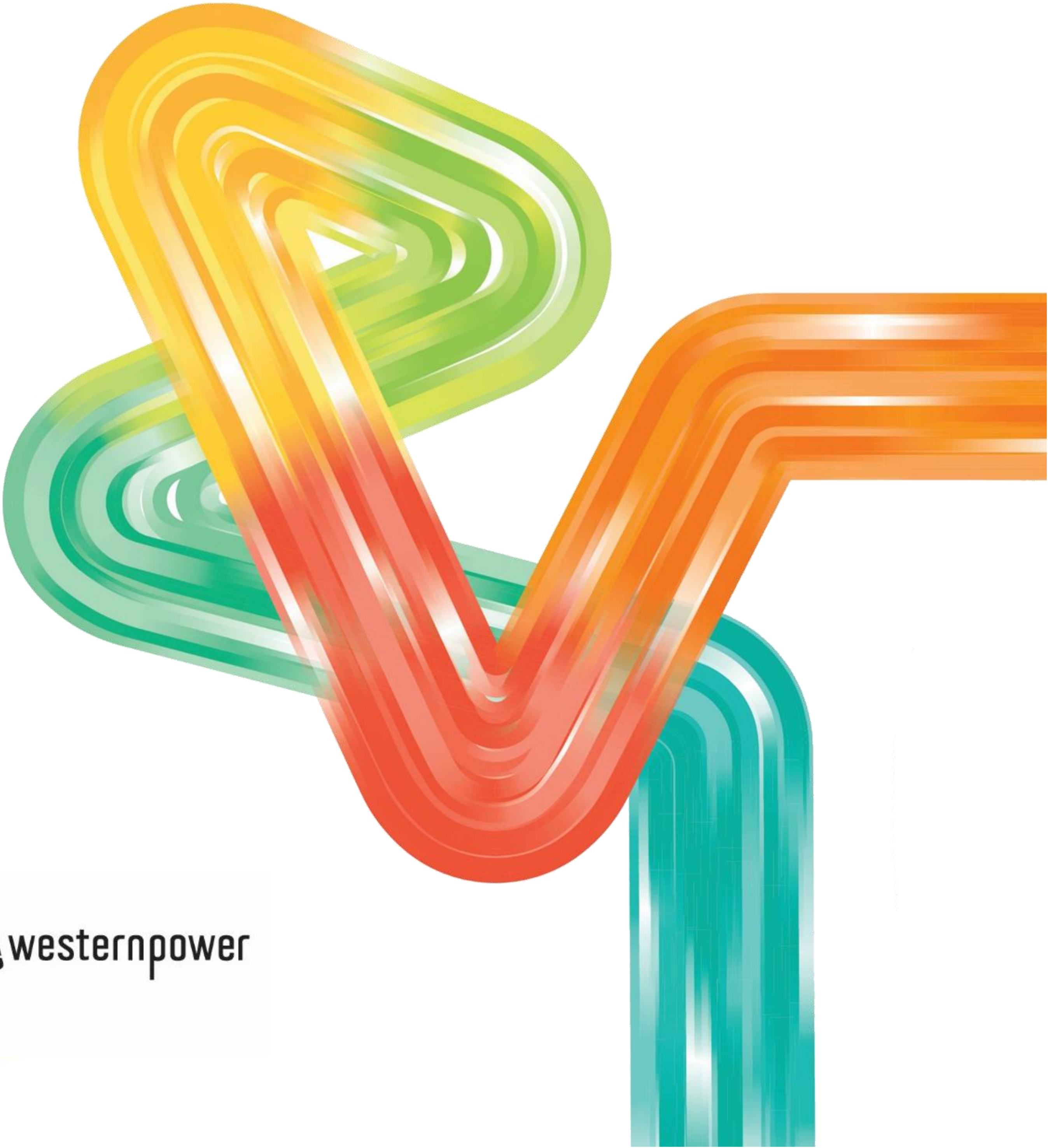
Under Frequency Load Shedding (UFLS) scheme

Customer connection guidelines

11 November 2022



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Contents

1. Purpose

The purpose of this document is to provide high-level guidelines for the mandatory Under Frequency Load Shedding (UFLS) Scheme requirements for new large commercial and industrial customers load connections[1]. Existing customers that need to upgrade their facility must also comply with these requirements.

