Interlocking Requirements Guideline

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Part of the Energy Queensland Group

1 Purpose

This document is intended to inform and guide proponents when making application for new connections or alterations to an existing installation that has more than one point of connection from the distribution network, and where interconnection exists. This document provides additional guidance as to the proponent's responsibilities under the relevant embedded generation standards, which state the interlocking requirements, being: Dynamic Standard for Low Voltage Embedded Generation Connections STNW3511, Standard for Low Voltage Embedded Generator Connections STNW1174, Standard for HV Embedded Generator Connections STNW1175, Queensland Electricity Connection Manual (QECM) and Standard for Major Customer Connections STNW3522.

The Distribution Network Service Providers (DNSPs), Ergon Energy and Energex, have obligations under the National Electricity Rules (NER) to maintain the safety, security and stability of its distribution system and the broader power system. This can be affected by improper connections that lead to paralleling of the distribution network within a customer installation. Installation of fail-safe interlocking schemes is therefore essential to maintain safety for all network users.

Contents

This guideline is in addition to the National Electricity Rules (NER) and relevant DNSP standards and should be applied in accordance with the standards. Nothing in this document should be read to contradict or make void any elements of the NER or DNSP standards. Where the interlocking guidelines differ or conflict from the NER, legislation or DNSPs standards, the rules and standards prevail.

Information in this guideline is informative only and should not be used as the basis for any design or design decisions. This guideline does not override or replace professional engineering advice.

2 Background

Some facilities require more than one physical connection point to the network because of the quantity or importance of their load. This is usually due to diversity, reliability or specific load requirement needs.

Some sites may have embedded generation and need to supply the whole site from a single point, in case of loss of either supply source. This requires transition from one source of supply to another without creating a network configuration that would damage equipment, affect power flow and quality in the Distribution Network Service Provider (DNSP) network or create a safety risk.

In order to manage this safety, interlocking is required as defined in the relevant connection standards. This guideline explains how different types of interlocks should be incorporated in various arrangements, and what information is required to be submitted to the DNSP for review at the appropriate stage of the project lifecycle.

These interlocking schemes must be assessed by the Distribution Network Service Provider (DNSP) and shall be included in the connection agreement.

3 Introduction

Where one or more sources of network supply are connected to a customer's premise to provide the desired power supply requirements, it is vital that appropriate design is undertaken to ensure the distribution network cannot be connected in parallel at any time, or that any network assets exceed their stipulated ratings. This is achieved through interlocking. Fail-safe interlocking is essential to ensure safety for personnel, power workers and the general public is maintained throughout the life of the connection.

The DNSP Standard for Major Customer Connection (STNW3522), Standard for Low Voltage Embedded Generator Connections (STNW1174), Dynamic Standard for Low Voltage Embedded Generation Connections (STNW3511), Standard for HV Embedded Generator Connections (STNW1175) and the Queensland Electricity Connection Manual (QECM) stipulate the interlocking requirements for new and upgrading customer connections.

Fail-safe interlocking mechanisms shall be required as specified in the QECM, STNW3522, STNW1174, STNW3511 and STNW1175 for Premises with multiple transformers or multiple Connection Points, bumpless transfer and off-grid Connections. Table 1 below shows the interlocking mechanisms required for different connection arrangements. It should be noted that interlocking design is not covered by a prescriptive design or standard, and as such, RPEQ design and oversight is required.

Table 1 - Interlocking requirements

Connection Arrangement	Fail-safe[1] interlocking requirements
Multiple transformers or multiple Connection Points	No distribution transformers or DNSP service points are connected in parallel.
Bumpless transfer	During the transfer from one source to another, the interlock operation cannot enable the Embedded Generation (EG) Unit and the Distribution System to both supply the load at the same time for longer than the maximum allowable duration in the relevant EG Standard as applicable. No distribution transformers will be connected in Parallel at any point during the bumpless transfer.

Off grid	During the transfer from one source to another, the interlock operation cannot allow the Generating Unit/s and the Distribution System to both supply the load at the same time, for any duration.

Note 1: The interlocking mechanism should be a mechanical fail-safe system. Electronically controlled interlocking systems may be allowed after DNSP review and agreement of a proponent submitted, RPEQ certified functional design (Functional Specification) and operational specification provided in the application stage. This should be submitted for review well before any construction. This enables any iterative amendments and corrections to be made at the design stage, thereby avoiding additional costs and delays due to need to rectify. Where embedded generation is connected, no DNSP asset is to have their stipulated ratings exceeded.

4 Types of Interlock

4.1 Mechanical

A mechanical interlock uses direct mechanical blocking (such as a pin or key) to prevent switching. An example of this is a trapped key arrangement. These require manual intervention and the correct application of keyed locks, which prevent the paralleling of the relevant busses and are considered “fail safe” as they cannot be easily bypassed and do not rely on software.

4.1.1 Types of Mechanical Interlocks

There are three types of mechanical interlock.

- Trapped key
- Mechanical contacts
- Transfer switch / break-before-make

An example of a trapped key system is the Castell Key arrangement. A lock cylinder will extend a bolt to prevent the closing of a switch. These systems incorporate a removable key, so that once initiated, the system cannot be inadvertently switched.

