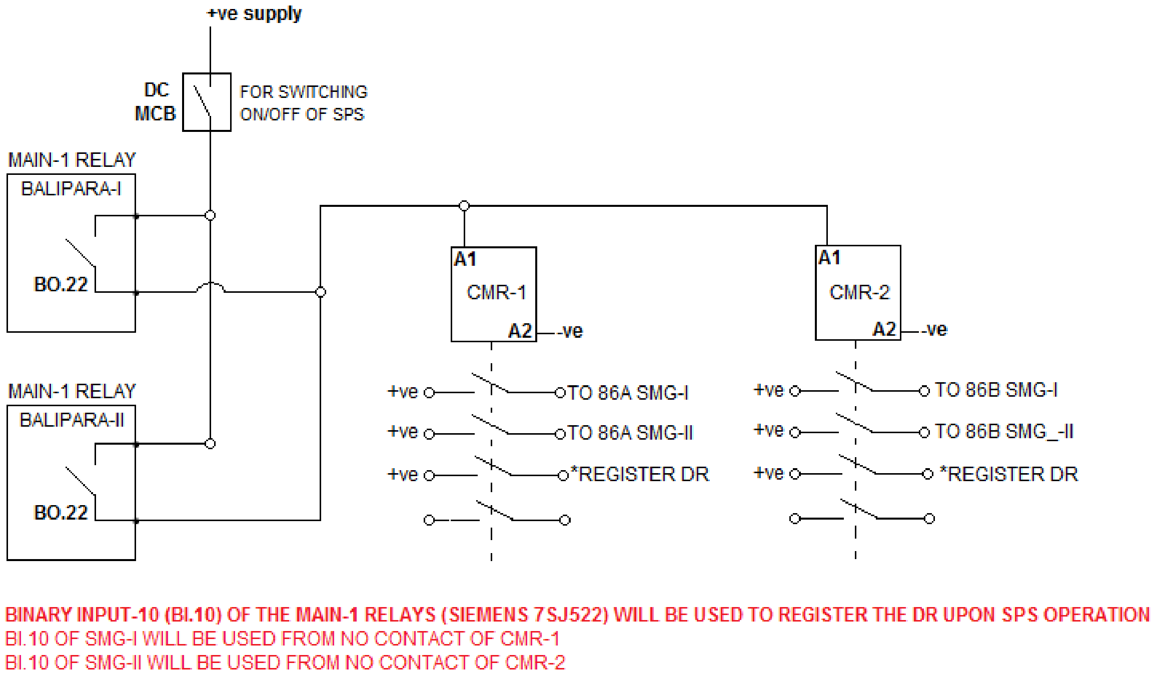

Fig 26: Connection Diagram for SPS Implementation (Triggering Criteria-I)

B. TRIGGERING CRITERAI-II

Tripping of both 220kV Sonabil – Balipara D/C line

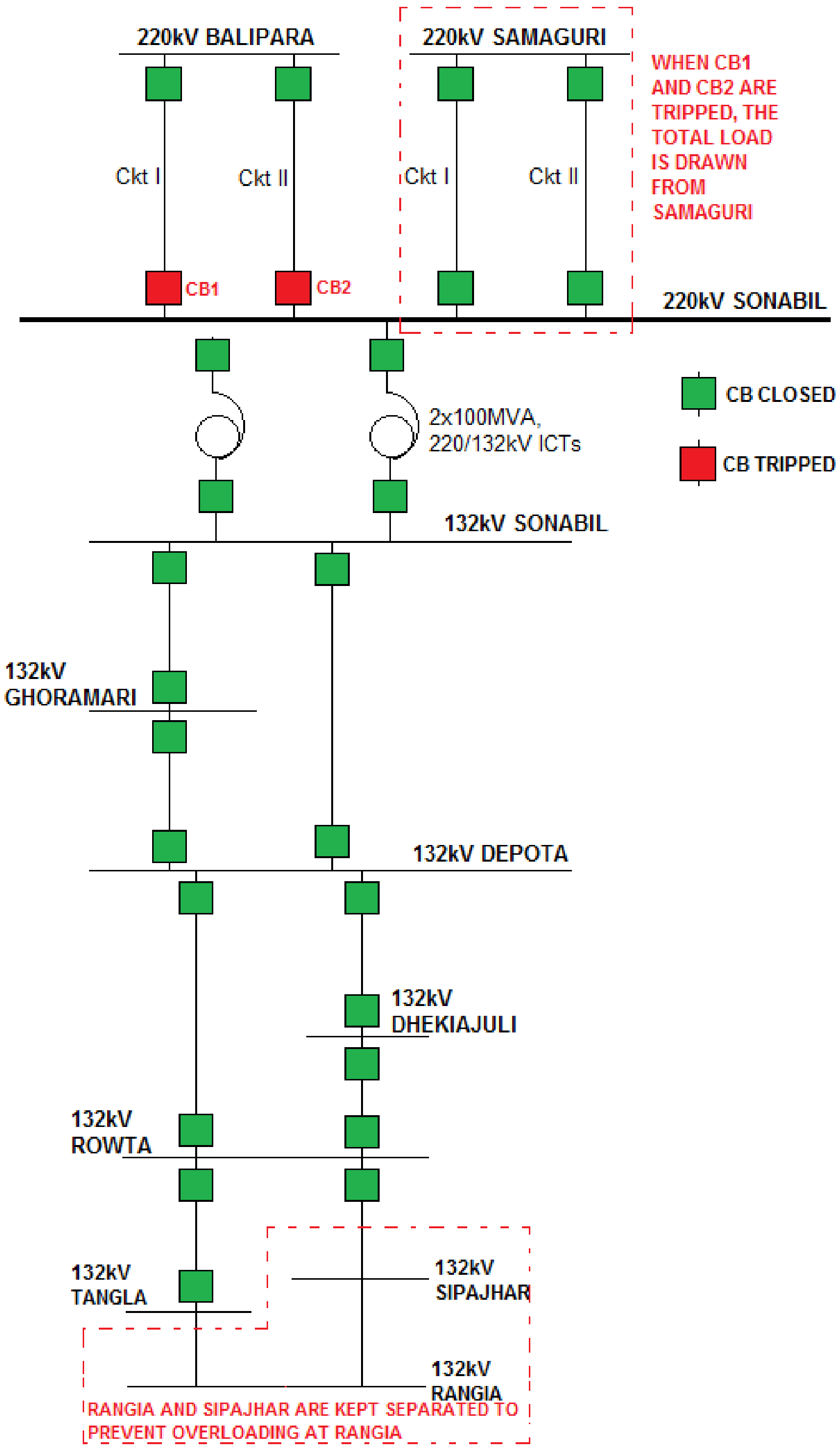

Fig 27: Loss of both Circuits of 220kV Sonabil – Balipara D/C line

The transmission system in the Sonabil area is as follows:

a. The only power source for 132kV Depota, 132kV Ghoramari, 132kV Rowta, 132kV Dhekiajuli, 132kV Tezpur and 132kV Tangla is 220kV Sonabil Grid Substation. The 132kV network is kept in radial configuration as synchronizing the same with Rangia Grid pose potential threat of overloading of Rangia 2x100MVA ICTs.
b. As such, if both the circuits of 220kV Sonabil – Balipara D/C line are lost, the total load of (Depota, Ghoramari, Rowta, Dhekiajuli, Tezpur and Tangla) would be fed from 220kV Sonabil – Samaguri D/C lines. This condition is vulnerable for 220kV Samaguri – Misa D/C lines and interconnectivity of Samaguri with Guwahati (Capital) area

Hence, as per system study performed by NERLDC and SLDC, it was decided that, a total controlled load shedding of 90MW (in case of loss of Sonabil – Balipara D/C line) would be sufficient with respect to present load conditions to safeguard the Sonabil transmission network. The shedding would be achieved by tripping of 33kV Outgoing Feeders (DISCOM) at the downstream 132kV Substations. The exchange of SPS tripping signals would be achieved by using spare codes of the PLCC protection coupler in the 132kV Lines.