The guidelines will include the functional UFLS requirements and provide a range of acceptable UFLS implementation options.

1 Existing large commercial and industrial load customers are in the process of being connected to UFLS.

2. Background

Western Power is obligated to design and implement an UFLS scheme in accordance with the UFLS Requirements[2] document, as prescribed within section 3.6 of the Wholesale Energy Market (WEM) Rules.

Frequency stability is maintained through the balance of load (energy demand) and generation. Large disturbances or contingencies such as the sudden loss of generation or network on the SWIS can alter the supply-demand balance and cause the frequency to decline. To manage frequency variations, the power system frequency is designed with a series of coordinated control and protection layers.

Figure 1 illustrates the system response following a system disturbance such as the loss of generation that results in an under-frequency event. As the frequency declines, the intact generators initially provide an inertial response, with the transfer of kinetic energy into the system from the rotating units. This is then followed by the primary frequency response provided by generator's turbine-governor control systems. Based on the available 'headroom' at the time of the disturbance, the generator output will increase proportionally to the frequency decline, with the aim of arresting the frequency decline and stabilising the frequency. A combination of Essential System Services and generation redispatch is then used to recover the frequency back within the Normal Operating Frequency Band region. Through a combination of generators providing primary frequency response and loads being interruptible, AEMO ensure that the frequency nadir remains above 48.75 Hz for the largest single credible contingency.

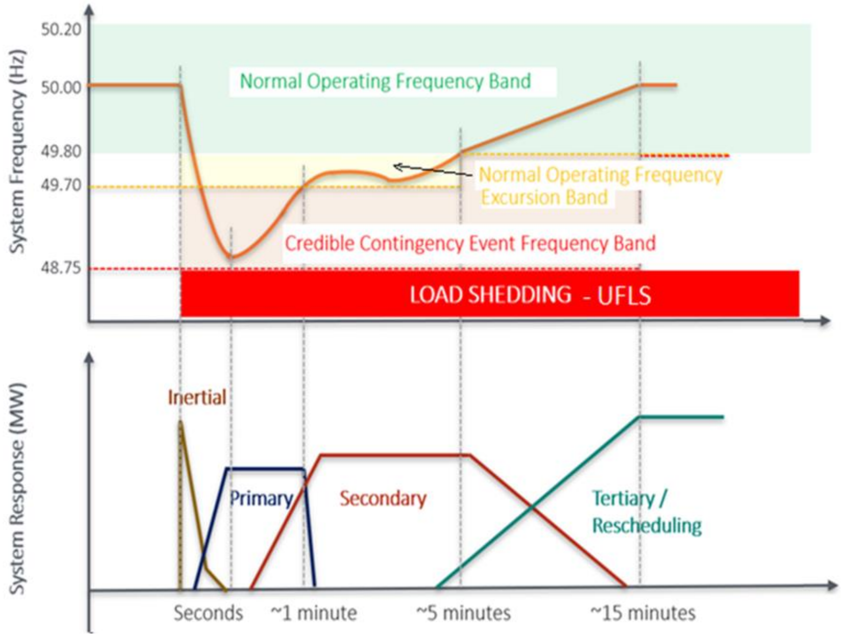

Figure 1: System Response during an under-frequency event.

Large system disturbances resulting from multiple generators and/or network contingencies are considered non-credible events. As these events have high impacts but very low probabilities, it is uneconomic to design the power system using market-based control system layers, resulting in the use of protection layers to mitigate non-credible events. Western Power's protection layer is the UFLS scheme, which is designed as a 'last resort' to prevent frequency collapse beyond the Credible Contingency Event Frequency Band region.

Under the requirements prescribed in the UFLS Requirements document, the UFLS scheme is designed to disconnect up to 75 % of the system load in five equal discrete blocks when the system frequency falls

2 https://www.wa.gov.au/system/files/2022-06/UFLS-Requirements.pdf

below 48.75 Hz. The UFLS design settings, as prescribed under the UFLS Requirements, are shown in Table 1.

Table 1: SWIS Under-frequency load shedding scheme design settings

Stage	Frequency (Hz)	Time delay (sec)[3]	Load Shed (%)	Cummulative load shed (%)
1	48.75	0.4	15	15
2	48.50	0.4	15	30
3	48.25	0.4	15	45
4	48.00	0.4	15	60
5	47.75	0.4	15	75

Western Power's UFLS system has been designed and implemented using both distribution and transmission loads, though is currently predominantly composed of distribution loads. Due to the increasing variability with the system demand throughout the day, there is an increased need to more actively manage the portfolio of UFLS load shedding reserves to meet the current design requirements shown in Table 1. This is facilitated through the remote telemetry capability that allows Western Power to re-allocate the UFLS stages for loads in real-time, when required.