A mechanical contact utilises mechanical linkages to block the operating mechanisms of contactors from being activated simultaneously. Typically, these are used for emergency-stop and door monitoring type functions, and do not require programming.

A transfer switch certified compliant to AS/NZS IEC 60947.6.1 is break-before-make and is considered an off-grid connection for embedded generation.

For bumpless transfer installations, ATSE that have manufacturer/vendor certification of system conformance to the performance criteria of AS/NZS IEC 60947.6.1 or IEC 60947.6.1:2021 is considered to meet the requirements under the applicable Ergon Energy Network/Energex standard for bumpless transfer.

If no such conformity is available, at minimum a proponent provided RPEQ test and commissioning plan of the interlock system will also need to be provided to demonstrate the conformity is met in practice. When used for bumpless transfer, it may be paralleled with the network for no more than 2 seconds.

4.2 Electrical Interlocks

Switches, relays, and use of logic controllers are examples of electrical interlocks, which use electrical signalling to enable interlocking. Without proper assessment and design rigour, these projects are not considered "fail safe". To guarantee the proposed interlocking system is properly maintained during its life, additional controls, such as testing over the system's lifespan, could also be necessary.

4.2.1 Relay Operated Interlocks

Relays can be used to implement switching logic to prevent undesirable interlocking, however relays have an unknown failure state (that is, they could fail either “on” or “off”). Relays also have a higher failure rate than other electronic components. As such, in most circumstances relays are no longer utilised for interlocking, having been replaced with PLCs (programmable logic controllers).

4.2.2 Electronic interlocks

Electronic or logical interlocks utilise software logic to ensure appropriate interlocking occurs. The benefit is that switching can occur without manual intervention in the case of an emergency, though without appropriate programming logic and design, improper switching or isolation may occur. In addition, the failed status may be unknown (device failure, signal loss, etc), leaving the interlock system in an unknown state. To reduce the safety risk, the NSP must perform adequate due diligence on the proposed system.

Generally, a Programmable Logic Controller (PLC) is used to implement this. In some cases, a “safety PLC” may be proposed, which is a PLC compliant with IEC 61508-2 and/or EN 954-1 and has the ability to detect broken contacts or lost signals, and thereby fail to a more secure state. While use of a compliant “safety PLC” is preferred, if used improperly “safety PLCs” can still lead to an unsafe outcome and hence assessment is still required.

5 Process - Overview

The interlocking assessment process is part of the connection application process for new connections, alterations and addition of embedded generation. It is therefore a sub-process that is incorporated in the main application process.

5.1 Enquiry Stage

At the enquiry stage, no details of the interlocking system are required, however the customer should indicate an intention to use interlocking, and indicate the likely technology to be used, to ensure that the DNSP can provide appropriate advice.

5.2 Application Stage

The details of the interlocking system are submitted in this stage and assessment is conducted by the DNSP. The details required and type of assessment done depend on the type of interlocking system that is used.

All the acceptable and forbidden states of operation are assessed for conformity to the non-paralleling scenarios required; where necessary the DNSP and the customer shall discuss how the interlocks provide the failsafe system.

Note: the design should be submitted to the DNSP for acceptance prior to equipment being purchased and/or installed. This is to avoid the need for expensive and time-consuming rectification if the proposed design is inadequate.

5.3 Offer Stage

The customer makes a final review, amongst other technical details, of the interlocking system as advised by the DNSP and confirms by signing the offer letter.

5.4 Commissioning Stage

The commissioning process shall include testing of the functionality of the interlocking system as required, as part of the commissioning tests of the plant. Relevant documentation for filing and display on the equipment shall also be inspected at this stage.

Under the Professional Engineers Act of Queensland, the commissioning plan requires RPEQ sign-off, and all switch/generation states shall be tested to confirm compliance.

5.5 Interlocking Process Flow Chart

Below is the summarised flow chart for the interlocking review process.