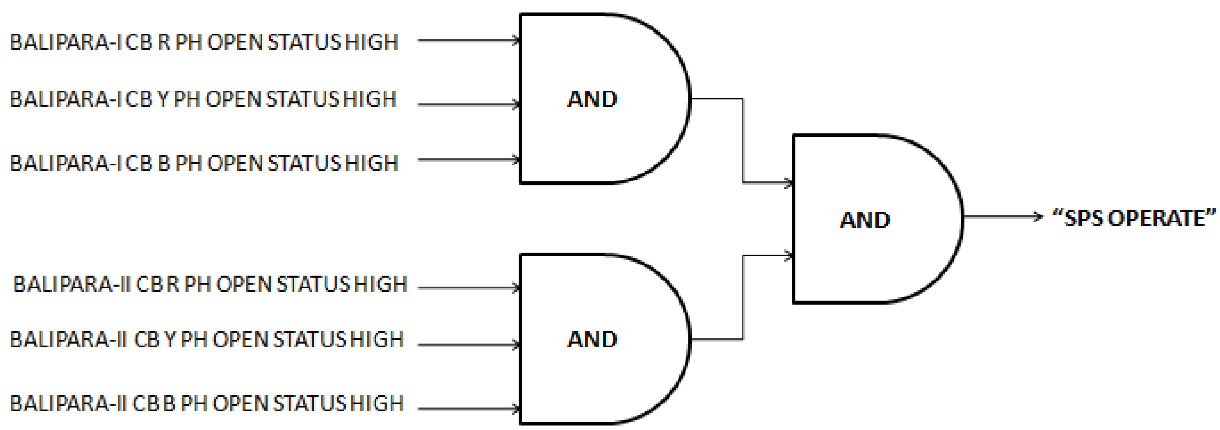

Fig 28: SPS Initiation Logic for loss of both circuits of 220kV Sonabil – Balipara D/C Line

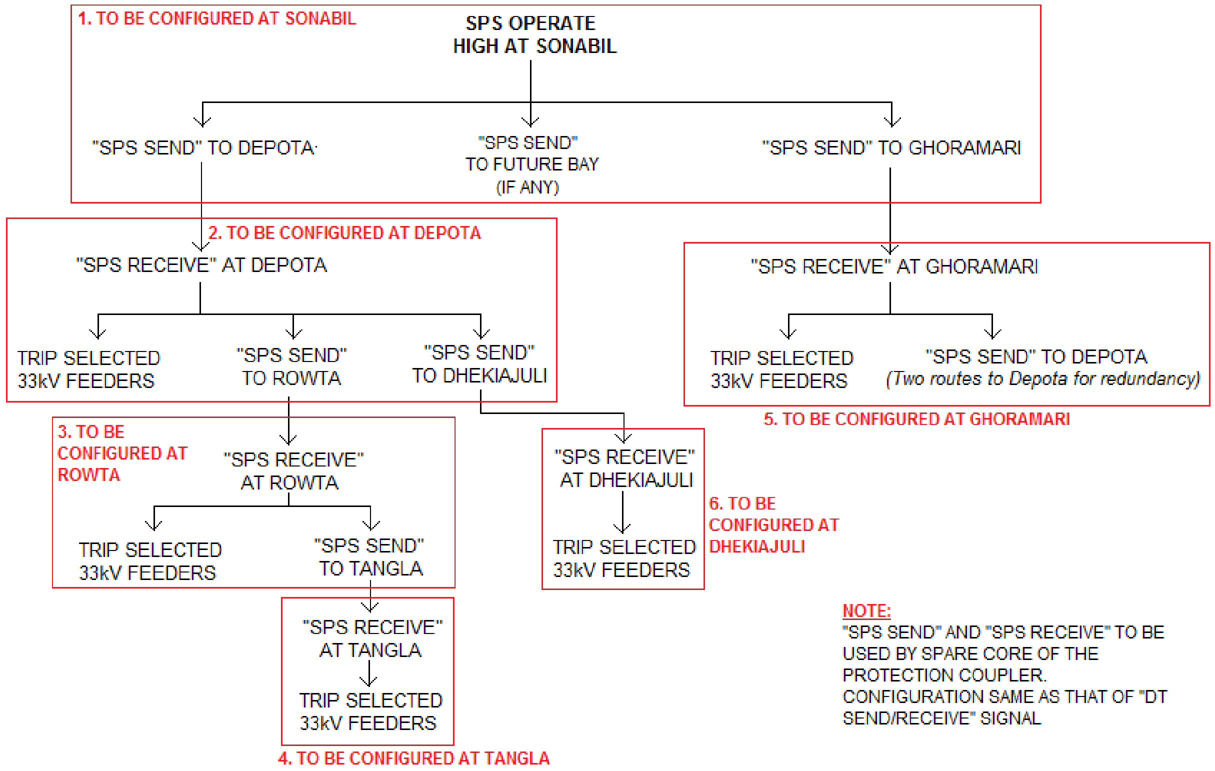

Fig 29: Exchange of "SPS Operate" signals between substation and 33kV trip operations

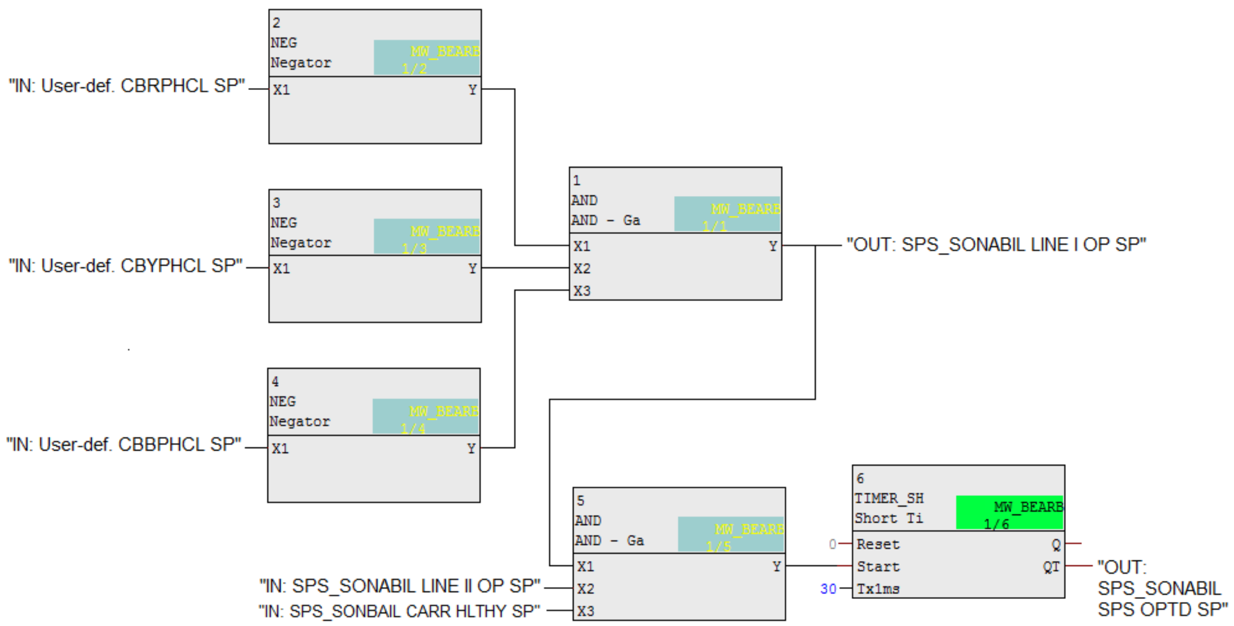

Fig 30: SPS OPERATED "TRIGGERING CRITERIA-2" LOGIC DIAGRAM "SIEMENS CFC LOGIC"