More recently, the significant increases in rooftop PV capacity connected to the SWIS is resulting in a substantial reduction in distribution demand and increased numbers of distribution feeders experiencing reverse power flows. Consequently, lower levels of UFLS load shedding reserves are resulting in a reduction in the effectiveness of the UFLS, representing higher levels of system security risks. Therefore, it is increasingly important for all new large commercial and industrial load connections to have UFLS capability to manage these risks going forward.

Over the past 10 years, Western Power's UFLS scheme has operated four times, with load shedding limited to UFLS Stage 1 on all four occasions.

[3] The maximum total clearance times for the UFLS scheme must not exceed 600ms for an UFLS event. This includes relay pickup time, any time delays, relay timer errors, relay output contact operating times, signal transfer times and circuit breaker operating times.

3. UFLS Requirements

3.1 General requirements

The following general requirements for all new load customers relating to the design and implementation of an UFLS scheme include:

- All new large commercial and industrial load customers connected to Western Power's transmission network (i.e. supplied at a voltage of 66 kV of above) are subject to providing UFLS.
- All new large commercial and industrial load customers connected to the to Western Power's distribution network (i.e., 11/22/33 kV) will not be required to design and implement an UFLS scheme within their Facility. However, they will still be subject to load shedding via Western Power's existing UFLS scheme that involves the tripping of entire distribution feeders during an under-frequency event. For loads greater than 10 MW, a customer may request a multi-staged UFLS solution to be implemented at their facility[4], but the Customer must fund all works to achieve the same level and standard of remote control and monitoring requirements as those loads connected to the transmission network.
- All protection apparatus providing UFLS functionality must comply with IEC Standard 60255 and all current transformers and voltage transformers supplying this protection apparatus comply with IEC Standard 61869.
- Protection equipment installed to provide UFLS must have capability to apply to a minimum five individual UFLS stages in accordance with the frequency and time delay settings shown in Table 1.
- Each of the loads made available for load shedding will be assigned to an individual UFLS stage at any given time. These frequency band settings for each UFLS stage will be fixed however, the protection relays must also have the capability to allow Western Power to remotely control and toggle between one of five UFLS stages[5] to manage the portfolio of load reserves to meet the UFLS Requirements.
- The system frequency measurement should be measured within a maximum of 4 cycles (80ms), as well as a maximum of 4 cycles for the drop-off time. The measurement can be taken from voltage inputs at either the HV or MV level within the Customer Facility. In addition, a voltage changeover scheme is required where the voltage instrument transformer that is providing a voltage input can be taken out of service through switchable bus section.
- Undervoltage blocking should be set in each relay to prevent maloperation for the loss of the voltage transformer. Western Power's standard practice is to set this at 20% of the nominal voltage.
- The contacts driving tripping following UFLS stage operation must be latched until remotely reset by Western Power.

[4] The coordination of the UFLS stage allocations between the MV feeder and customer facility loads may not always align. In planning to meet the UFLS Requirements, Western Power may need to adjust the MV feeder CB UFLS stage allocation such that is set to an earlier UFLS stage than the UFLS multi-stage allocations within the customer's facility.

[5] Western Power does not envisage frequent changes as distribution UFLS loads will be used to adjust the UFLS stage allocation throughout the variations within the day. However, this functionality is required as greater levels of rooftop PV are connected, more flexibility will be required to manage the available load shed reserves to meet the current UFLS design parameters.

- The maximum total clearance times for the UFLS scheme must not exceed 600ms for an UFLS event. This includes a relay pickup time of 400ms, any time delays, relay timer errors, relay output contact operating times, signal transfer times and circuit breaker operating times.

- Any connection that can result in reverse power flows at the connection point for any period, must install an automatic scheme that prevents UFLS tripping when the relevant circuits within the facility are a net exporter of power into the grid (reverse power UFLS trip blocking functionality) to ensure the facility circuit is not disconnected during an UFLS event that would exacerbate the frequency decline.

