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THE HANDBOOK OF BULK SUPPLY INTERCONNECTION

Bulk Supply Interconnection Guideline

Disclaimer: This document serves as a generic guideline for the types of interconnections and TNB's requirements for LPC to be connected to the Grid System. However, detailed boundaries of asset ownership, operation/maintenance and control of the respective plants shall be clearly demarcated and highlighted in the *Interconnection Operation Manual (*IOM) document that shall be signed off prior to commercial operation of the plant.

ACKNOWLEDGEMENT

The committee would like to thank the following people, from various departments of TNB, namely Grid Strategy, Grid System Operation Department, and Business, Strategic and Performance Department, Grid Division for their full effort and support in drafting this valuable document ;

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Foreword by Chief Grid Officer (Grid Division of TNB)

Datuk Ir. Haji Husaini Husin
Chief Grid Officer

Assalamualaikum & warm regards to all our esteemed customers.

TNB's aspiration, under TNB's Strategic Plan 2017-2025 Reimagining TNB (RT) is to become amongst the top 10 Power Company globally by 2025. Grid Division plays a vital role in facilitating the Grid of The Future, with inevitable challenges from faster rate of digital disruption and modernised technology.

As a core division in Tenaga Nasional Berhad (TNB), Grid Division strives to excel in providing safe, reliable and economical operation of the grid system for the whole nation. Besides securing connection of the nation's grid system to TNB Generation and Distribution counterparts as well as the Independent Power Producers, the grid system is also connected directly to TNB's large power consumers (LPCs) to serve their energy demand. Therefore, connectivity to the LPCs are of utmost importance to us in Grid Division and TNB to ensure stable overall operation of the grid system.

With this responsibility, Grid Division of TNB has undertaken the initiative to revise the Bulk Supply Interconnection Guideline handbook. The purpose of this handbook is to appreciate the technical considerations for bulk supply connection to the grid network as well as facilitates interconnection between TNB's grid system and LPCs, as part of assurance for the reliability of our electricity supply to our customers.

This handbook is developed and benchmarked with recognized and best international practices of other energy utility companies globally. The content provides insight to the operational and technical details for the benefit of our LPCs. By clearly defining scope of operation and maintenance of electrical transmission interconnection installations including the ownership boundaries of these installations between TNB and LPCs, the awareness and understanding becomes transparent on operation and maintenance requirements in compliance with TNB's licence and statutory requirements under the Electricity Supply Act 1990.

Lastly, this handbook will also benefit and serve as a technical reference guide to TNB's internal network planners and external consultants, involved in grid and network planning, to improve connectivity scheme planning, procurement and designing of electrical interconnection installations and facilities in the future.

Thank you.
Datuk Ir. Haji Husaini Husin

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1.0 INTRODUCTION

This document serves as a guideline ("Guideline") for Network planners ("Planners") and Large Power Consumers ("LPC") and Consultants to appreciate the requirements for interconnection/bulk supply connection to Transmission 's installations/facilities to facilitate and ensure the reliability of supply as well as the area/boundary of responsibility for Operation & Maintenance of these installations/facilities between Tenaga Nasional Berhad and LPC, depending on the type/mode of connectivity to the grid network system ("Grid System").

2.0 OBJECTIVE

Grid Division of Tenaga Nasional Berhad ("TNB") is responsible for the management of transmission network system as provided under the provisions of TNB's Conditions of License issued in accordance with Electricity Supply Act 1990 (Act 447). All electric power system licensees in its course of its business shall comply with the Malaysian Grid Code ("Grid Code") which provides for criteria guidelines and procedures for the development and operation of the Grid System. In compliance to the Grid Code and TNB's Conditions of License, Grid Division has developed Transmission Reliability Standards relating to provisions of sufficient Transmission capacity, operational facilities, maintenance activities and coordination with generation and distribution functions so as to enable continued supply of electricity energy to the distribution system and LPC.

The main objectives of this guideline are as follows: -

i. To guide Planners (Grid & Distribution Network), Consultants and LPC on the technical considerations/aspects of supply interconnection to Grid Division and other salient requirements with regards to system security, availability and reliability of supply in the Grid System as well as to the LPC.

ii. To ensure LPC connected to Grid Division network system are in compliance with TNB's License Condition 13 and Transmission Reliability Standards under Clause 3.3.1, which require sufficient investment in planning, development and operation of the system under normal and secured n-1 contingency outage condition.

iii. To enable Consultants and LPC to better plan, procure and design plant facilities in accordance to Grid Division's requirements, having knowledge of technical and operational advantages/constraints of the various types of interconnection modes.

3.0 MAINTENANCE / OPERATION / OWNERSHIP BOUNDARIES & OPERATIONAL REQUIREMENTS

This section describes the different supply interconnection modes, boundaries and the specific operational requirements between Grid Division and LPC. The interconnection point shall be used to demarcate the boundary between TNB and LPC and shall be referred/considered as the supply and delivery point. The interconnection point shall depend on the medium of interconnection as well as the type of substations involved, either Air Insulated Substations ("AIS") or Gas Insulated Substations ("GIS").

3.1 Medium of Interconnection

Supply connection to LPC shall be provided through three (3) mediums:

3.1.1 Overhead Line ("OHL")

Interconnection point shall be the T-clamp used to support down-dropper to LPC's equipment. In this case, the clamp and down-dropper itself is under LPC's jurisdiction. However, the OHL landing to LPC's gantry is under TNB's purview.

3.1.2 Underground Cable("UGC")

Interconnection point shall be at the sealing end (termination) or at cable compartment of GIS at LPC's end. The cable at LPC's end belongs to TNB whilst the sealing end/cable compartment in GIS at LPC's end onwards belongs to LPC.

Note: UGC medium of connection to LPC shall only be considered if its spur connected and auto-reclosing facility is NOT critical to/required by the Grid System.

3.1.3 Gas Insulated Bus-Duct("GIB") – Special Cases

Interconnection point shall be the first landing/termination at the GIS in LPC's premise, namely the VT or isolator compartment of GIS.

***Note: GIB medium of connection to LPC shall only be considered if its spur connected and the auto-reclosing facility is NOT critical to/required by the Grid System. Unit protection shall be required for the GIB portion*.**

Refer to Appendix I for the typical mediums of interconnections between TNB and LPC as well the defined boundary demarcations.