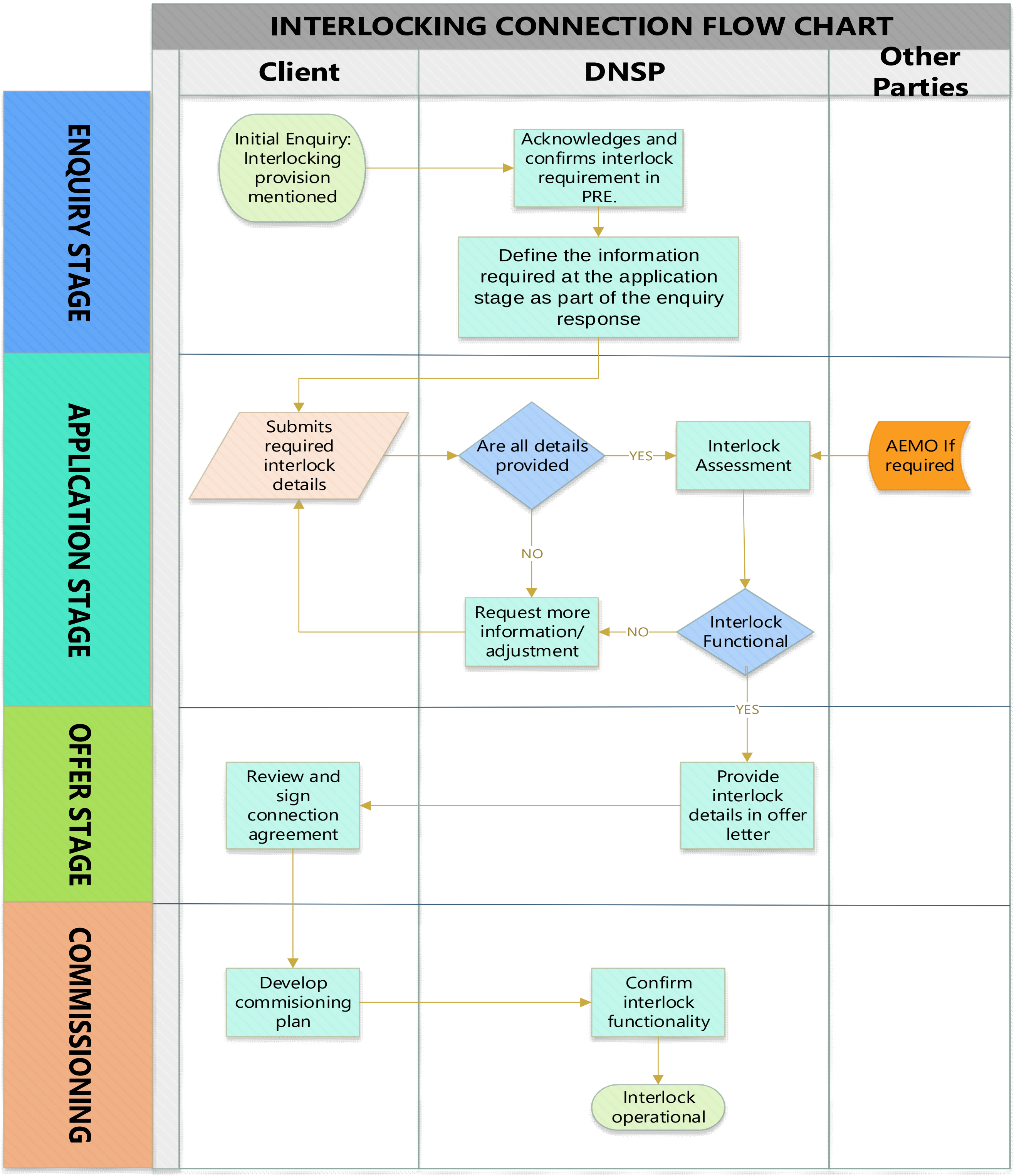


Figure 1: Interlocking Process Flow Chart

6 Application Information Requirements

6.1 Mechanical Interlock

At the application phase, for a mechanical, fail-safe interlocking method, proponents shall provide:

- Single-line diagram of the system, indicating make, model and arrangement of the interlocking, showing all generating systems, bus-ties, and each interlocking system as relevant
- Detail the function of the equipment
    - List the parts of the system
    - Describe how the system achieves interlocking
- Detail the operating specification of the equipment
- Describe the normal and contingency state of the equipment
- Describe how the system is intended to be operated to achieve interlocking
- States not permitted, for example, bus-tie closed with both network connections energised
- RPEQ sign-off and endorsement

The details provided should clearly state all the modes of operation applicable to the customer's load/generator without paralleling the DNSP network, including the forbidden modes of operation.

The DNSP will review the Single Line Diagram (SLD) and keyed arrangements. The interlocking arrangements on the SLD should be clear and easy to follow and demonstrate an appropriate scheme to prevent paralleling of distribution transformers or network incomers, and where relevant, generation plant.

Where an ATSE is utilised, certification of compliance with AS/NZS IEC 60947.6.1 is required.

6.1.1 Mechanical Interlock Information

For a mechanical interlock, a single line diagram of the system is required, clearly indicating the castell key arrangements, including any automatic transfer switches for bumpless generators, if applicable. There should also be a clear truth table indicating how the switched key arrangement operates.

For bumpless transfer installations, ATSE that have manufacturer/vendor certification of system conformance to the performance criteria of AS/NZS IEC 60947.6.1 or IEC 60947.6.1:2021 is considered to meet the requirements under the applicable Ergon Energy Network/Energex standard for bumpless transfer. If no such conformity is available, at minimum a proponent provided RPEQ test and commissioning plan of the interlock system will also need to be provided to demonstrate the conformity is met in practice. When used for bumpless transfer, it shall be paralleled with the network for no more than 2 seconds.

Mechanical Interlock Example

Below is an example of some of the information provided for an interlock assessment.

The two transformers operate independently and when one is out of service, the other one can supply all the load by closing the bus section. The standby generator operates in a break-before-make mode and can only supply load on Bus 1, independently from TX1.