- The Customer must provide Western Power with remote control and visibility as per the requirements detailed in section 3.2 of this document.

- Customers UFLS scheme will be subject to an ongoing compliance via a self-monitoring programme. As per clause 5.8 of the Technical Rules, Western Power can request information regarding the maintenance of equipment. Western Power will request evidence of compliance of UFLS related equipment on reasonable grounds that the customers equipment did not operate correctly.

- Customers are to provide evidence of their UFLS design and operational philosophy during the connection application process. Western Power will review and provide approval upon the UFLS design meeting all requirements.

- Any deviations from the requirements and options provided below are subject to negotiation with Western Power for approval during the connection application process.

3.2 Remote control and visibility requirements

All implementation options must meet the following UFLS remote control and visibility requirements.

3.2.1 Remote Control

The following remote-control requirements provide Western Power the flexibility to manage the portfolio of load shedding quantities within the current UFLS design parameters. Only Western Power will have the capability to control these functions.

- UFLS reset[6] – Post UFLS operation, Western Power will send an UFLS reset signal to UFLS customer loads when the system is safe and secure to commence an orderly restoration of the system.

- UFLS Stage Selection – to enable Western Power flexibility to reallocate the stages for UFLS loads, with the aim of optimising the UFLS performance within the UFLS design parameters, including "OFF".

Note: Western Power will **NOT** be controlling the operation of the customer circuit breakers.

3.2.2 Remote Visibility

The following remote visibility requirements are essential for providing real-time data on the quantities, health and operation of all loads providing UFLS in the SWIS. This information will be used to determine if there is sufficient UFLS load shedding reserves and whether Market intervention (e.g. generation re-dispatch, limiting generator output) is required to improve system security risks relating to UFLS.

6 Prior to Western Power issuing a remote reset, the circuit breakers that tripped during the UFLS event will not be able to be closed. This is to ensure a safe and coordinated restoration after the UFLS event.

- UFLS real-time measurements and status:
    - UFLS Stage load shedding quantity - the ‘MegaWatt’ directional measurements of each of the UFLS load shedding stages are required
    - UFLS Stage Selection – back indication of the UFLS Stage allocations (i.e. 1, 2, 3, 4, 5, OFF) for each UFLS Stage is required.
- UFLS Alarms/Status (for all UFLS Stages):
    - UFLS Stage ‘X’ Protection Operated
    - UFLS Stage ‘X’ - UFLS Equipment Defective

A detailed SCADA points mapping list will be determined during the design phase between Western Power and the Customer.

An example of the remote control and visibility points for an UFLS scheme with two UFLS stages providing 80% load shedding capability is shown in Table 2.

Table 2: Example of the remote control and visibility requirements for a two stage UFLS scheme

Type of SCADA Point	SCADA Point Name	Description
Analogue	UFLS load_1	Directional real-time UFLS load shedding measurement for first block of UFLS load (MW)
Analogue	UFLS load_2	Directional real-time UFLS load shedding measurement for second block of UFLS load (MW)
Status	Current UFLS load_1 stage selection	The stage selection status for the first block of UFLS load (1 – 5, OFF)
Status	Current UFLS load_2 stage selection	The stage selection status for the second block of UFLS load (1 – 5, OFF)
Alarm	UFLS load_1 operated	Alarm indication for the operation of first block of UFLS load
Alarm	UFLS load_2 operated	Alarm indication for the operation of second block of UFLS load
Alarm	UFLS load_1 defective	Alarm indication for defective equipment for the first block of UFLS load
Alarm	UFLS load_2 defective (assuming different device is used)	Alarm indication for defective equipment for the second block of UFLS load

Type of SCADA Point	SCADA Point Name	Description
Control	UFLS Reset	Ability to receive a remote-control signal from Western Power to reset the UFLS scheme, post UFLS operation. This is to allow for the restoration of loads that operated under an UFLS event.
Control	UFLS load_1 stage selection	Ability to receive a remote-control signal from Western Power to reallocate the UFLS stage for a UFLS load shedding stage.
Control	UFLS load_2 stage selection	Ability to receive a remote-control signal from Western Power to reallocate the UFLS stage for a UFLS load shedding stage.