3.2 Interconnection Facilities

The interconnection facility between Grid Division and LPC (at both end/s of interconnectors) shall comprise complete or typical equipment of a standard bay, namely with isolators, Surge Arrestors("SA"), Circuit Breakers("CB") and busbar, inclusive of Current Transformers ("CT") and Capacitive Voltage Transformers ("CVT") and the associated remote control and protection panels, relays, metering, AC and DC distribution system located at the LPC substation. It is imperative that LPC shall design and provide the appropriate ratings of interconnecting equipment, in line/tandem with interconnecting facility's rating. (Refer Appendix II).

TNB highly recommends that the supply feed to the installation LPC adopt the criteria for duplicated in-feed to enhance supply security and reliability to the customer. TNB shall not be liable at any time whatsoever for any disruption or loss of load that occurs due to LPC's refusal or failure to comply with the recommended secured/reliable mode of interconnection.

Note: LPC shall be fully responsible for the design and operational flexibility of their plant, particularly in terms of paralleling the supply in-feed from TNB to their plant and for their downstream operations and requirements. TNB shall not be liable at any time whatsoever for any supply disruption to the LPC (either under abnormal situation or under external disturbance/contingencies) as a consequence of the LPC's inability to fully utilize the supply in-feed provided.

3.3 Responsibilities

This section describes the operational, ownership and maintenance responsibilities between Grid Division and LPC interconnection boundaries.

3.3.1 Ownership and Maintenance

Each party at their own cost is responsible for the maintenance of equipment within each party's respective boundary. The interconnection point shall define the ownership boundary. Grid Division and LPC are required to be responsible for the operation, maintenance, replacement and refurbishment of the equipment under both respective jurisdictions as demarcated in Appendix I.

Each party at their own cost is responsible to replace/ refurbish as and when any apparatus obsolesces prior to its end of service life and/or when any apparatus reaches its end of service life (whichever comes first).

3.3.2 Operation

Each party is responsible for the operation of equipment under each party's purview. Only authorized personnel shall be allowed to carry out switching activities on the equipment. Both parties shall jointly agree on the switching operations that involve the interconnection facility. Issuance of Record of Interconnection Safety Precaution ("RISP") shall be made compulsory before any switching operation can be performed.

3.3.3 Control

Switching operations, governed by the RISP procedure for high voltage ("HV") equipment, shall only be permitted once approval/sanction from both control centres is obtained.

In general, all operations and maintenance activities, either planned/scheduled or unplanned (breakdown or corrective works) shall be governed by the Interconnection Operation Manual ("IOM") to be signed by both parties prior to the commercial operation of the plant as described in section 3.6 below.

However, TNB shall reserve the absolute right to carry out any switching operation and disrupt supply to LPC either under contingency and/or emergency situations, whichever may be, without prior consultation and approval from LPC to safeguard the integrity, reliability and safety of the Grid System.

3. 4 Record of Interconnection Safety Precaution ("RISP")

RISP shall be used to record switching, isolation, earthing and cancellation of outages upon completion of work. RISP document shall be filled up by the authorized engineers who shall ensure that all safety procedures, precautions and isolations of the plant to be worked on, from the live system is strictly adhered and complied to.

3. 5 Energy Commission ("EC") Competent Engineer

LPC shall provide details of their Energy Commission ("EC") Competent Engineer to Grid Division. LPC shall engage an in-house EC Competent Engineer ("Residence Engineer") whom shall be available at all times for any switching operations.

3. 6 Interconnection Operation Manual (IOM)

Interconnection Operation Manual ("IOM") is a document that shall be duly agreed and endorsed by both parties prior to the commercial operation of the plant. A copy of IOM shall be made available to the person(s) directly involved with the control and operation of Interconnection Facility. This document outlines a few main functions and the highlights of its contents are as stipulated below: -

i. Apply prudent utility practices to ensure safe and reliable operation of the interconnection facilities.
ii. Facilitate the control and operation of the Facility by the control engineers at Grid System Operator ("GSO") of TNB and LPC control room.
iii. Ensure the coordination of interrelated operations of the TNB power system and LPC facility.
iv. Outlines the duties and routine procedures to be carried out by those persons who are directly involved with the control and operation of both the TNB and LPC Interconnection Facilities as defined in the Electrical Supply Agreement ("ESA") and/or IOM, whichever may be.
v. Supplementary to, but does not authorize any departure from the PPA/SLA, Malaysian Grid Code, Electricity Supply Act 1990, Electricity Regulations 1994 and TNB Supply Rules and/or any successor Act(s). If any conflict should arise between the PPA/SLA and the Malaysian Grid Code and / or the TNB Supply Rules and/or any successor Act(s), the provisions of such PPA/SLA shall prevail except during System Emergencies as defined in the PPA/SLA.

3. 7 Selection Criteria for Interconnection System Voltage

The decision on the system voltage provided to LPC customers is governed by the maximum demand ("MD") declared by the LPC customer. New LPC applicants are required to give an accurate projection of their MD. The general criterion used for system voltage selection is illustrated in Table 1 below: -

Table 1: Supply Voltage Requirement for LPC customer in TNB system

Option	Maximum Demand (MD)	TNB System Voltage Requirement
A	25MVA≤MD<100MVA	132kV or 275kV
B	MD ≥100MVA	275kV

However, TNB shall reserve the absolute right to provide alternative arrangements after taking into consideration the location, economic and system security factors.

4.0 GENERAL REQUIREMENT

Unless specified otherwise, the LPC's plant and the switching station shall comply with the latest edition and corrigendum of the appropriate IEC International Standards, and where no IEC Standard exists, the appropriate British Standard in terms of equipment specification and ratings shall be applied.

LPC plants that have "step-loads", shall prove (by calculation) that their plant systems and operations shall NOT generate harmonics or disturbances above the stipulated limits to the Grid System, with or without compensating devices/equipment [Static Var Compensators ("SVCs") or harmonic filters).

This Guideline focuses on the requirements of the Protection and Control systems that need to be adhered to by the LPC. It is the responsibility of the LPC to provide all the necessary protective devices to protect the LPC's equipment from damage by any abnormal external system conditions and operations that may occur on the interconnected power system. Additionally, the protective devices shall selectively, reliably and speedily isolate faults/failures on LPC's equipment/premise to safeguard the interconnection facilities and TNB's equipment.

This includes but not limited to the following conditions: -

i. Short circuit conditions (Ground fault, two phase or three phase fault conditions).
ii. Open circuit conditions.
iii. Over and under frequency/voltage conditions.
iv. Other system condition such as overloading, phase unbalance, Phase/current reversal conditions.
v. Automatic reclosing.