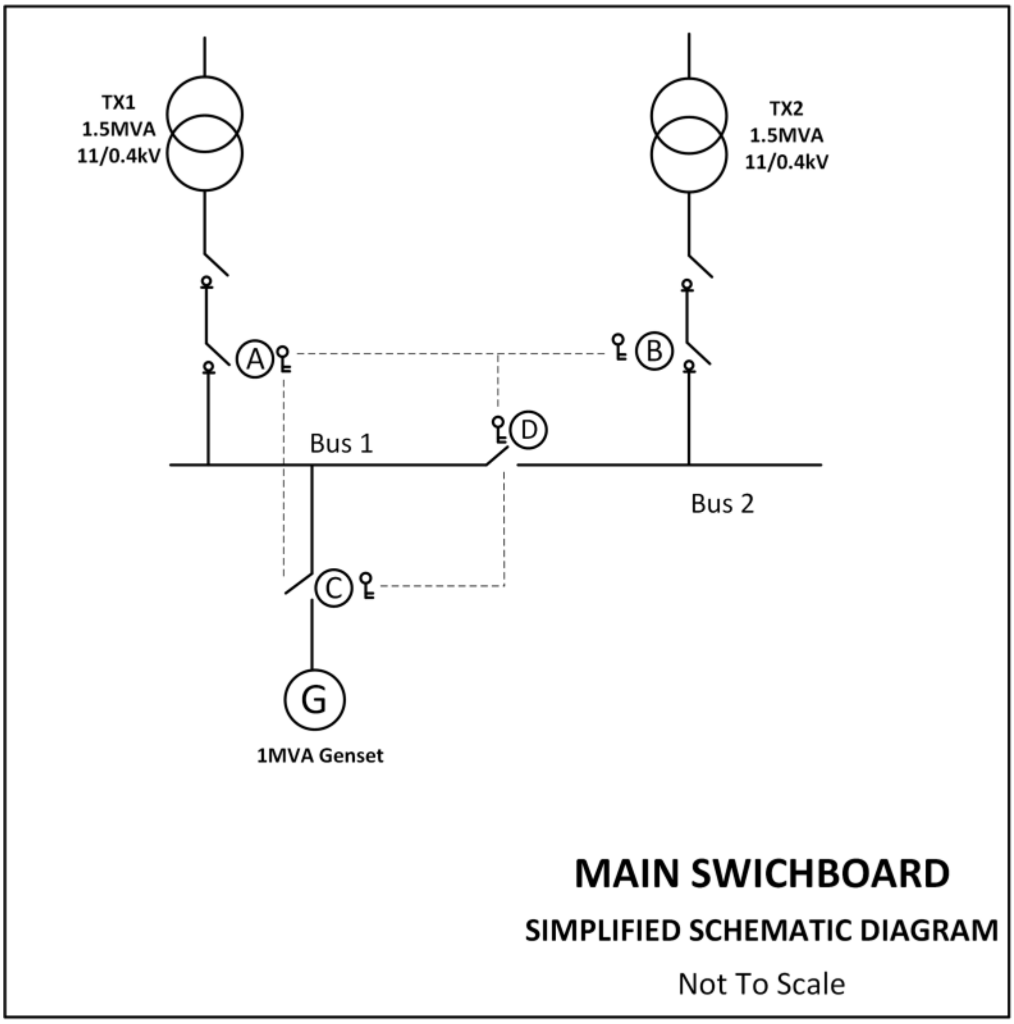


Figure 2 - Mechanical Interlocking Example Diagram

"D" KEY IS REQUIRED TO CLOSE BUS-TIE SWITCH AND IS NORMALLY TRAPPED IN KEY EXCHANGE BOX. EITHER KEY "A" OR KEY "B" IS REQUIRED TO ACCESS KEY "D" IN THE KEY EXCHANGE BOX. KEYS "A" AND "D" ARE REQUIRED TO BE RETURNED TO THE KEY EXCHANGE BOX TO RELEACE KEY "C" **CASTELL KEY EXCHANGE**

Prohibited States

1. Transformers TX1 and TX2 shall not be paralleled.
2. The generator shall not be paralleled with any of the transformers.
3. The generator shall not supply Bus 2

Table 2 - Truth Table Example

SCENARIO	A	B	C	D	STATUS
NORMAL	CLOSED	CLOSED	OPEN	OPEN	ACCEPTABLE
BOTH TRANSFORMERS MAINS FAIL	OPEN	OPEN	CLOSED	OPEN	ACCEPTABLE
TX-1 FAIL (GEN OFF)	OPEN	CLOSED	OPEN	CLOSED	ACCEPTABLE
TX-1 FAIL (GEN ON)	OPEN	CLOSED	CLOSED	OPEN	ACCEPTABLE
TX-2 FAIL	CLOSED	OPEN	OPEN	CLOSED	ACCEPTABLE
TEST-SYNCH TO BUS 1	CLOSED	CLOSED	CLOSED	CLOSED	ACCEPTABLE
SUPPLY FROM TX1 AND TX2	CLOSED	CLOSED	OPEN	CLOSED	FORBIDDEN[1]
SUPPLY ON BUS1	CLOSED	CLOSED	CLOSED	OPEN	FORBIDDEN[2]
BOTH TX FAIL	OPEN	OPEN	CLOSED	CLOSED	FORBIDDEN[3]

Note 1: The transformers cannot be paralleled by closing the bus-section when both transformers in circuit.

Note 2: TX1 And the generator should not operate in parallel.

Note 3: The generator has no capability to supply the two buses.

6.1.2 Mechanical Interlock Submission Checklist

The following is required for a mechanical interlocking system and should be submitted to the DNSP at the application stage.