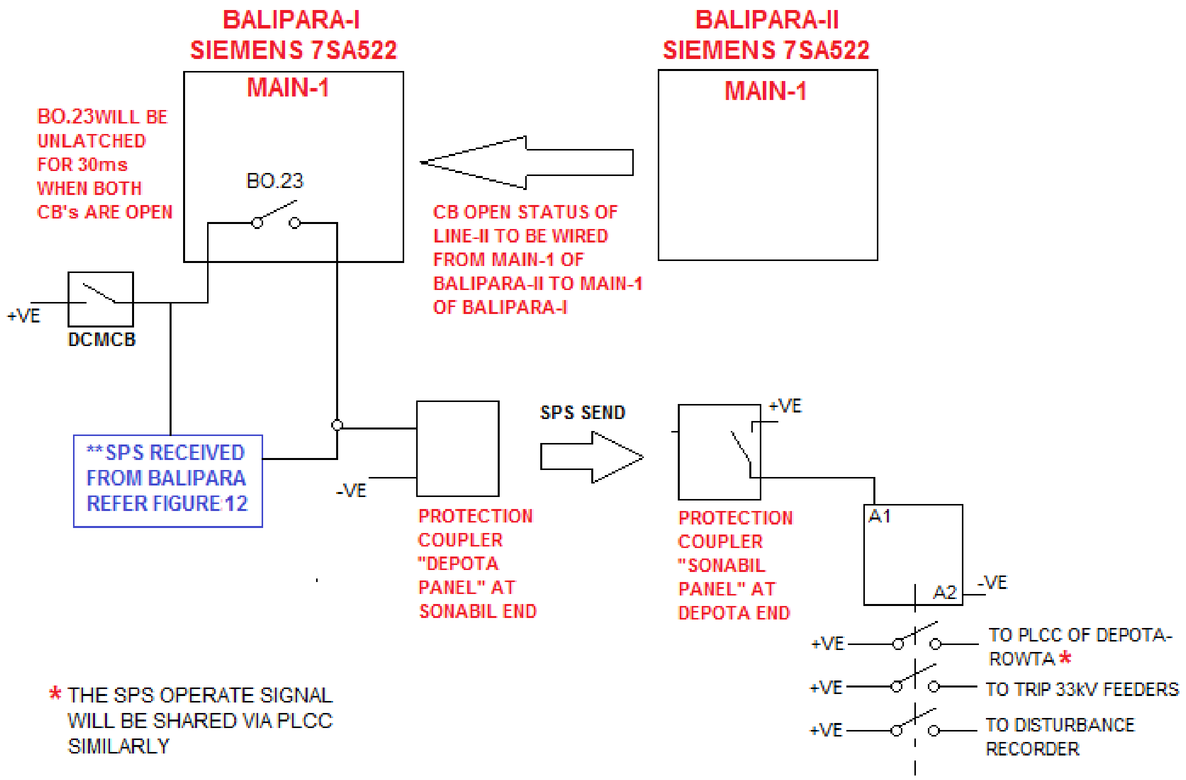

Fig 31: SPS TRIGGERING CRITERIA-II CONNECTION DIAGRAM

As the initiation and operation of SPS depends solely on the healthiness of PLCC channel of 132kV Lines at Sonabil end, the extended logic is designed to trip the ICT's at Sonabil (2x100MVA) in case of loss of two circuits of 220kV Sonabil – Balipara I & II during unhealthy PLCC links of 132kV Lines at Sonabil GSS.

The Carrier Healthy status of 132kV Lines will be connected to the Main-1 relay of 220kV Sonabil – Balipara Ckt I. In case of loss of carrier healthiness, the former logic will be blocked and the logic as per figure-10 will be activated. The output will trip both the ICTs at Sonabil end.

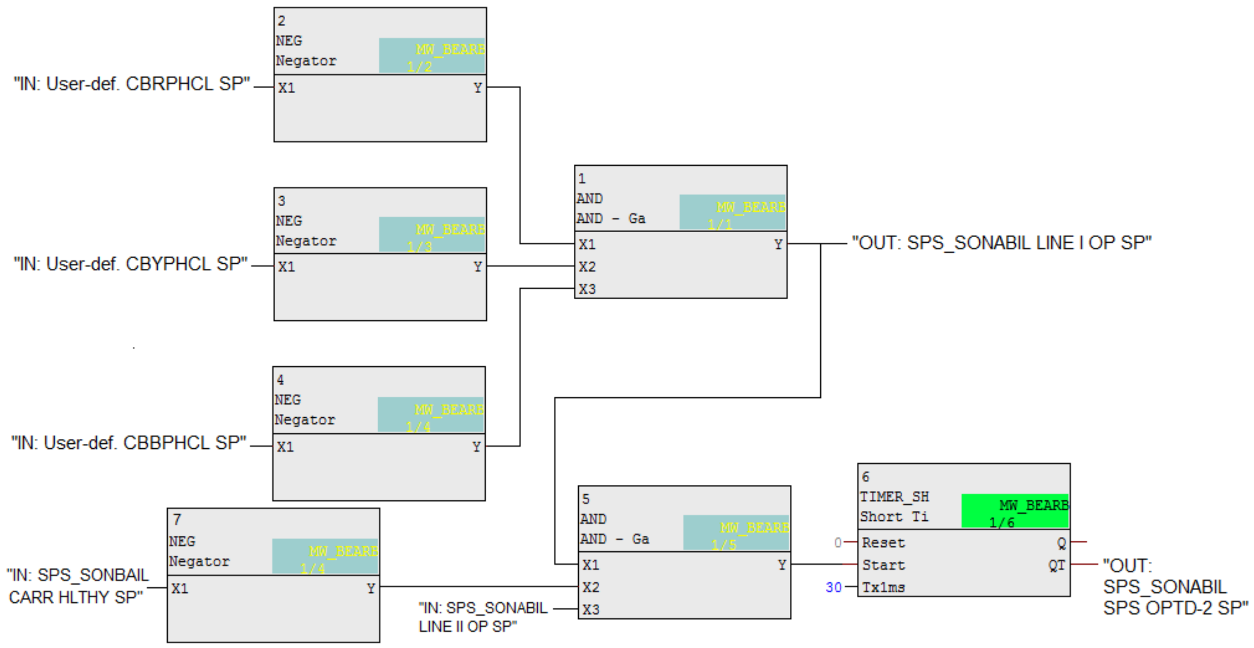

Fig 32: SPS Operate logic in case of Carrier Healthiness

A. LIST OF 33kV FEEDERS TO BE TRIPPED DURING OPERATION OF SONABIL-SPS

DEPOTA	GHORAMARI	DHEKIAJULI	ROWTA	TANGLA
AIR FORCE	HANCHARA	MAJBAT	HARISINGA	KALAIGAON
GOHORDOUL	PATANJALI	BORSOLA	UDALGURI	PANERI
SONABIL	JAMUGURI	MIJIBARI	DALGAON	TANGLA
TEZPUR 3	DABUR	SINGRI	MAZBAT-1	**14MW**
LAXMN MRG	**15.6MW**	**9MW**	ROWTA	
MISSAMARI			KHARUPETIA	
TEZPUR TWN			**27MW**	
TMC				
DHEKIAJULI				
MISSMRI CVL				
28.8MW				