4.1 Basic Requirements

All relay schemes, setting calculation and coordination at the interconnection facility shall adhere to the practice and requirement of TNB and shall be submitted to TNB for approval.

The protection system requirement of the LPC installation shall comply with the latest version of TNB's "Transmission Protection Application Guideline" document. This document provides guidelines on the following: -

i. Type of protective relays based on system configuration and connectivity
ii. Redundancy of protective system: main and backup protection.
iii. AC/DC system requirement.
iv. Fault clearance time/speed.
v. Auto-reclosing requirements.

Compatible relaying equipment shall be used/provided on each side of the interconnection facility, which is subjected to the list of TNB's approved types (make and version) of relays. The rest of the protective relays used in the LPC plant shall comply with TNB's required characteristics of protective functions and speed of detection and isolation of faults.

4.2 Additional requirements

Upon completion of construction, a registered testing company with TNB shall perform functional tests of all the protective and primary equipment, with special emphasis given at the interconnection facility. TNB shall reserve the absolute right to witness these pre-commissioning tests.

LPC shall investigate and keep a log of all protective relay operation and indications as required. TNB shall reserve the absolute right to request this log for investigation or restoration purposes of the interconnection in the event of an emergency(ies).

Depending upon the nature, source and supply in-feed of the interconnection, it may be necessary to install special relaying or transfer trip equipment. Some relay protection schemes may require communication channels as below: -

i. Transfer trip of the interconnection circuit breakers, specifically GIS interconnection.
ii. Protection scheme requirement for Current Differential and Distance relays.
iii. For LPC installations of 275kV and above, direct transfer trip through Breaker Fail operation shall be provided.

The preferred choice of communication channel is through fibre optic links but other modes maybe considered due to constraints.

Note: Fibre/pilot cable is supplied by TNB and LPC's responsibility on the fibre/pilot starts from where the pilot/fibre first terminates (junction/terminal box) within the LPC's premise, unless it is stated otherwise in IOM. Maintaining the communication equipment at the LPC's premise shall be the responsibility of the LPC.

4.3 Protection Scheme Guideline

LPC shall ensure that their protective equipment (multifunction protective relays or discrete relays) shall be suitable for the type of interconnection. Table 2 below describes the protection function, detection functions, equipment involved and boundaries/responsibilities for radial feed interconnection, both spur from existing TNB Main Intake Substation ("PMU") or switching station.

Table 2: Protection Scheme for Radial Feed

Protective function	Set to Detect	Equipment Tripped	Responsibility
1.Feeder Main/backup protection (if applicable)	System fault along the interconnection feeder	Feeder circuit breakers	Installed by LPC Maintained by LPC
2. Busbar protection or special protection	Busbar fault	All HV CBs connected to busbar	Installed by LPC Maintained by LPC
3. Complete Transformer protection	1. Transformer and ancillary equipment fault (CT, CVT, LA) 2. Remote fault after transformer LV side	Transformer circuit breakers	Installed by LPC Maintained by LPC

4.4 SCADA Requirements

The interfacing system at LPC substation (SCS or RTU based), should be capable of conveying all the SCADA signals required to meet the Malaysian Grid Code (MGC) requirements. The SCADA signals will be communicated to OPU via TNB Remote End Station. The signals will only pass through the TNB station.

Among the basic required (but not limited to) SCADA facilities:

- Status of Circuit Breaker: Line Isolator, Main Bus Isolator, Reserve Bus Isolator
- Status of Bus Section (Circuit Breaker and Isolator)
- Status of Bus Coupler (Circuit Breaker and Isolator)
- Measurement of MW and MVar
- Measurement of Voltage at Main Busbar and Reserve Busbar.

The interfacing system (RTU/SCS) for switching station shall be selected from the latest TNB List of Approved Products of Telecontrol.

The Interfacing System may communicate with the Facility either by data communication link (serial/packet) or by hardwired connection. In the former, dual redundant links and communication apparatus must be provided. Data communication is preferred over hardwired solution and is usually based on latest TNB standard protocols

For existing LPC, communication between the Interfacing System and GSO Master System must be based on latest TNB standard protocols via a redundant channel A (Main) and B (Backup) on serial links to different Remote Terminal Communication Servers (RTCS) for GSO

For new LPC connection, the standard communication protocol shall be connected using latest TNB standard protocols via a redundant channel A (Main) and B (Backup) on TCP/IP links to different Remote Terminal Communication Servers (RTCS) for GSO

SCADA Database and Test Sheet shall be submitted to GSO within a month before date of commissioning.

Table 3 below describes sequence of test shall be conducted prior commissioning:

Table 3: SCADA tests

No	Tests	Descriptions
1.	Communication Test	A test to ensure that end-to-end data communications have been properly established on both channels (Channel A & B). A test to ensure ICT and GSO network configuration readiness.
2.	Protocol Test	Protocol Test Random testing for each type (ASDU Type) of Analog, Digital and Control Signals based on given signal list configured at DCS/RTU

Plant needs to pass each test before they can proceed to the next test

5.0 TYPES OF INTERCONNECTION OPTIONS ALLOWED BY TNB

In general, there are only two (2) types of network interconnection options that are allowed by TNB, after taking into consideration system reliability and security factors. The allowed choice of configuration, as illustrated below, would differ depending on factors such as location, system constraints, land acquisition, loading and other factors. The allowed configurations are: -

5.1 Option 1: LILO from existing Double Circuit OHL/UGC through Switching Station to customer substation

This configuration options consist of new dedicated OHL line feeders and UGC feeders from a new switching substation as illustrated in Diagram 1. This configuration has the advantage of highest system reliability and security with greater operational flexibility and extendibility for future projects or extensions at customer end.

Switching station and LPC's station shall be completed with physical tubular busbar/GIS whilst the Bus Section/Bus Couplers shall be completed with isolators and busbar protection.

Note: This scheme of connection shall require LPC to bear all the expenses incurred for the new dedicated switching station and other associated project costs. The Ownership and Maintenance Boundary demarcation as in Diagram 1 also denotes the ownership boundary of the assets.