Table 3 - Mechanical Interlock Submission Checklist

Item	Description
1	Single Line Diagram of the System: ▪ Showing the arrangement of the interlock(s) ▪ including all generating systems, bus-ties, and each interlocking system ▪ Indicating make and model of interlocking device model
2	Design Compliance Report as per generation requirements, including standards compliance
3	Registered Professional Engineer of Queensland (RPEQ) Endorsement
4	Switching sheet, which details: • normal and contingency states of the system • operation of the system to achieve interlocking • states not permitted, such as paralleling of any distribution transformers

6.2 Electronic Interlock

At the application phase, a Functional Specification is required in addition to the single line diagram and equipment datasheets. A Functional Specification should be written in plain English, describing in a logical fashion the operation of the system. RPEQ certification of the following is required:

- Single-line diagram of the system, indicating make, model and arrangement of the interlocking, showing all generating systems, bus-ties, and each interlocking system.
- Detail the function of the equipment in a function description, written in plain English:
  - List the parts of the system.
  - Describe how the system achieves interlocking.
  - Describe how the interlocking is fail-safe.
  - Describe the normal state of the equipment.
  - Describe the contingency state.
  - Describe how the system is intended to be operated to achieve interlocking,
  - States not permitted, for example, bus-tie closed with both network connections energised.
  - Logic statements, diagrams, and/or tables, demonstrating the logic used to ensure the requirements are met.
  - Describe how the system executes commands for the interlock logic, to avoid potential race conditions; for example, is sequential logic used, what timing calculations are used (including refresh rate/s), what signalling protocol is used etc.
  - Generation states, start-up, synchronisation and shutdown, as relevant
- RPEQ sign-off and endorsement

6.2.1 Electronic Interlock Information

Below is an example of the information required to be submitted for assessment.

This site comprises two transformers, and two generators. The transformers have a capacity of 1.5MVA each and the generators have a capacity of 1MVA each. The generators' operation mode is NOT bumpless, but continuous parallel, and each generator has capacity to supply only one bus. This means the generators can remain connected to the network whilst in operation.

Under 'normal' state of supply, the two DNSP transformers supply the two busses separately and they cannot be paralleled under any circumstances. When one transformer is out of circuit, the respective generator shall supply the load on that bus, and the bus can also be supplied by the other transformer. The two generators cannot be operated in parallel to each other while connected to the network.

The various scenarios represented by the respective logic diagrams were used to program the Programmable Logic Controller (PLC) that controls the interlocks.

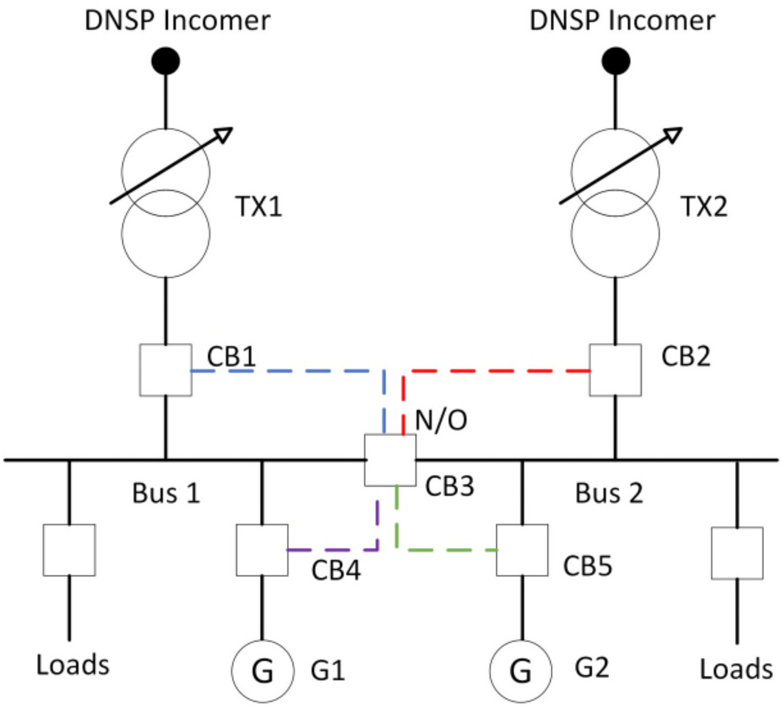


Figure 3 - Example Single Line Diagram for Electronic Interlock. Generation can be operated in parallel with the network.

Prohibited states.

1. The transformers cannot be paralleled to each other through the LV buses.
2. The generators cannot be operated in parallel with each other whilst connected to the network.

A table has been developed, to demonstrate the modes of operation and the relevant scenarios, to inform system design.

Note: This example does not show all the operational scenarios.

Table 4 - Electronic Interlocking States Table

Scenario	EXPECTED STATES	BUS 1		BUS 2		Tie	STATUS
		CB1	CB4	CB2	CB5	CB3	
1	System Normal	C	O	C	O	O	Achieved
2	System Normal – Generators operating	C	C	C	C	O	Achieved
3	Backup supply to Bus 1 from G1	O	C	C	O	O	Achieved
4	Backup supply to Bus 2 from G2	C	O	O	C	O	Achieved
5	Supply Buses 1 and 2 Through TX1, G1 ON	C	C	O	O	C	Achieved
6	Supply Buses 1 and 2 Through TX2, G2 ON	O	O	C	C	C	Achieved
7	Supply Buses 1 and 2 Through TX2, G1 ON	O	C	C	O	C	Achieved

8	Bus Tie Closed, Supply from TX1 and TX 2	C	O	C	O	C	Scenario Fail[1]
9	Bus Tie Closed, Supply from TX1, G1 ON, switch G2 ON	C	C	O	C	C	Scenario Fail[2]
10	Isolated from Grid, G1 and G2 on	O	C	O	C	C	Achieved

O - OPEN

C - CLOSED

Note 1: CB3 will not close as this will parallel transformers TX1 and TX2.

