Low Frequency Demand Disconnection

Summary

This article assesses the suitability of current low frequency protection on the network as more distributed generation is connected to WPD's network.

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Note: a glossary and diagram key can be found in the DSOF introduction document on our website

Background

Low Frequency Demand Disconnection (LFDD) schemes are designed to limit the fall in frequency for extreme events beyond those defined as 'secured' events in the SQSS [1] and Operating Code OC6 (Demand Control) of the Grid Code [2].

Frequency plays a very important role in power transmission and distribution in relation to the balance between the demand and generation requirements of the network. The maintenance of system frequency within set levels is required to maintain stability and prevent a full system collapse.

Under normal operating conditions National Grid as the System Operator (GBSO) is obligated to maintain the system frequency between 49.8 and 50.2 Hz. If the network generation is higher than the demand the frequency rises, however conversely if generation is lower than the demand the frequency reduces. As the generation at any instant is unlikely to equal the demand the frequency constantly varies. The variation in frequency is normally small and has little impact on customers. Any variation in frequency must be controlled to enable certain items of equipment (e.g. clocks) to operate correctly. The GBSO continuously monitors the frequency and dispatches the appropriate generator output. Should the total dispatch of generation available be insufficient to meet the demands due to a fault or loss of generation or an unexpected increase in demand, the frequency will fall.

Under exceptional circumstances (e.g. loss of a large generator) the frequency should not deviate outside the range 49.5 to 50.5Hz for more than 60 seconds. In order to achieve this, the GBSO contracts frequency response to secure the power system for a number of events.

There may be certain circumstances where the contracted frequency response may not be sufficient to maintain the system frequency between the statutory limits where the total loss of generation exceeds the amount secured for and a deficit of generation arises. .

In order to reduce the generation deficit (or excess in demand) to maintain stability, Distribution Network Operators (DNOs) have low frequency relays to disconnect demand. This procedure is called LFDD and is described in Operating Code OC6 (Demand Control) of the Grid Code.

Network Impact

DNO Obligations

To comply with the requirements of the Grid Code, Western Power Distribution as a DNO is obligated to install LFDD schemes. The schemes are designed to automatically disconnect at least 60% of the total DNO demand on a stage by stage basis at the time of the forecasted National Electricity Transmission System peak Demand.

Implementation

The demand subject to automatic low frequency disconnection is divided into 9 predetermined discrete MW blocks which are disconnected at defined low frequency levels. Each block of demand is distributed across each license area, so far as reasonably practical, so that the demand at different Grid Supply Point (GSP) sites is reduced evenly, as shown in Table 1.

Table 1: Low Frequency Demand Disconnection settings for each frequency disconnection block [2]

Frequency (Hz)	% of Demand Disconnection
48.8	5
48.75	5
48.7	10
48.6	7.5
48.5	7.5
48.4	7.5
48.2	7.5
48.0	5
47.8	5
Total % Demand	60

LFDD schemes are fitted at 132kV substations and are designed to trip the lower voltage side of the incoming 132kV transformers or some or all of the outgoing feeders. The operating time of an LFDD scheme is as far as reasonably practicable be less than 200mS.

Growth of Distributed Generation

The growth of distributed generation connected on DNO networks at voltage levels below where the LFDD relays are installed is likely to impact on the effectiveness of the scheme. If the level of distributed generation output is high when the relay is triggered, the amount of demand disconnected may be lower than expected. Conversely if the level of distributed generation output is low the amount of demand disconnected may be higher than expected.

Decreasing System Inertia

In addition levels of system inertia are decreasing (e.g. due to the closure of large power stations) along with net transmission system demand. This reduces the effectiveness of LFDD schemes as changes in frequency will be faster and larger. Should the frequency fall at a high rate, more than one LFDD stage could operate resulting in too much demand being disconnected.

Detailed Assessment

The following examples consider the impact of an LFDD scheme on a 132/33kV substation with a significant level of distributed generation connected (35.8MVA at 33kV & 28.2MVA at 11kV and below). The LFDD relays are connected to the 33kV circuit breaker on each 132/33kV transformer. The total installed capacity of Wind generation is around 16MVA and Solar PV 36.3 MVA.

Winter with Minimal Generation

A typical winter demand and load profile on a day with minimal distributed generation is shown in Figure 1 for a 132kV substation. The underlying network demand is deflated by any distributed generation connected at 11kV and below.