The salient technical advantages of this option are as below: -

- Highest system reliability /security/contingency
- No supply interruption during maintenance
- Easier/Faster extendibility (at TNB's side) for future upgrading works/projects on LPC's side
- Better system operational flexibility

Table 4 below describes the requirements for implementation of LILO from existing Double Circuit OHL/UGC through Switching Station to customer substation

Table 4: Requirements for Mode of Interconnection (Option 1)

Mode of Interconnection	**System Requirement**		
Double circuit OHL/UGC LILO Connection from new switching station	Operation	Primary	Secondary
	▪ Requires appointment of full time RE ▪ Compliance to RISP procedures ▪ CB control at switching station required ▪ CB control at LPC substation not required by GSO	▪ All incomers and transformers operated using circuit breakers and with complete typical bay equipment(s) ▪ Requires Bus Section/Bus Coupler installations with isolators ▪ Requires primary /physical Busbar **(Refer Appendix II)**	▪ Complete Feeder Protection ▪ Completed Transformer Protection ▪ Busbar Protection or special protection scheme (IOC)

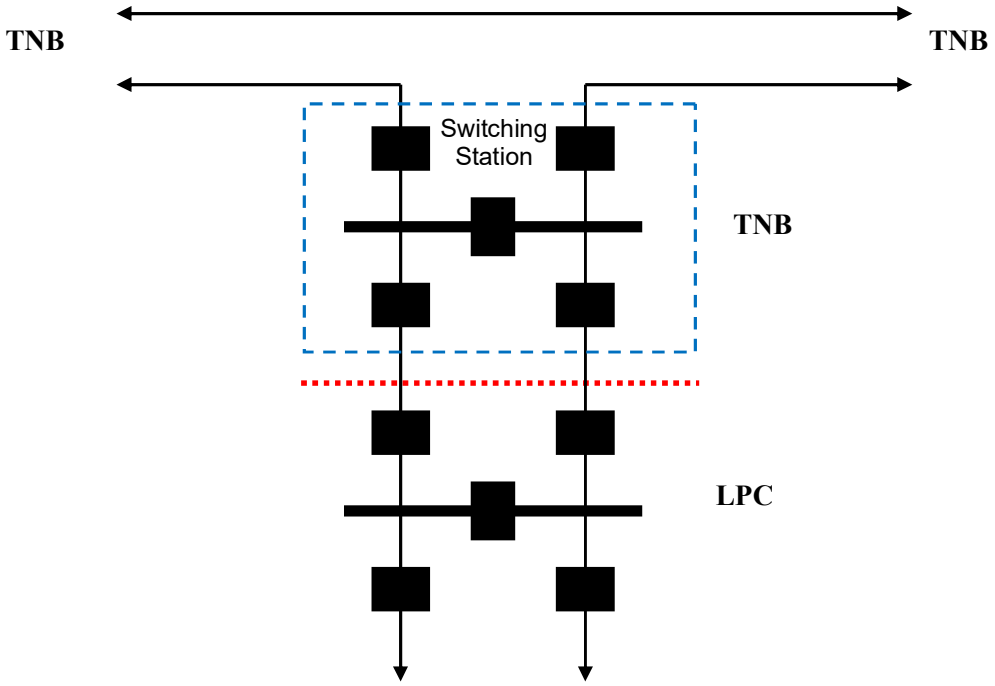


Diagram 1: Typical Configuration with Spur Double Circuit OHL/UGC from new Switching Station (Option 1)

5.2 Option 2: Spur feed connection double circuit OHL/UGC from existing PMU through switching station

Spur feed connection from existing PMU through switching station, via dedicated feeders from nearby substation using OHL or UGC connections as shown in Diagram 2 below. This configuration has the advantage of high system reliability and security/contingency where system interruption is minimal during forced or planned outages, as long as the system is in parallel operation mode at the customer's end.

However, factors of availability of nearby PMUs, extendibility facilities at existing PMU and the right of way (ROW) may have to be considered prior to any approval for this type of configuration to new customers.

Note: LPC's station shall be completed with physical tubular busbar/GIS whilst the Bus Section/Bus Couplers shall be completed with isolators and busbar protection. The Ownership and Maintenance Boundary demarcation as in Diagram 2 also denotes the ownership boundary of the assets.

The salient features of these options are as below: -

- High system reliability /security/contingency
- No supply interruption during maintenance/ forced outages on single circuit
- Less maintenance required for cable feeders
- Good system maintainability/operational flexibility

Table 5 below describes the requirements for implementation of spur feed connection double circuit OHL/UGC from existing PMU through switching station

Table 5: Requirement for Mode of Interconnection (Option 2)

Mode of Interconnection	**System Requirement**		
Spur Feed Connection	Operation	Primary	Secondary
Double circuit OHL/UGC from existing PMU through switching station	▪ Requires appointment of full time RE ▪ Compliance to RISP procedures • CB control at LPC substation not required by GSO	▪ All incomers and transformers operated using circuit breakers and with complete typical bay equipment(s) ▪ Requires Bus Section/Bus Coupler CB installations with isolators ▪ Requires primary Busbar (**Refer Appendix II)**	▪ Complete Feeder Protection ▪ Complete Transformer Protection ▪ Busbar Protection or special protection scheme (IOC)

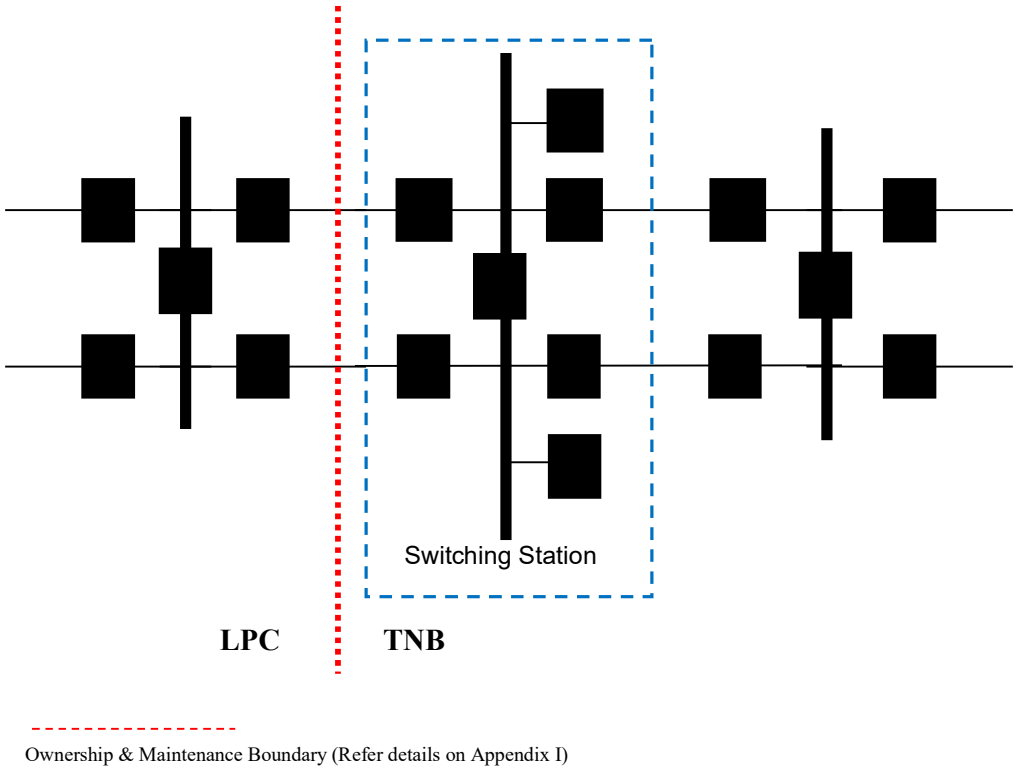


Diagram 2: Typical Configuration with Spur Double Circuit OHL/UGC from Existing PMU (Option 2)