Note 2: CB5 will not close as this will parallel the generators.

As part of the development of the logic for the control system, logic statements are required to articulate the requirements of the system.

Logic Statements – Generator Circuit Breakers

Generator Number 1 Connection

The logic diagrams below show the scenarios where Generator 1 can be connected, by closing **CB4** and initiating the generator start sequence.

G1 can supply:

- Scenario 2: bus 1 when supplied by TX1 and the bus-tie is open;
- Scenario 3: bus 1 when TX1 is out of service and the bus-tie is open ;
- Scenario 5: buses 1 and 2 when supplied by TX1 and G2 is not already on;
- Scenario 7: buses 1 and 2 when supplied TX2 and G2 is not already on;
- Scenario 10: buses 1 and 2 when both TX1 and TX2 are disconnected (i.e., the site is isolated from the grid).

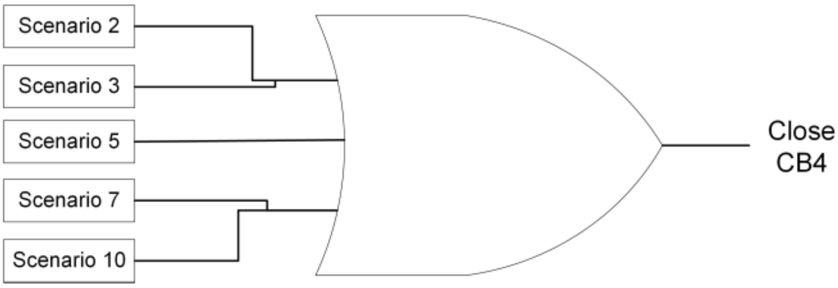


Figure 3 - Generator 1 Connection Overall Logic Diagram

The scenarios logic diagrams are detailed below.

Scenario 2- System normal: That is, CB3 is open AND CB4 is open. CB1 can be open or closed, and is closed in this scenario (being system normal). Generator start is initiated manually.

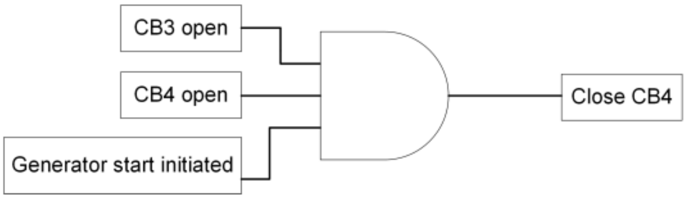


Figure 4 - Scenario 2 Logic

Scenario 3- Supplying bus 1 when TX1 is out of service (CB1). The bus tie (CB3) is open. The generator start is initiated automatically.

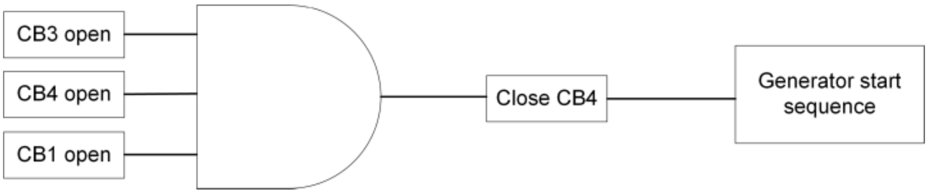


Figure 5 - Scenario 3 Logic

Scenario 5 – Supplying buses 1 and 2 when supplied by TX1 (CB1 closed and CB3 closed) and G2 is not already on (CB5). TX2 is out of service (CB2). Generator start is initiated manually.

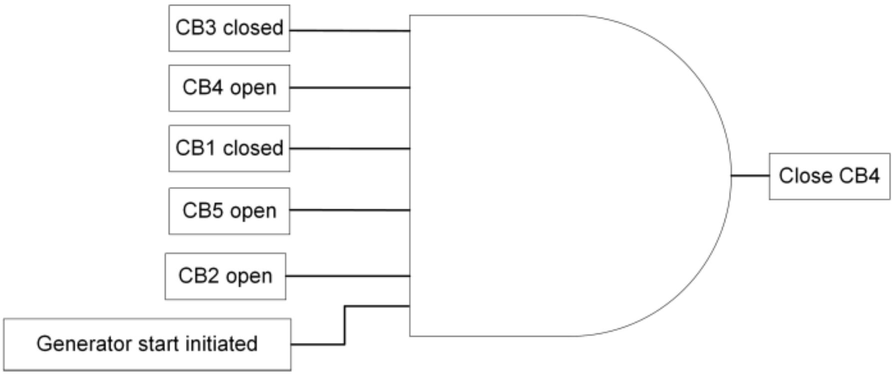


Figure 6 - Scenario 5 Logic

Scenario 7 - Supplying buses 1 and 2 (CB3 closed) when supplied by TX2 (CB2 closed) and G2 is not already on (CB5). TX1 is out of service (CB1). Generator start is initiated manually.