3.3 Implementation Criteria

This section describes the UFLS implementation criteria to be applied to the design of a Customer's UFLS scheme. The key UFLS design criteria include providing:

- an aggregate load shedding capability of at least 75% of the Contract Maximum Demand (CMD)
- a minimum number of balanced UFLS load circuits to limit the potential adverse network impact of tripping large bulky loads during an UFLS event[7]. When considering the design within the customer facility it should be noted that providing an UFLS scheme with 5 balanced load stages (or as many as practicable up to 5) benefits Western Power in managing its UFLS obligations[8]. It also benefits the customer as less load is shed within each UFLS stage.
- remote control and monitoring requirements, as detailed in section 3.2.

The UFLS stage consisting of frequency threshold levels and time delays shown in Table 1 are applicable for each UFLS load circuit. An UFLS load circuit can include an aggregate of many sub circuit loads in meeting the requirements shown in Table 3. **Any variations to these requirements are subject to a risk assessment by Western Power[9].**

Each UFLS stage load will be monitored and operate at its local circuit breaker, as detailed in section 3.2.

The Customer will fund all works within the Customer facility up to the Western Power interface equipment.

7 Western Power may consider unequal UFLS stage loads where it is demonstrated that the differences are not material, or it is not practical to achieve a more balanced design.

8 This relates to minimising the amount of load shed and preventing prolonged system wide outages.

9 Customers will be expected to provide detailed justification for any variations to Western Power's UFLS criteria.

Table 3: Implementation criteria[10]

Size of facility (MVA)	Number of UFLS stages	Criteria
> 100	Five balanced stages.	Aggregate load shedding capability of at least 75% of the Contract Maximum Demand (CMD)
> 10 to ≤ 100	Minimum of two balanced stages.	Aggregate load shedding capability of at least 75% of the Contract Maximum Demand (CMD). In addition, maximum load per UFLS Stage of 20 MVA[11]
≤ 10	Minimum of 1 UFLS stage	Aggregate load shedding capability of at least 75% of the Contract Maximum Demand (CMD).

Figures 2-4 illustrate several design implementation examples for a 40 MW CMD customer facility.

10 In planning to meet the Western Power's obligations under AEMO's UFLS Requirements, Western Power may need to adjust UFLS stages during certain periods. For multi-staged UFLS implementations, Western Power will endeavour to maintain the customer nominated preferred sequence of UFLS loads that are tripped.

11 Facilities greater than 20 MVA per load circuit are subject to an impact assessment by Western Power during the connection application process.