TOTAL SHEDDING = 94.4MW

NOTE: In case of loss of carrier healthiness in any of the downstream lines (viz. 132kV Sonabil - Depota, 132kV Sonabil – Ghoramari, 132kV Depota – Rowta, 132kV Rowta –

Tangla, 132kV Depota – Dhekiajuli), the 132kV Incomer CB will be tripped at the connecting sub-station end. The necessary logic for the same will be implemented in the distance relay (similar to the logic defined in fig-10)

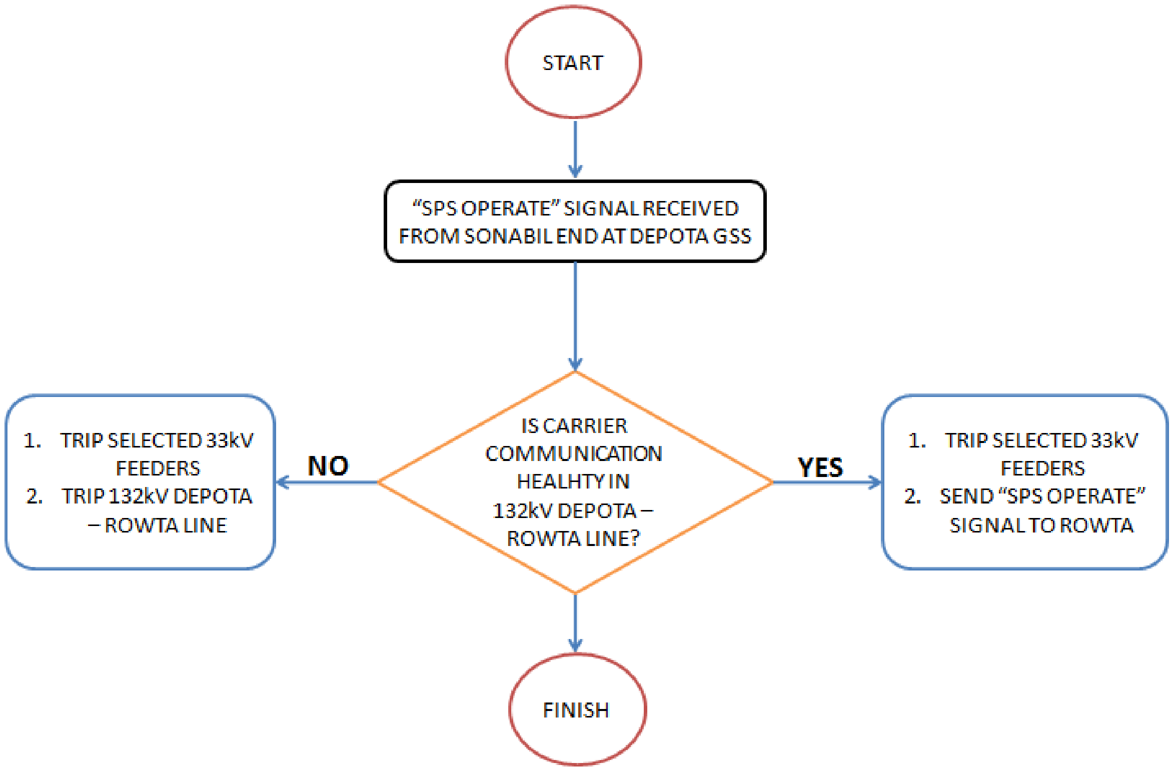

Fig 33: SPS Logic in downstream substation considering the healthiness of Carrier Channel

B. SPECIAL CASE: AR SUCCESSFUL FOR BOTH LINES AT SONABIL END WHERE BOTH CB's TRIPPED AT BALIPARA END

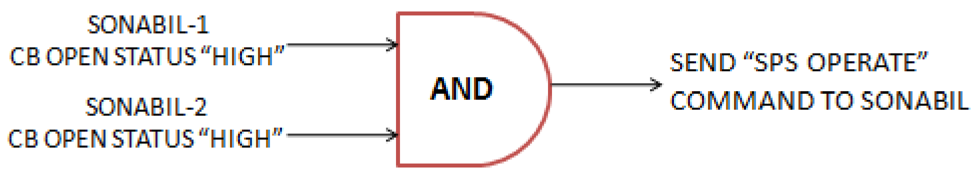

Fig 34: SPS Logic to be configured at Balipara end

Note: Presently, due to absence of Healthy Carrier Protection network between Sonabil – Ghoramari – Depota – Rowta links, the extended Logic of SPS Triggering Criteria-II is active. As per the logic, on Initiation of SPS Triggering Criteria-II, both the ICTs (2x100MVA) are tripped at Sonabil GSS. The logic will be updated as per the above literature once the carrier healthiness is restored in the concerned transmission links

ANNXEXURE -VIII: SYSTEM PROTECTION SCHEME (SPS) IMPLEMENTED IN THE 132kV TINSUKIA – MARGHERITA – RUPAI - CHAPAKHOWA LINK TO PREVENT OVERLOADING OF THE TRANSMISSION LINES OF 132kV TINUSKIA – RUPAI AND 132kV TINSUKIA - MARGHERITA

TIGGERING CRITERIA I - The current carrying capacity of the 132kV Tinsukia – Margherita – Rupai and 132kV Tinsukia – Rupai Lines are restricted to 300A. (The limitation is maintained due to prevailing conductor constraint)

However, during the loss of any of the parallel circuits viz. 132kV Tinsukia – Margherita or 132kV Tinsukia – Rupai during peak load condition, the other circuit is prone to be overloaded which may cause subsequent damage to conductors.

The SPS logic is designed as per which, if current in any of the circuits of 132kV Tinsukia – Margherita or 132kV Tinsukia – Rupai crosses 300A in real time scenario, the Circuit Breakers of 132kV Chapakhowa – Roing Lines I & II will be opened along the Bus Reactor (20MVAr) at Roing. A further automatic load shedding of 8 to 10MW will be carried out at Rupai end if current still exceeds 300A after operation of the 1st step in the SPS logic.