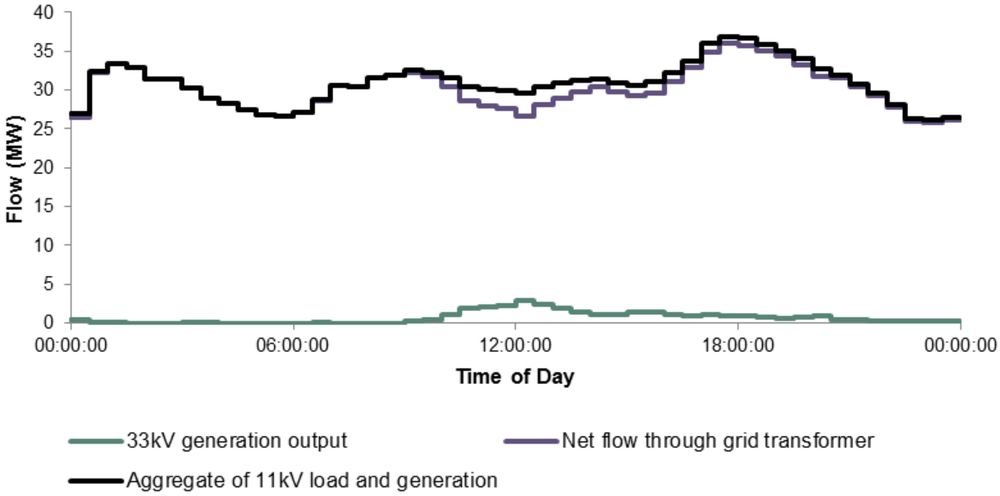


Figure 1: Typical Winter demand and load profile (minimal 33kV distributed generation)

In the above graph the underlying network demand requirement and load-flow through the 132/33kV transformers is similar with only a small offset when the 33kV connected generation is exporting. At 12:00hrs the network demand is 29.5MVA of which 26.7MVA is fed via the 132/33kV transformers plus 2.8MVA from the distributed 33kV connected generation. If LFDD was required at this instant it would remove 26.7MVA of demand plus 2.8MVA of generation.

Winter with Significant Generation

A typical winter demand and load profile on a day with significant distributed generation is distorted as shown in Figure 2. The underlying network demand is deflated by any distributed generation connected at 11kV and below.

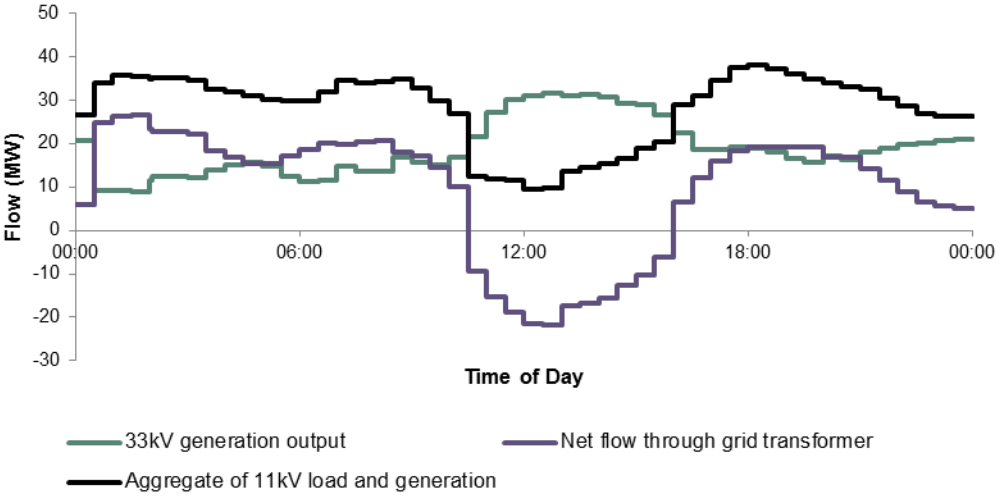


Figure 2: Typical Winter demand and load profile (significant 33kV distributed generation)

In the above graph the 33kV distributed generation output peaks during daylight hours causing reverse power-flow through the 132/33kV transformers for a 5.5 hour period (between 10:30 and 16:00 hrs).

Should the LFDD relays be required to operate at 18:00 hrs, the load disconnected will consist of 19.21MVA of net demand as seen flowing through the 132/33kV transformers (the demand being deflated by generation at 11kV and below) along with 18.88MVA of 33kV distributed generation. In the event of LFDD relays being required to operate at 12:00hrs, the net load disconnected as seen at the 132/33kV transformers is 21MVA which is effectively generation rather than demand.

Summer with Significant Generation

When a typical summer's day is considered the demand and load profile is further distorted as shown in Figure 3.