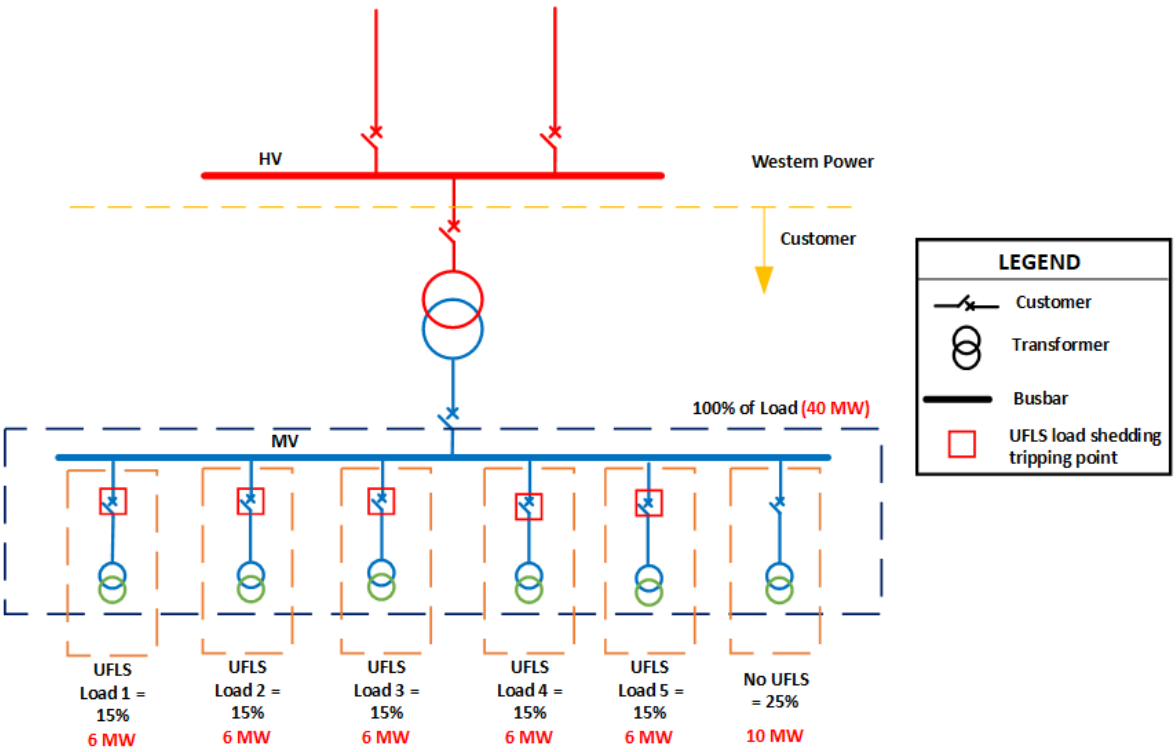

Figure 2: Example of implementation demonstrating the preferred 5 stage UFLS design

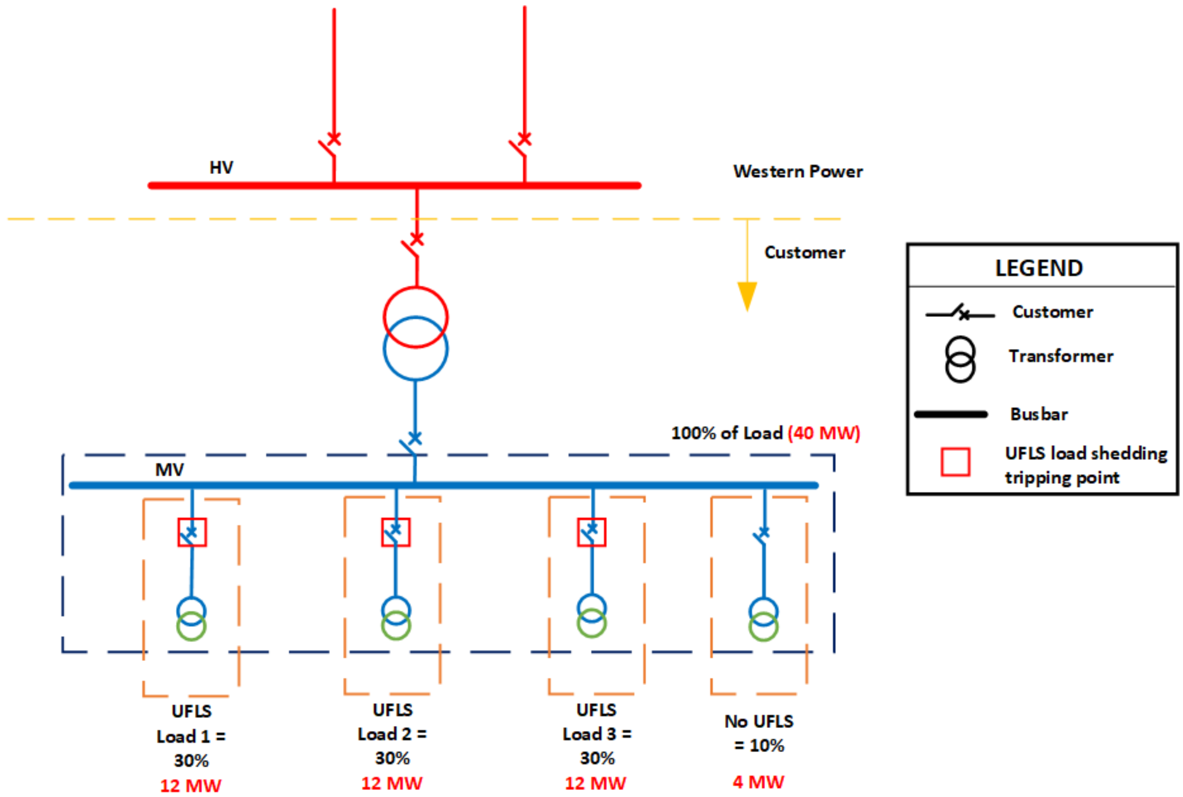

Figure 3: Example of implementation for a load (between 10- 100MVA) with <100% UFLS provided