6.0 SPECIAL INTERCONNECTION (CO-GENERATION, STANDBY GENERATOR etc.)

If co-generation or standby generation at LPC's end is involved, the mode of interconnection is as described in clause 5.1, where TNB's fully switched switching station with synchronizing facility shall be used to ensure safe synchronisation to the Grid System. All technical and operational requirements as stipulated in clause 5.1 shall apply. However, depending on the complexity and criticality of the co-generation plant, TNB shall impose additional technical requirements after a detailed study is carried out, to ensure that the security of the Grid System is not jeopardized.

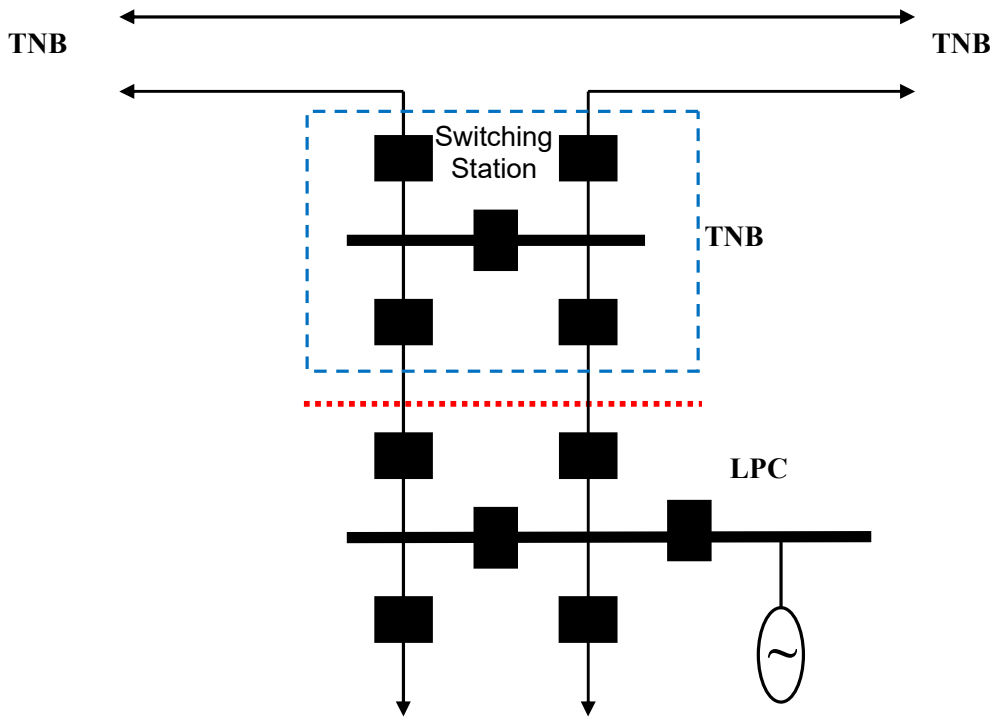


Diagram 3: Typical Special Configuration with Co-generation at LPC

7.0 OTHER MODES OF INTERCONNECTIONS

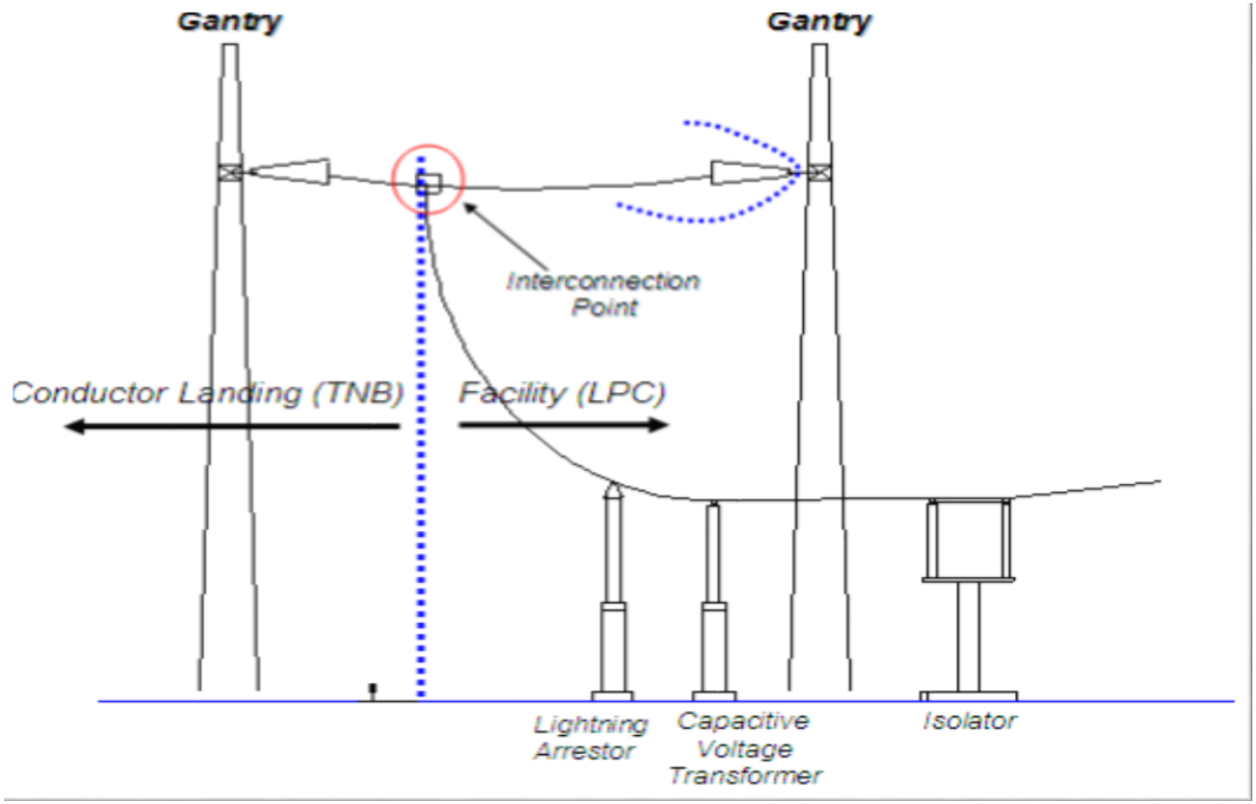
Any other interconnection mode or medium suggested/proposed by LPC that deviates and is “inferior” to the technical and operational requirements as stated in this Guideline, shall be considered on a case-to-case basis, with the ULTIMATE PRIORITY being the integrity, security and reliability of the Grid System.