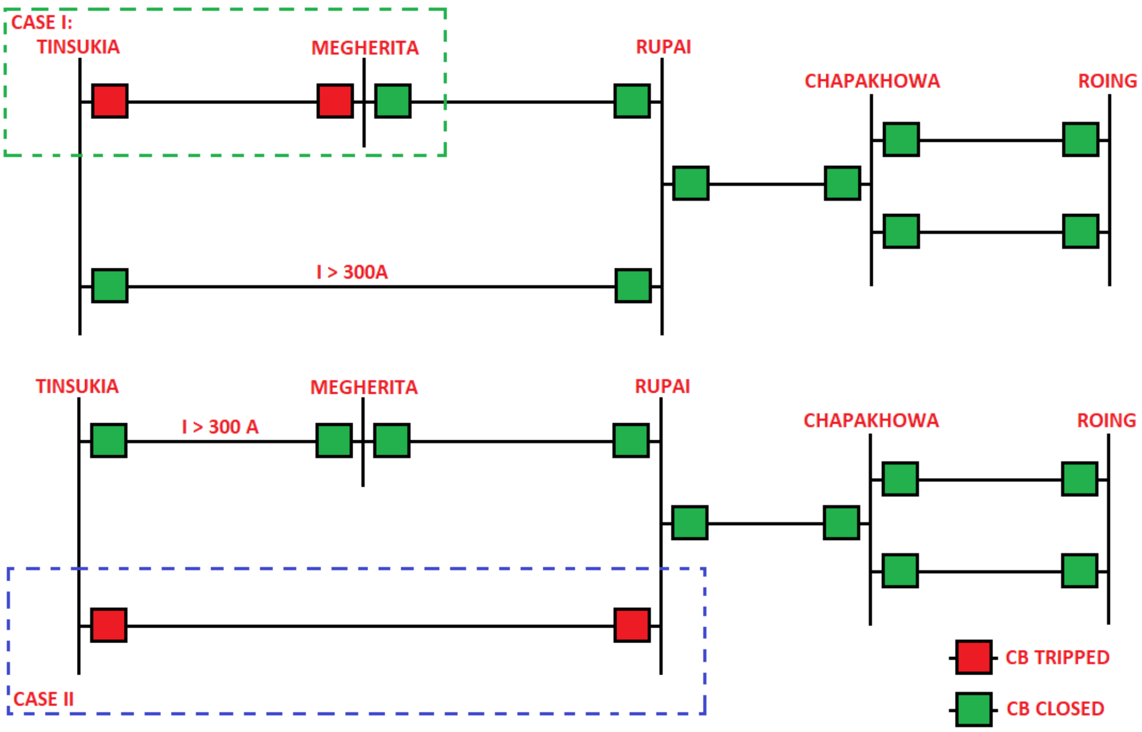

Fig 35: SPS initiation condition

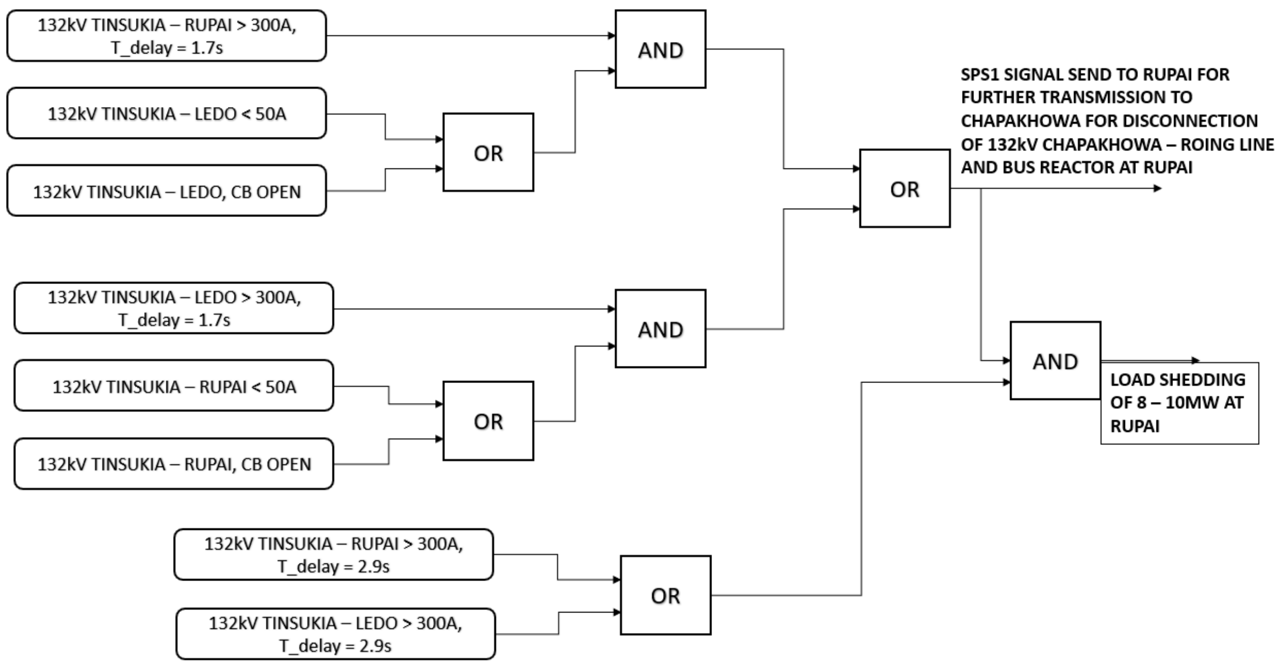

Fig 36: SPS Triggering Criteria I

TIGGERING CRITERIA II – On event of loss of 132kV Ranganadi – Ziro line in the Arunachal Pradesh System, to mitigate the overloading of 132kV Tinsukia – Rupai line, an automatic load shedding of 8 – 10MW will be carried out at Rupai end, when the current in the 132kV Tinsukia – Rupai line exceeds 300A

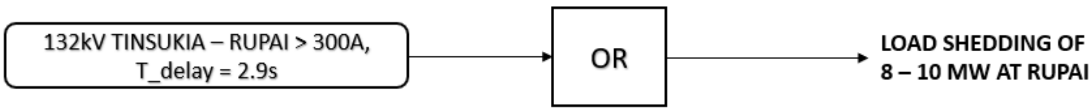

Fig 37: SPS Triggering Criteria II

ANNXEXURE -IX: 220kV SALAKATI GSS – SYSTEM STABILITY AGAINST LOSS OF N-1 CONTINGENCY FOR 2X160MVA, 220/132kV ICTs AT SALAKATI DURING PEAK LOAD CONDITIONS

A. PRESENT SYSTEM CONDITION

220/132/33kV Salakati GSS is one of the most critical substations in Lower Assam Region catering load to the districts of Kokrajhar, Dhubri, Bongaigaon, Barpeta and critical industrial loads of IOCL, Railways etc.

The highest peak load was recorded at **323 MW** (340MVA considering a PF of 0.95) during the summer of 2023. During period from January – June 2024, it has been observed that the transformers have time and again failed to satisfy the N-1 contingency criteria.

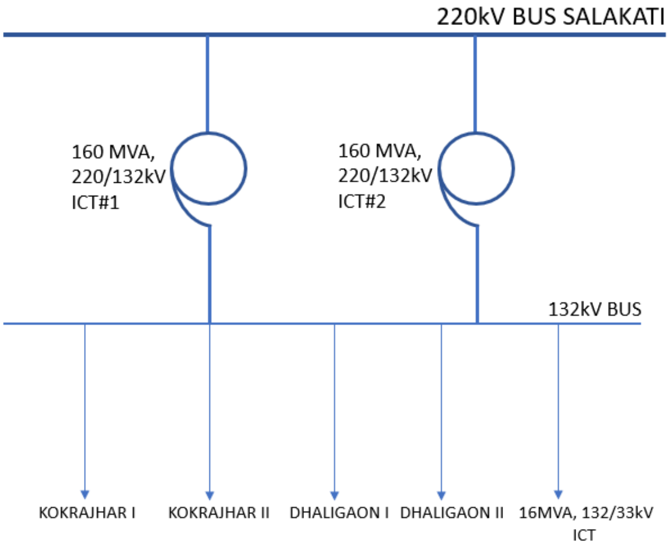

Fig 1: *Feeder connected to the 132kV Bus at 220kV Salakati GSS*

In that case, on the event of loss of one 160MVA ICT, the healthy ICT is prone to be overloaded resulting in blackout of the entire transmission network as shown below:

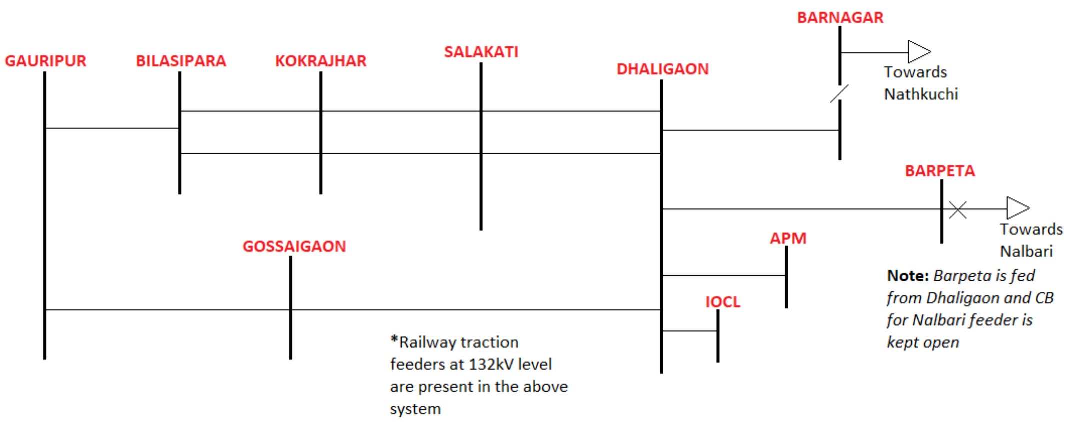

Fig 2: *Affected network in case of loss of both ICTs at Salakati GSS*

B. DESIGN OF SYSTEM PROTECTION SCHEME

i) **SCHEME DESCTIPTION:** The 2X160MVA ICTs are allowed to be loaded to 120% of its capacity (As per the relay settings). The overloading above nominal rating is monitoring continuously with respect to the healthiness of OFAF system of the transformer.

As per system studies (conducted by NERLDC and SLDC), a total load shedding of 140 MW (instantaneous) is required to preserve the stability of the system in case of loss of one ICT during peak load condition. The remaining percentage of overload (if exists any post the controlled shedding) must be manually controlled by the operations team

ii) IDENTIFICATION OF LESS CRITICAL 33kV LOADS:

A list of feeders was shared by concerned authorities of DISCOM (APDCL) which were allowed to be included in the controlled load shedding logic of the SPS.

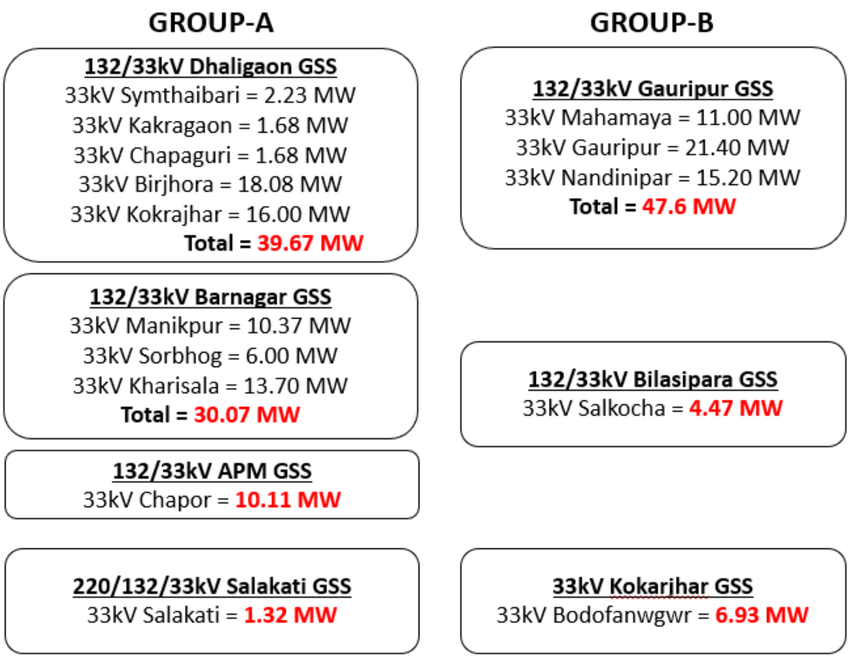

Fig 3: *List of 33kV feeders (to be included in the controlled load shedding) as approved by APDCL*

The substations to be included in the designed SPS are viz. 220kV Salakati GSS, 132kV Kokrajhar GSS, 132kV Bilasipara GSS, 132kV Gauripur GSS, 132kV Dhaligaon GSS, 132kV APM GSS and 132kV Barnagar GSS. The loads are grouped into two different groups: **GROUP-A** and **GROUP-B**

The PLCC/Optical Link between the substations would be utilized for transmitting the SPS signals from one substation to another as per the SPS defined logic.

iii) THE IDENTIFIED LOADS ACROSS THE TRANSMISSION NETWORK

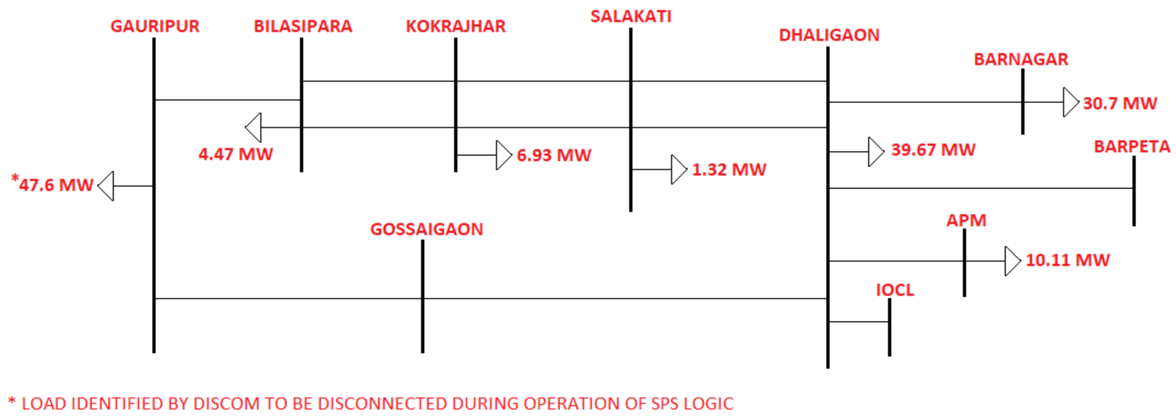

Fig 4: *Less critical loads across the transmission network included in the SPS Logic*

iv) DESIGN OF THE SPS LOGIC:

The protection scheme for 160MVA, ICTs at Salakati is: **Main 1 and Main 2 Protection**

The LV side protection functions are included in the Main 2 relay (ABB Make REL 650). As the scheme is dependent upon overloading of transformer (irrespective of voltage phasor), a non-directional definite time overcurrent protection function will be used for the SPS Logic

Overcurrent Protection Stage-1 is already used for the basic Overcurrent protection of the transformer. The settings are as follows:

- **Direction:** Non-Directional
- **Pickup:** 120% of Full Load
- **TMS:** 0.35
- **Curve:** IDMT Normal Inverse Curve

The designed SPS will include the Overcurrent Stage-2 and Overcurrent Stage-3 protection functions.