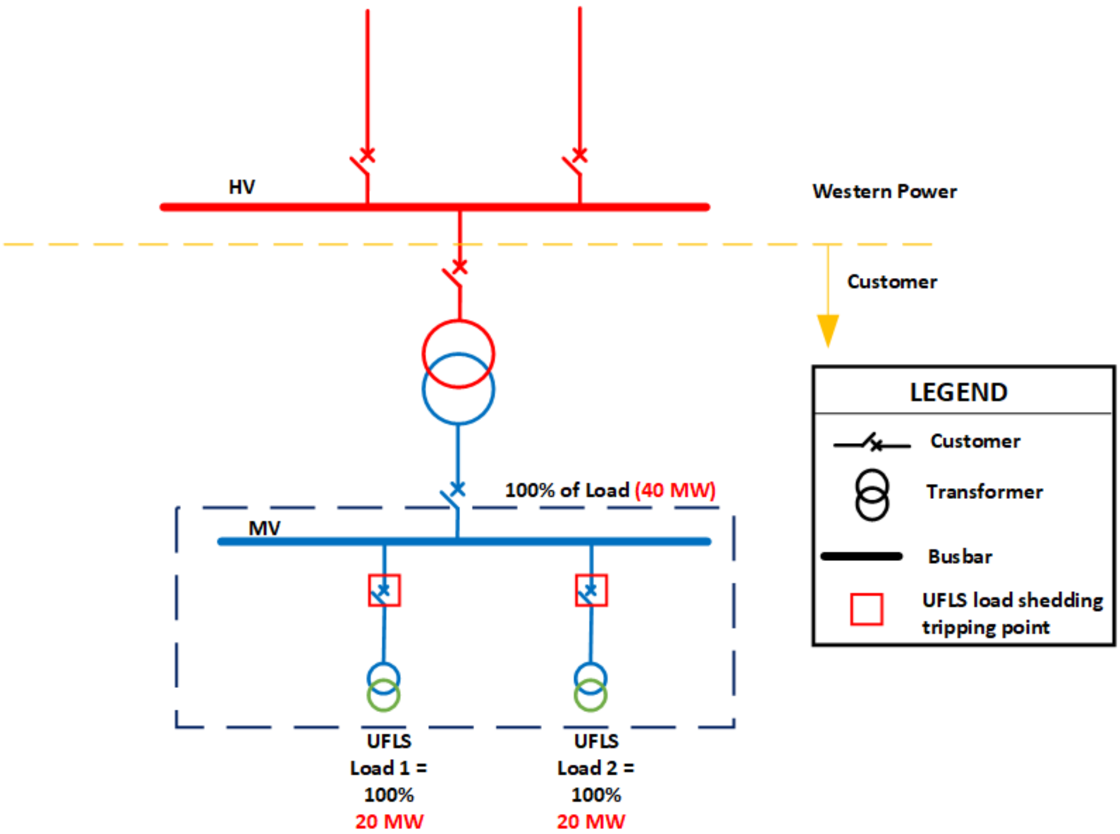

Figure 4: Example of implementation for a load (between 10- 100MVA) with 100% UFLS provided

3.4 Automation and Communication Requirements

This section provides a general overview of the Automation and Communications equipment and interfaces to Western Power in relation to Customer implementing UFLS.

3.4.1 Standard Arrangement

To facilitate the remote control and visibility requirements of the Customer UFLS by Western Power, the following standard arrangement has been developed.