8.0 REFERENCES

1. Electricity Supply Act 1990 (Act 447).
2. Malaysian Grid Code
3. TNB’s Transmission Reliability Standards
4. TNB’s Transmission Protection Application Guideline
5. TNB License – 1st September 1990
6. Interconnection Operation Manual (IOM)
7. Electricity Regulations 1994

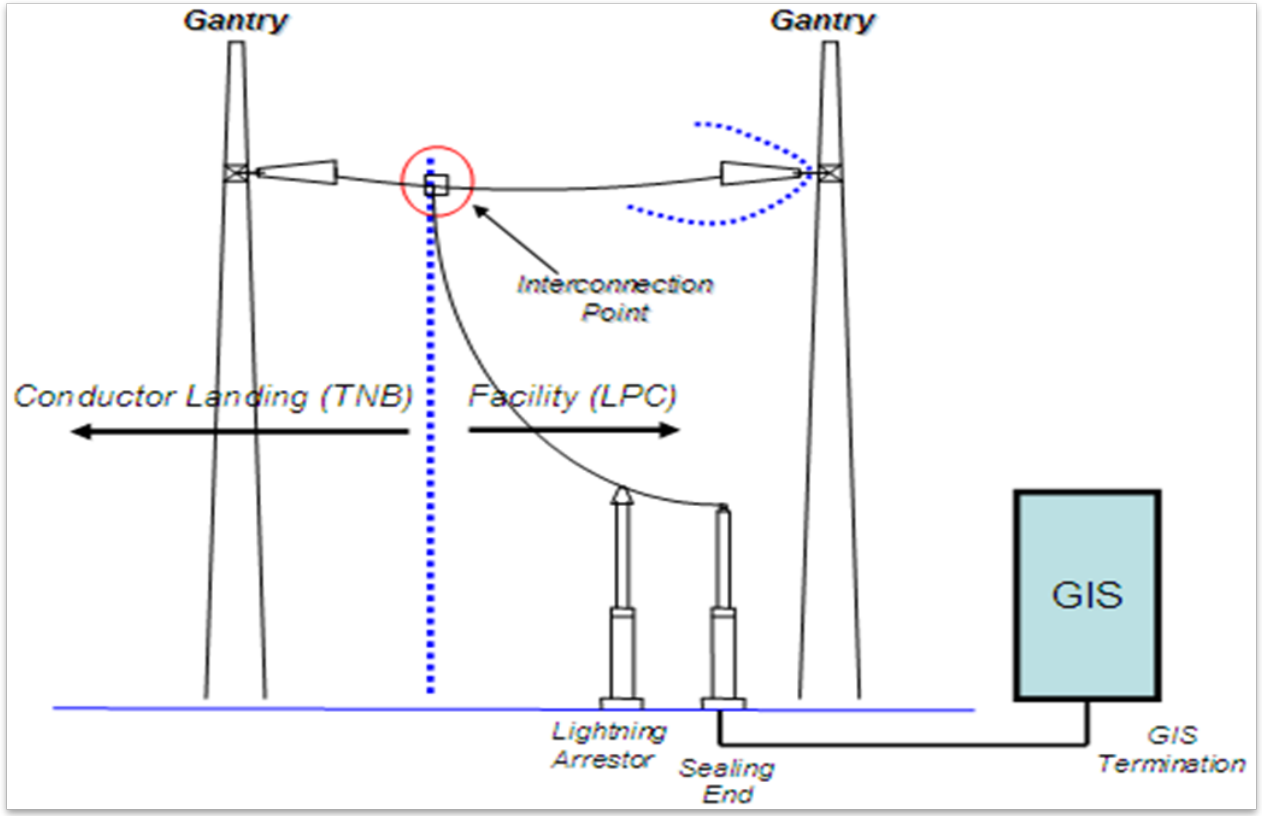
Appendix 1: Ownership and Maintenance Boundary

1) Landing: Conductor to Conductor (OHL – AIS)