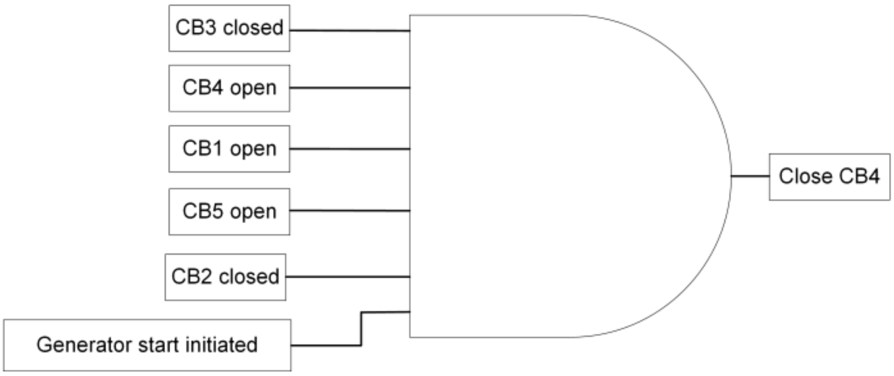


Figure 7 - Scenario 7 Logic

Scenario 10 – Disconnected from the DNSP network (CB1 and CB2 open). In this scenario, the bus can be closed, and both generators can operate. The generator starts automatically.

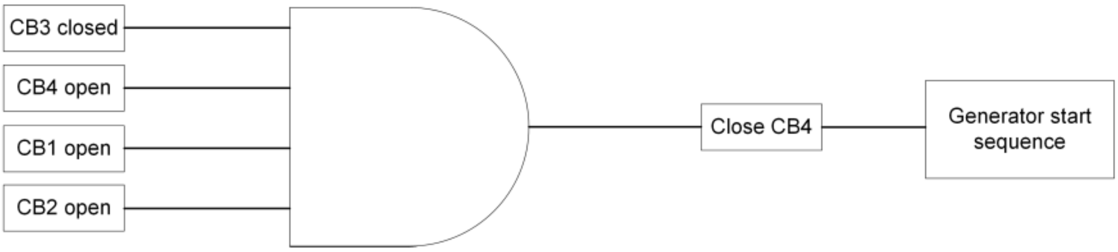


Figure 8 - Scenario 10 Logic

Similar logic assessments are required for Generator 2, the bus tie, and the transformer circuit breakers (for return to network supply). This has not been included here for brevity.

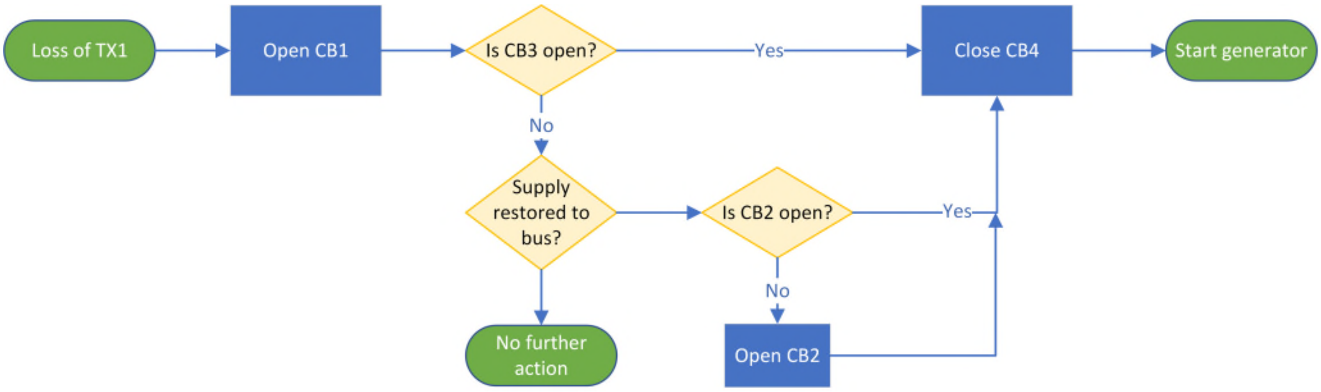
Generator Start Sequence

In the event of loss of power from the DNSP network, the generators can be connected without violating the forbidden states of operation. The status of relevant circuit breakers and isolators should be confirmed before the respective generator is energised. Below are examples of the start-up sequence operations following loss of supply during normal network status.