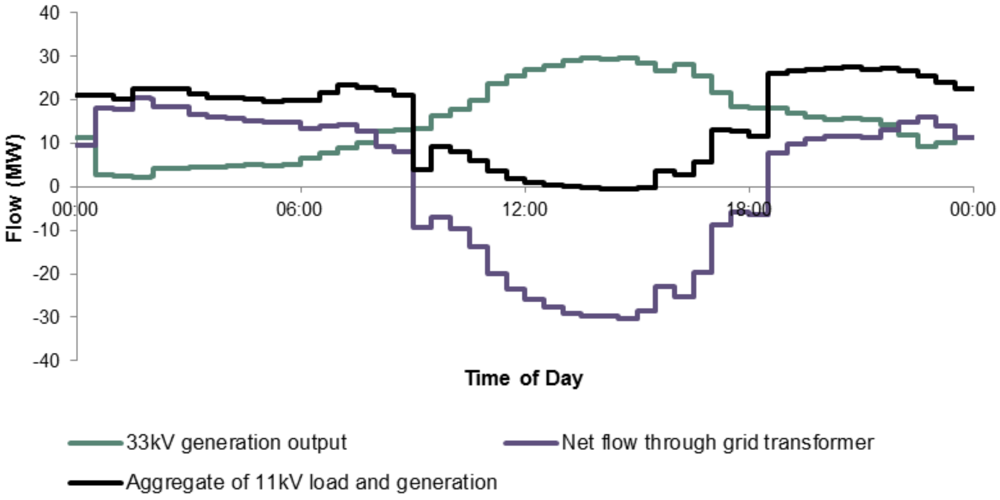


Figure 3: Typical Summer demand and load profile (significant 33kV distributed generation)

The level of distributed generation causes reverse power-flow through the 132/33kV transformers for a 10 hour period (between 08:30 & 18:30hrs).

Should the LFDD relays be required to operate at 14:30hrs, the load disconnected will consist of 0.5MVA of net generation as seen flowing through the 132/33kV transformers (the demand being deflated by generation at 11kV and below) along with 29.7MVA of 33kV distributed generation.

Impact on Operability

The above scenarios show when there is an excess of generation over demand an LFDD scheme will disconnect generation rather than demand which will contribute to a further deficit in generation rather than a demand reduction.

In summary, whilst LFDD schemes will still function and address shortages in generation, the presence of distributed generation reduces their effectiveness and predictability for the GBSO. The reduction in the effectiveness of LFDD schemes may impact on the DNO by disconnecting a higher number of customers to achieve the required disconnection of demand.

Short Term Mitigation and Solutions

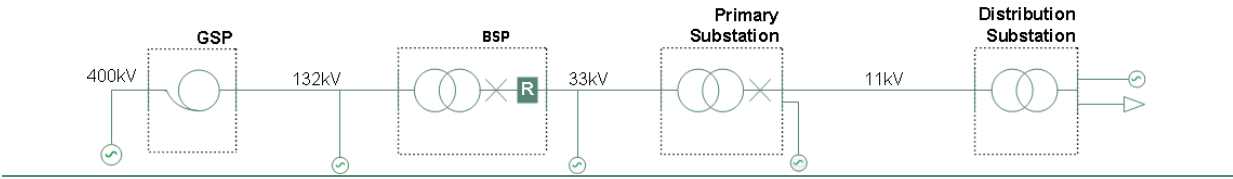
A short term solution is to assess on a seasonal basis the likelihood of 132/33kV substations being net exporters of generation rather than importers of demand and impacting on the effectiveness of LFDD schemes. If necessary the selected substations for each selected 'block of load' could be modified to reduce the risk of creating a further deficit of generation.

Long Term Solutions

Move LFDD Relays to a Lower Voltage Level

A longer term solution could be to connect the LFDD schemes at a lower voltage level closer to the demand (e.g. at 33/11kV substations). This will potentially improve the effectiveness of the LFDD scheme as it will not be disconnecting any 33kV connected generation and reduce amount of any deficit in generation. Figure 4 below shows the current location of LFDD relays on the 33kV transformer circuit breakers at 132/33kV bulk supply points (BSPs) and the proposed re-location of the relays to the 11kV transformer circuit breakers at 33/11kV (Primary) substations.

Current Practice



Proposed Practice

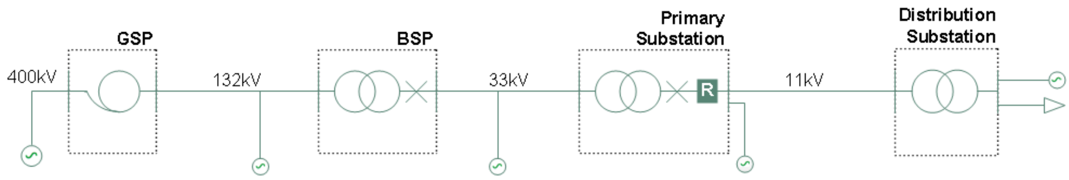


Figure 4: Illustrative example of moving LFDD relays locations

Monitor Direction of Power-flow

A further refinement to an LFDD scheme could be to automatically monitor the direction of active power-flow and block operation when there is an export of power (when the local distributed generation output exceeds network demand).

Bibliography

[1] The SQSS Review Panel, “National Electricity Transmission System Security and Quality of Supply Standard,” Version 2.3, 8th February 2017.

[2] National Grid Electricity Transmission plc, “The Grid Code, Issue 5, Revision 21,” 21 March 2017.