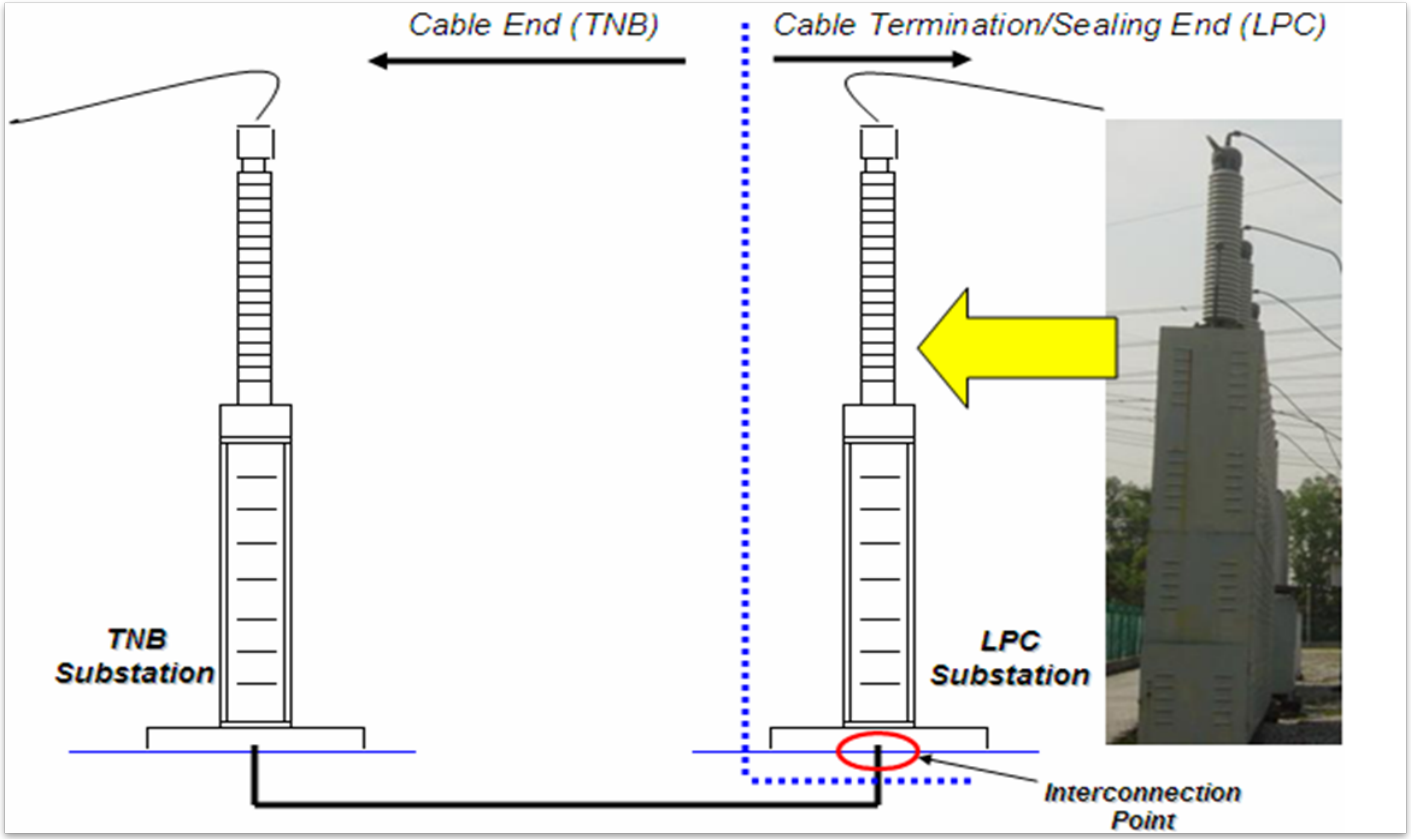
Note: The Interconnection Point between TNB and LPC Facility for the 132kV or 275kV is (i.e. two physical points) at the T-clamp leading to the down dropper conductors of the LPC AIS Main Intake Substation

2) Landing: Conductor to GIS Station (OHL – GIS)



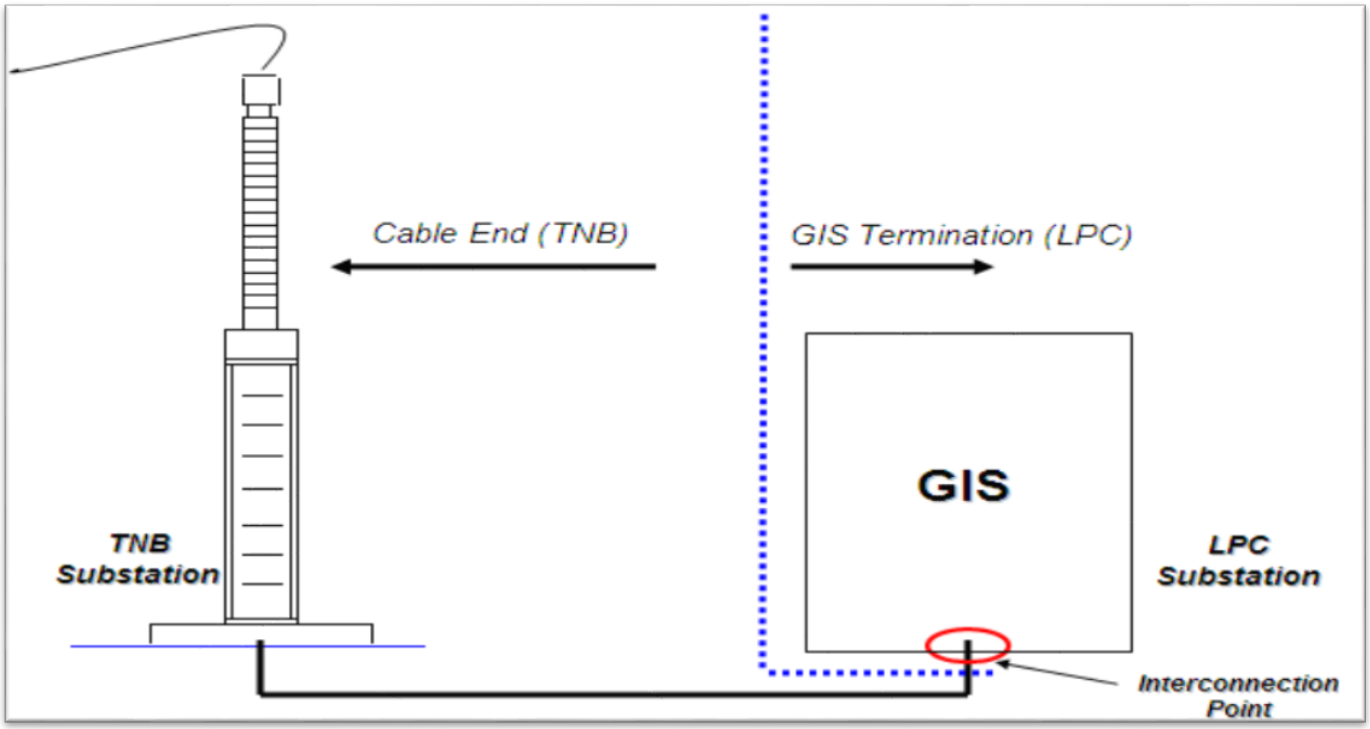
Note: The Interconnection Point between TNB and LPC Facility for the 132kV or 275kV is (i.e. two physical points) at the T-clamp leading to the down dropper conductors of the LPC AIS Main Intake Substation

3) Cable Connection Feeders to AIS Station (Cable – AIS)



Note: The Interconnection Point between TNB and LPC Facility for the 132kV or 275kV is (i.e. two physical points) at the T-clamp leading to the down dropper conductors of the LPC AIS Main Intake Substation. The ownership and maintenance of the termination and sealing end at LPC's ends is under the responsibility of the LPC.