The total load shedding of 140MW will be done in two stages. Stage-2 would include the 33kV feeders associated with "GROUP-A" and Stage-3 would include the 33kV feeders associated with "GROUP-B" (***Refer fig. 3***)

The settings are defined as:

Overcurrent Stage-2 (SPS)

Pickup: 121% of full load

Curve: IEC Definite Time

Delay: 2 Seconds

Overcurrent Stage-3 (SPS)

Pickup: 121% of full load

Curve: IEC Definite Time

Delay: 3 Seconds

The above delays for Overcurrent Stage-2 and Stage-3 are kept as 2 seconds and 3 seconds based on the following analysis:

As overcurrent function of the relay is not a protection function to detect "Overloading", hence any overloading would also pickup the normal Overcurrent Protection in the relay (In this case Overcurrent Stage-1)

Analysing the ROT against fault current as per the OC settings of (Pickup: 120% F.L. and 0.35 TMS), we have:

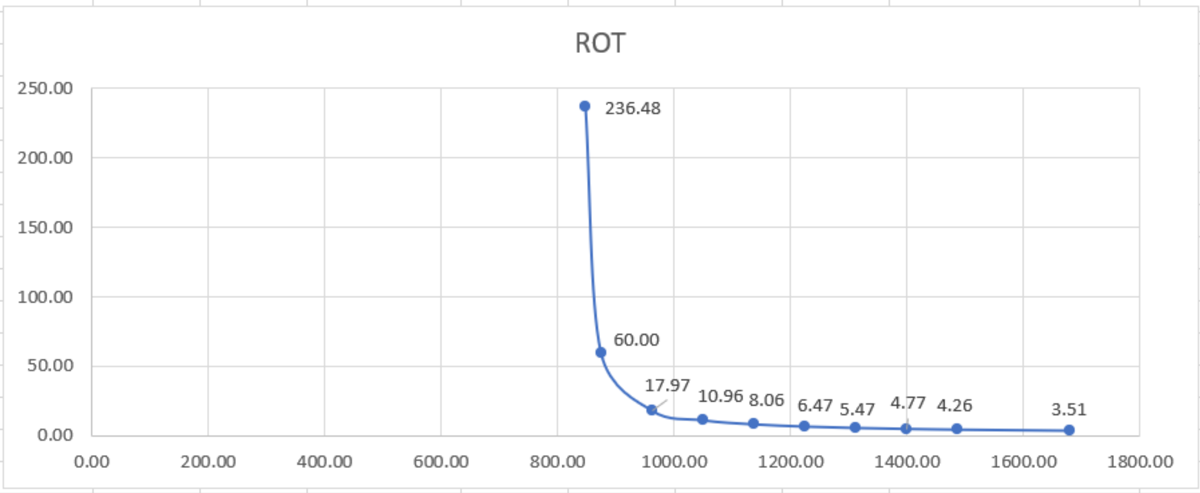

Fig 5: *ROT comparison with respect to fault current (X-axis: I_fault, Y-axis: ROT)*

With respect to the above data, it is observed that if both the transformers are loaded to 120% of their full load capacity (i.e. 384MVA), the loss of one transformer would overload the other transformer to 384MVA. The normal OC protection would trip after a time of **3.51 seconds**

Hence, the SPS operate delay of 2 seconds and 3 seconds would not overlap with the normal IDMT normal inverse curve of the basic overcurrent settings

v) PARAMETERS USED IN DESIGNING THE LOGIC:

The parameters to be included in the logic are viz:

a. CB Open status (LV side) of both ICTs
b. Master Trip (86LV) operate status of both the ICTs
c. Carrier healthy signal status of concerned transmission lines at 132kV level
d. Operate condition of Overcurrent Stage-2 and Stage-3 for both the ICTs
e. LBB block signal (LV side) of both the ICTs

vi) THE LOGIC DIAGRAM OF SPS:

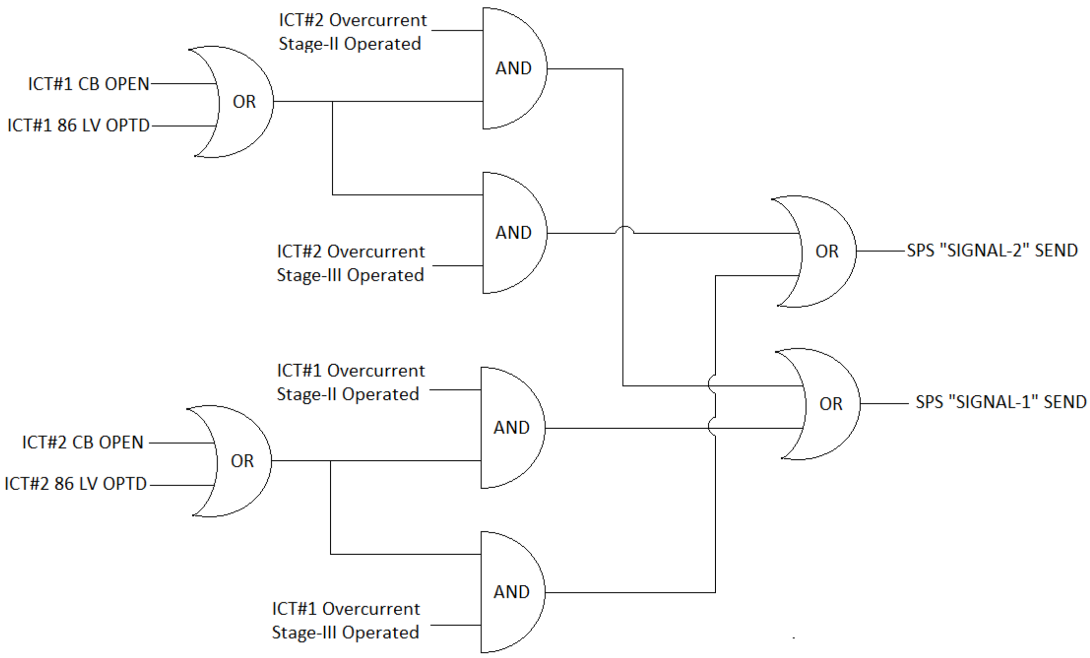

Fig 6: *SPS Logic Diagram*

Referred to **fig. 3**, the combined load for 33kV Feeders in GROUP-A is **81.17 MW** and that of the 33kV feeders included in GROUP-B is **59 MW**

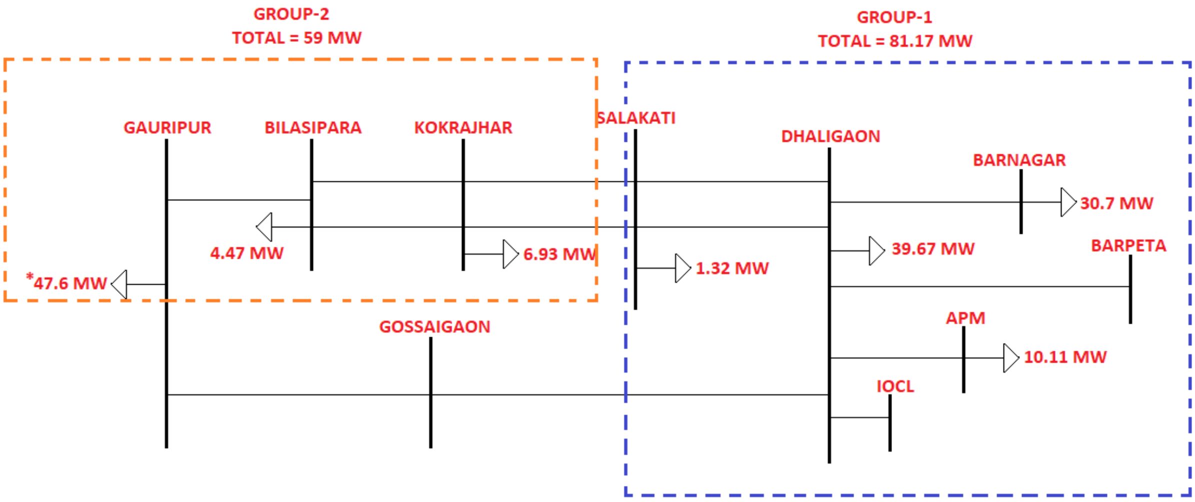

Fig 7: *Overload less critical loads are divided into two groups*

SPS "SIGNAL-1" would disconnect the feeders in GROUP-1 (after a delay of 2 seconds) and if overload still persists, **SPS "SIGNAL-2"** would further disconnect the feeders in GROUP-2 (after a delay of 3 seconds). A combined load shedding of **140.17 MW** will be achieved by the SPS operation. In case, if a minor overloading still persists after the operation of SPS, the same can be achieved by controlled manual load shedding by the operators.