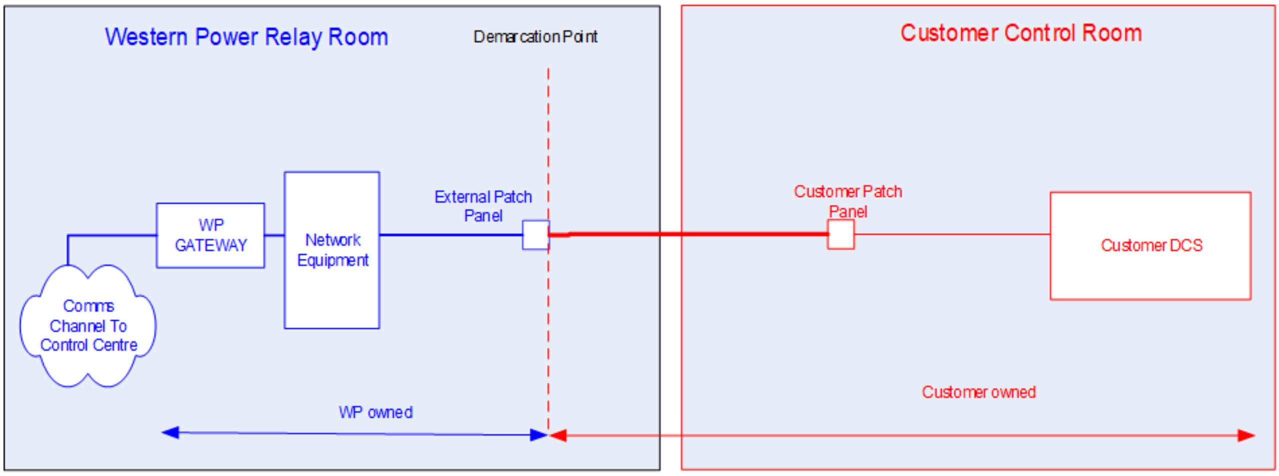

Figure 5: UFLS remote control and visibility: Standard arrangement

3.4.2 Interface Requirements

1. For transmission connected customers, where Western Power have a dedicated relay room on customer site, the interface point between WP Control Centre and Customer UFLS scheme will typically be an interface panel established outside of the Western Power relay room.
2. In the absence of a Western Power relay room on a transmission customer site, Western Power will establish an indoor automation cubicle in customer control room as the interface point. The customer shall:
   a. Provide floor / wall space for a floor / wall mounted cubicle.
   b. Provide 50VDC supply for Western Power equipment, with greater than 12 hours standby time. The power consumption of Western Power equipment depends on the interface requirements but is expected to be around 210W. This must be verified during detailed design.
   c. Complete all wiring into the Western Power cubicle at the customer site for telemetry and supply.
   d. Provide Western Power 24hr access to the customer site either via the appropriate Western Power substation key or an appropriate operational contact. A secondary contact is also required in case of unavailability.
3. For distribution connected customers, the interface point will typically be the closest WP transmission substation from which the customer is supplied. The customer will need to install a communications cabinet on the outside wall of WP relay room. WP will provide either a 50VDC or 110VDC supply to the customer.

3.4.3 Communications

The Customer is responsible to establish a new communications link to the agreed WP interface point for UFLS as detailed in 3.4.2, unless one has already been established for other purposes that is fit for use. The communications methods will primarily depend on Customer site location and existing infrastructure in the vicinity, and are typically:

- UHF point-to-point radio link
- Fibre Optic direct connection
- Alternative private telecoms service provider solutions

Additional requirements to those listed in 3.4.2 may be required at Customer site to facilitate the establishment of the Communications channel, such as the mounting of antenna, fibre cable installation etc.

3.4.3.1 Protocol Interface

The standard supported interface to Western Power equipment is DNP3.

Western Power will always act as the 'master' or 'client' during connection orientated transactions.

Physical Layer

Communications between the Customer and Western Power should utilise Ethernet based protocols over the customer communications link.

Where Ethernet is not available, communications shall utilise RS232 or RS485 4-wire serial data links.

DNP3

DNP3 protocol used in equipment must comply with the requirements of a 'Level 2 DNP3 implementation (DNP3-L2) as set out in IEEE Std 1815-2012 DNP3.

Equipment utilising DNP3 protocol shall be supplied with the manufacturer's DNP3 device profile and certification.

For serial connection, it must support Outstation device over serial connection.

For ethernet connection, it must support Server device over TCP/IP connection, Server device over TCP/UDP connection.

Provide the facility, via the configuration methodology, to undertake point address mapping and class configuration per point.

Assign data points to a DNP3 class (0, 1, 2 or 3).

Analogue inputs to be configurable as 32 bit or 16 bit (Object 32 Variation 01 or Object 32 Variation 02).

Provide settings, on a per-point basis, for analogue input dead-bands (to drive change of event reporting).

Latency Requirements

Operational Data shall be available to report to the Western Power RTU within 2 sec from the time the data is converted to digital form.

Analogue Data Representation

Analogue data shall be in the form of a 16-bit signed integer, the values shall be transmitted with a;

- Dead band of 0.5% of the full-scale range of the value.
- Maximum resolution of 1.0% of the full-scale range of the value.

DNP3 Binary Controls

Typically, DNP3 controls shall be a Pulse control with a duration of 1 second using Select-before-Operate method.