4) Cable Sealing End to GIS (Cable – GIS)

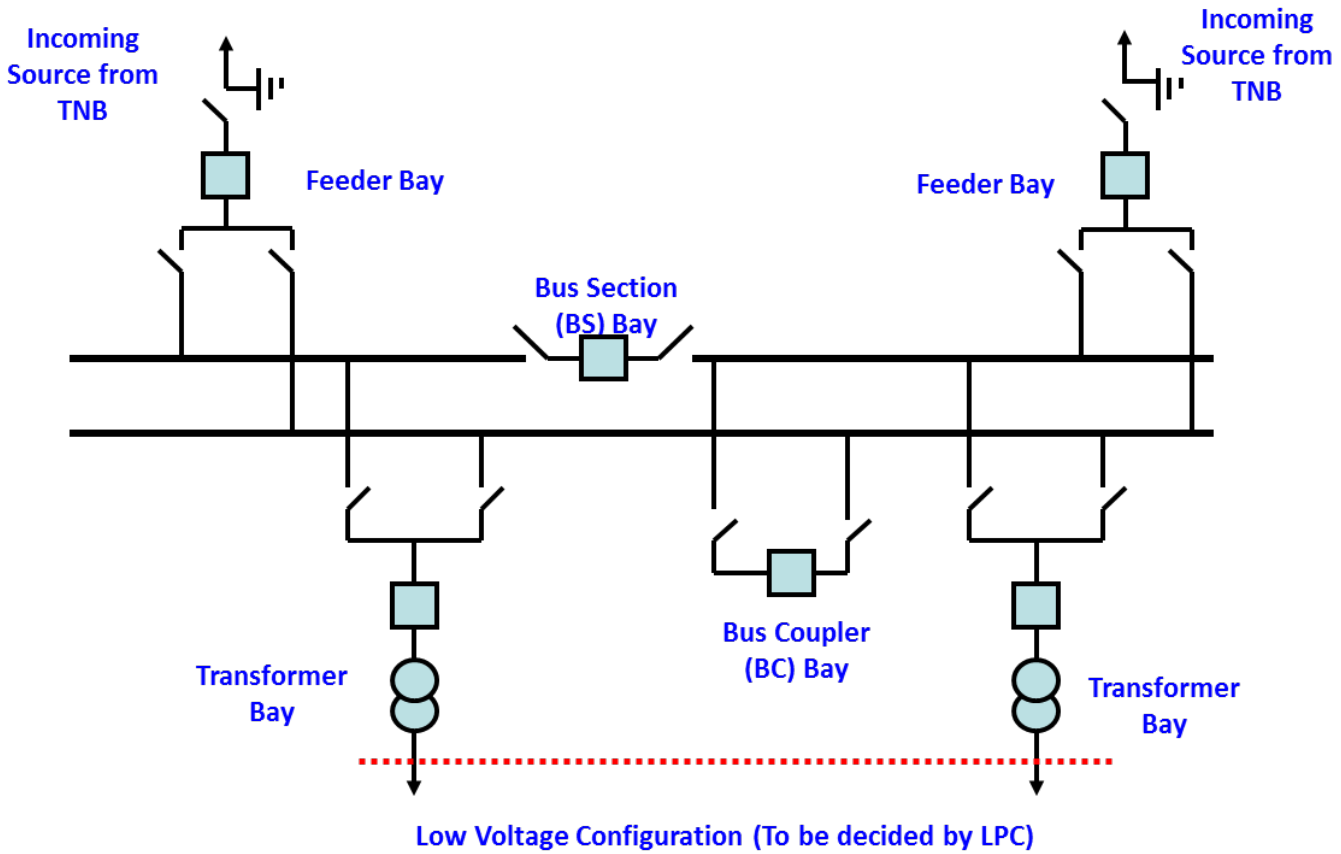


Note: The Interconnection Point between TNB and LPC Facility for the 132kV or 275kV is (i.e. two physical points) at the T-clamp leading to the down dropper conductors of the LPC AIS Main Intake Substation. The ownership and maintenance of the termination and sealing end at LPC's ends is under the responsibility of the LPC.

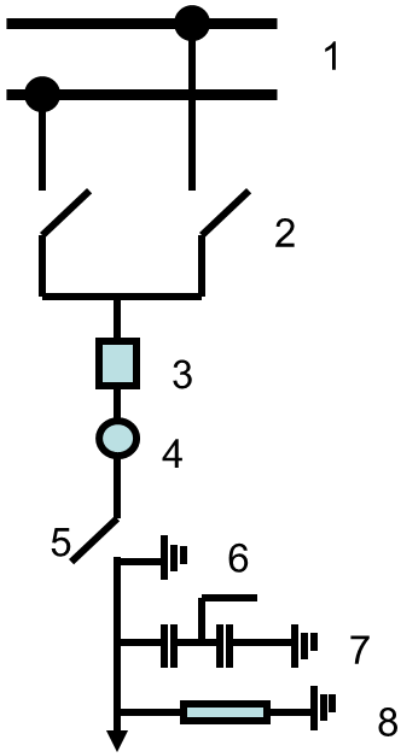
**** Note: For all the above interconnection, the boundary of ownership and maintenance of the DC fibre connection (for tele-protection and communication purposes between TNB and LPC would be at the first termination at the LPC's premise**

Appendix 2: Typical System Configuration or Installations

1) Typical complete LPC Substation Configuration (Double busbar AIS Configuration with HV BS and BC)



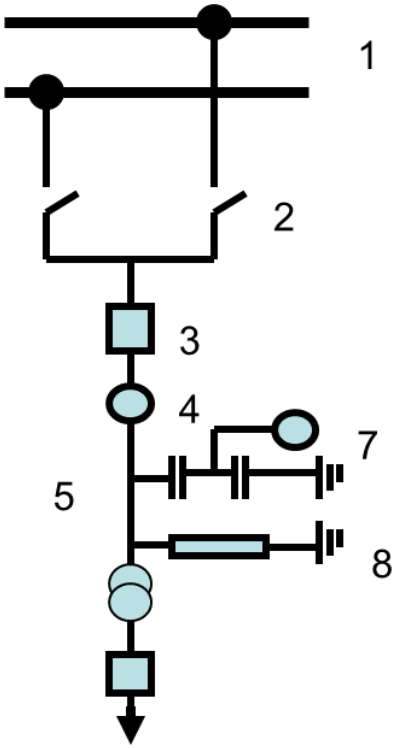
2) Typical Feeder Bay Configuration



LEGEND

1. Busbar
2. Busbar Isolator
3. Circuit Breaker
4. Current Transformer
5. Line Isolator
6. Line Earth Link
7. Capacitive Voltage Transformer
8. Surge Arrestor

3) Typical Transformer Bay Configuration



LEGEND

1. Busbar
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