vii) HARDWIRING DIAGRAM FOR THE SPS LOGIC

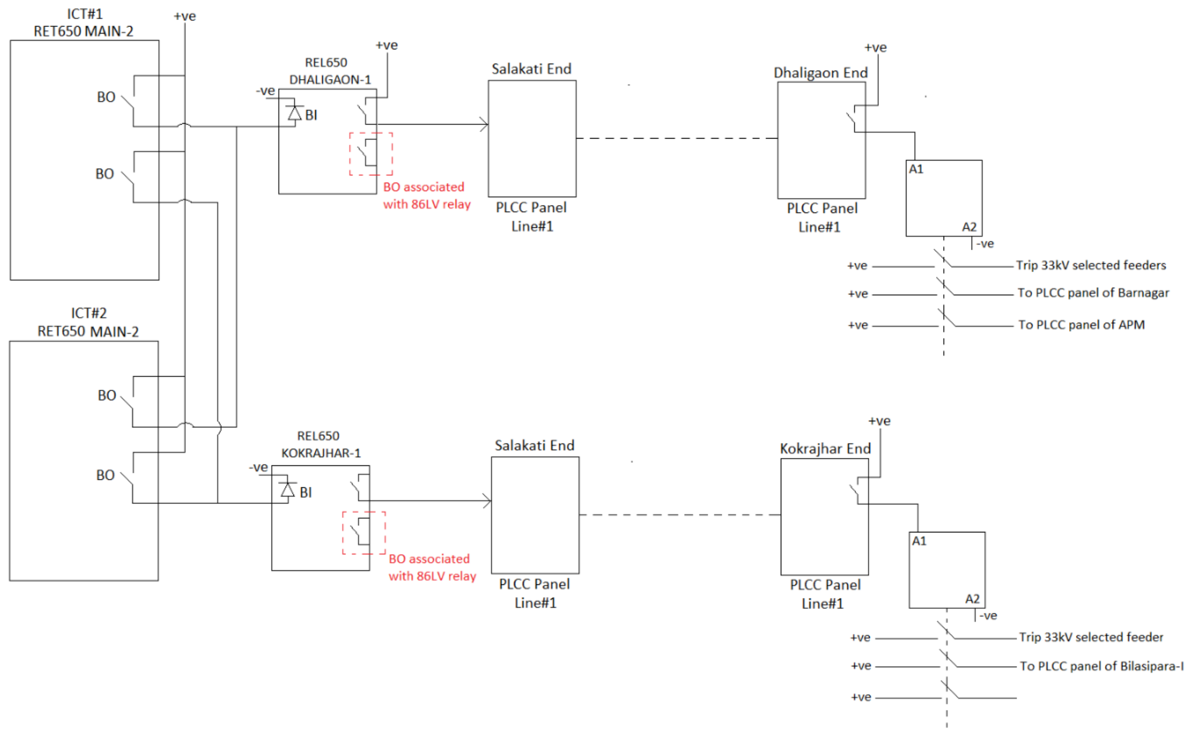

Fig 8: *Hardwiring of the SPS logic at 220kV Salakati, 132kV Dhaligaon and 132kV Kokrajhar*

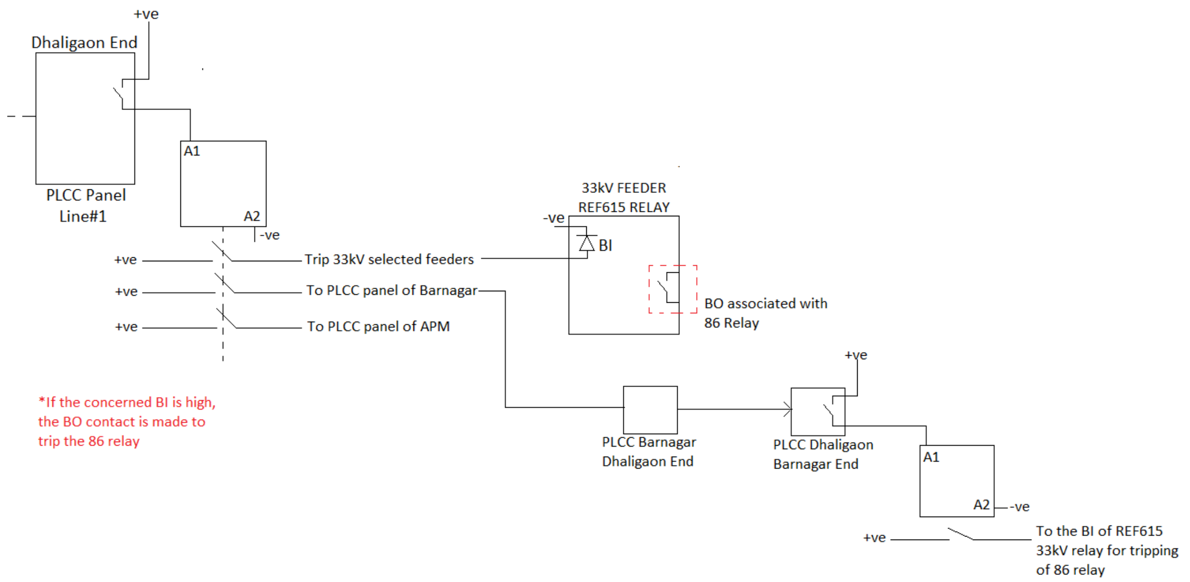

Fig 9: *Hardwiring of the SPS logic to be done at downstream substations (e.g. 132kV Barnagar GSS)*

The logic is to be extended for all the concerned feeders in the same way as mentioned in **fig. 9** for the downstream substations

viii) EXTENDED LOGIC IS "CARRIER IS NOT HEALTHY"

As the above SPS scheme is dependent on Carrier Communication between the substations, the healthiness of carrier communication is of critical importance. Absence/unhealthy carrier would fail the SPS upon operation. Hence, if carrier is found unhealthy at any point in the transmission lines associated in the scheme, the following logic would come into operation:

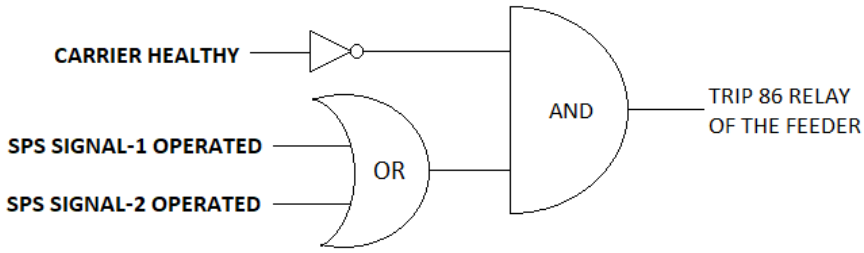

Fig 10: *Logic in case of unhealthy carrier communication*

As per the **fig. 8** and **fig. 9**, the SPS is received by the Binary Input of the relay. The relay also monitors the healthiness of carrier communication. If carrier is found unhealthy, the relay would trip the 86 relays of the 132kV respective feeder and cut off the total load in the lines. (downstream)

NOTE: As the tripping of 33kV feeders depend upon hardwiring, the provision to include/exclude 33kV feeders in the scheme based on trend of load demand may be carried out in discussion with APDCL.

The LBB protection function in the RET 650 (Main 2 relay) is to be blocked during operation of SPS related protection function (OC Stage-2 and Stage-3)

***************** END OF DOCUMENT *****************