Generator 1 Start Sequence

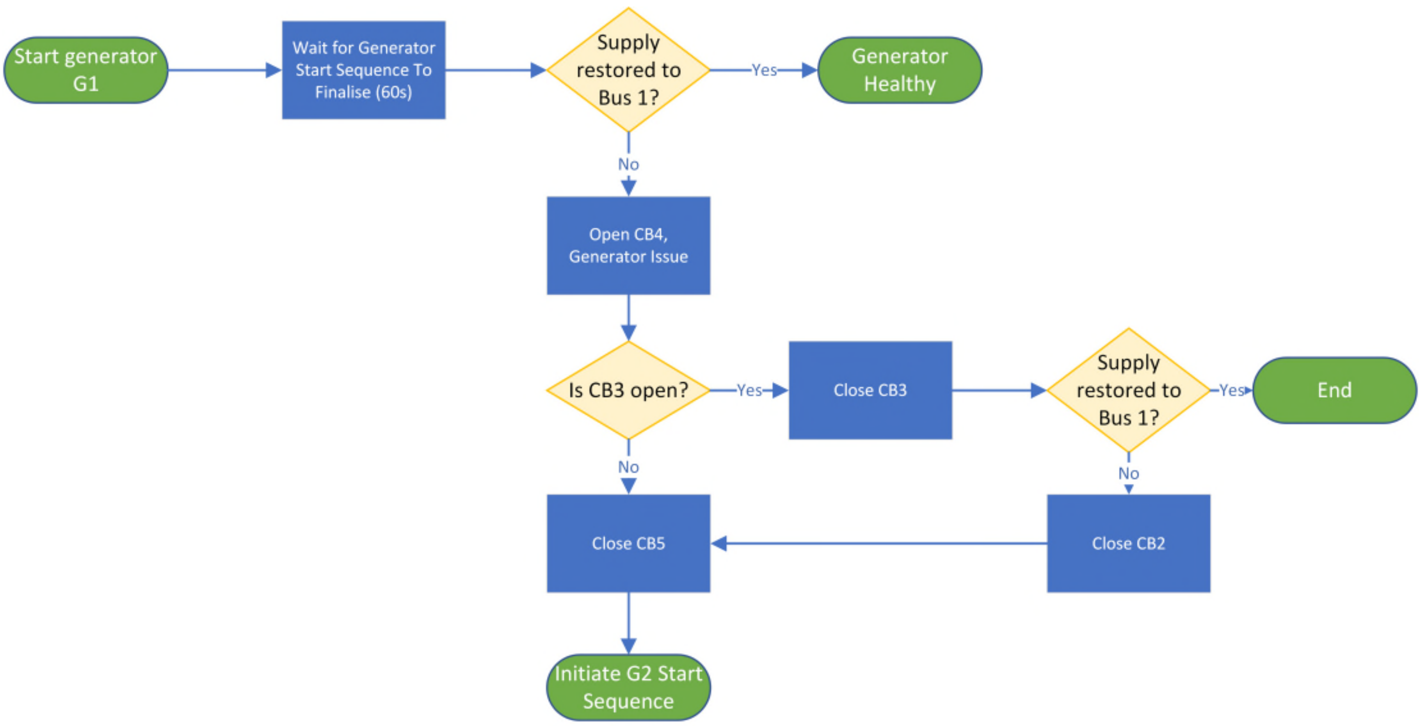
Loss of supply from Transformer TX1

1. Open CB1
2. Check and confirm CB3 is open. If it is open, go to step 4.
3. If CB3 is closed, confirm supply restored. If not, ensure TX2 not connected, and then to step 4.
4. Close CB4.



Loss of supply from Transformer TX1, Generator 1 not available.

1. Initiate process as above. On completion,
2. Check and confirm supply is restored. If so, end process.
3. If not, open CB4. There is an issue with G1. Confirm whether CB3 is open. If closed, go to 5.
4. If CB3, close. Open CB2.
5. Close CB5.
6. Start G2.



6.2.1.1 Generator Testing and Maintenance

A generator should be able to be tested without disrupting normal power supply.

When testing a generator, with normal operation network status (refer Table 4), the two busbars will be in isolation from each other. A generator is manually switched on for testing after confirmation that the busbar is isolated from other busbars. The generator is then synchronised to the network and the respective generator CB is closed.

In this case, the generation is permitted to run parallel to the network. Therefore, the transformer and generator will run in parallel for the required period to run the test before the generator is disconnected.

6.2.2 Electronic Interlock Submission Checklist

The following is required for an electronic interlocking system and should be submitted to the DNSP at the application stage.

Item	Description
1	Single-line diagram of the system:

	• indicating make and model of the interlocking device • showing arrangement of the interlock(s) • including all generating systems, bus-ties, and each interlocking system
2	Design Compliance Report as per generation requirements (template available on DNSP website)
3	Detail the function of the equipment in a Functional Specification, written in plain English: ▪ List the parts of the system ▪ Describe how the system achieves interlocking ▪ Describe how the interlocking is fail-safe ▪ Describe the normal state of the equipment ▪ Describe how the system is intended to be operated to achieve interlocking ▪ Logic statements, diagrams, and/or tables, demonstrating the logic used to ensure the requirements are met ▪ States not permitted, for example, bus-tie closed then both network connections active ▪ Describe how the system executes commands for the interlock logic, to avoid potential race conditions; for example is sequential logic used, what timing calculations are used (including refresh rate/s), what signalling protocol is used etc ▪ Generation states, start-up, synchronisation and shut-down, as relevant
4	Datasheets of the relevant equipment, including standards compliance
5	RPEQ sign-off and endorsement

7 Connection Agreement

The connection agreement shall capture all the interlocking requirements and the agreed scheme details, including the proposed maintenance requirements.

A copy of the Functional Specification shall be retained onsite, so it can be referenced by technicians throughout the life of the project.

Appropriate signage, particularly for electronic systems, is also required onsite.