Fingrid Oyj

Implementation of under-frequency load shedding (UFLS) in Finland

Application guideline

5.8.2019

Table of contents

1 Introduction

Pursuant to the Network Code on Electricity Emergency and Restoration, Commission Regulation (EU) 2017/2196 (Network Code on Electricity Emergency and Restoration), Fingrid Oyj and distribution system operators must jointly create an under-frequency load shedding scheme.

An automatic under-frequency load shedding scheme works during a serious disturbance when the disturbance reserve maintained at the time is not sufficient to cover the production deficit, causing a further drop in the power system frequency. In order for the system to cope with such disturbances as well as possible, the Nordic network organisations responsible for the systems have agreed to maintain an automatic load shedding system.

2 Under-frequency load shedding (UFLS)

30% of total Finnish consumption is equipped with under-frequency protection that sheds loads automatically when necessary. The frequency stages are shown in Table 1. For more details, see section 7.

Table 1. UFLS settings and the data reported annually by a Fingrid customer.

Target values		Total operation time(s)	% of consumption	The customer fills in % of consumption		
Stage	f (Hz)			February the 1st, 8-9 a.m.	July the 1st, 8-9 a.m.	The whole year
1	48,8	0,15	5			
2	48,6	0,15	5			
3	48,4	0,15	5			
4	48,2	0,15	5			
5	48	0,15	10			

DSOs are required to select the method for implementing UFLS in their own network.

Upon request by the DSO, Fingrid can, at the main grid level, automatically trip the radial powerlines that feed the customer's distribution network. If several different operators have connected their stations along such a radial powerline, all of these operators must create a joint request to Fingrid to include the powerline in the under-frequency protection scheme. Fingrid will not trigger a customer's radial powerline if at least one of the operators along the powerline wants to implement the protection in their own network.

An under-frequency protection device may not trip the trunk lines of the meshed main grid, since this impairs the stability and dependability of the power system.

If production is disconnected along with demand, the disconnected net power must be calculated. The amount of disconnected net power must correspond to Table 1.

However, an industrial customer connected to the main grid is usually connected in a way that enables Fingrid to selectively trip industrial consumption at the main grid level, although

an industrial customer is given the opportunity to select the parts of the consumption they want to include in the under-frequency load shedding scheme, as long as 30% of the consumption is included.

If 30% of the industrial load is tripped on the main grid level, the trip will target a few major consumers. Even if an industrial corporation selects the loads it trips, their number will be significantly less than the number of distribution system loads. For this reason, it is not always possible to divide industrial consumption evenly as described in Table 1. Thus, there might be less than five frequency stages per customer.

Industrial customers must notify Fingrid whether they intend to implement the under-frequency trip by themselves and into what kind of parts the demand to be tripped is divided. Based on this information, Fingrid will determine the final frequency stages and report them to the customer.

If an industrial customer connected to a main grid switching station wants to let Fingrid implement the under-frequency trip scheme, Fingrid will procure and set the under-frequency protection devices for the customer so that the percentage of demand covered by under-frequency load shedding is approximately 30% of the total demand nationwide.

3 Implementation of frequency stages

Option 1

Large DSOs have multiple substations. A single substation does not have to include all frequency stages listed in Table 1. The under-frequency scheme can be distributed across multiple stations as desired by the DSO. An individual substation can have 0–5 frequency stages, as long as the demand that is tripped within the distribution network (including other distribution networks connected to the distribution network in question) corresponds to the proportion of total demand shown in Table 1.

Option 2

Small DSOs have only a few substations, which might make it difficult to implement all frequency stages in Table 1. Nevertheless, it is recommended that the protection scheme is distributed to as many tiers as necessary. Start at the highest frequency stage (setting 48.8 Hz) and expand gradually to the lower frequency schemes. The lower frequency stages will only be adopted when the top stage contains at least 5% of the demand. In an extreme case, there is only one frequency stage (with a layout of 48.8 Hz), which triggers at least 30% of the total demand of the distribution network.

4 Reporting the loads that will be shed

All DSOs, including those whose networks are not directly connected to Fingrid’s network, report the tripped demands directly to Fingrid. Regional network companies only report demand other than distribution network demand. This avoids duplicate reporting of the same demand.

5 Total operation time of the protection scheme

The frequency function of the protection scheme has its own operation time and the same applies to logic circuits (if any), trip transfer and the circuit breaker. The total operation time of the protection scheme may not exceed 150 ms from the moment the frequency drops below the setting.

6 Demand selection and monitoring

The demand set to be triggered at each under-frequency stage should be such that their total cumulative annual energy corresponds as closely as possible to the proportion of average power (total annual energy) of the customer shown on Table 1. Next, the percentage of demand from the total demand at each stage is checked between the hours stated below. If the average demand on stage 1 during both hours is at least 5% of the total demand and the cumulative demand on all stages is 20–40% of the total demand, the amount of demand to be tripped is deemed appropriate. If the demand on stage 1 is less than 5% of the total demand and the cumulative demand on all stages is less than 20%, or greater than 40% of the total demand, the demand selection must be changed until the conditions are met.

Paragraphs 1 and 2 of Article 50 of the regulation obligate DSOs to report annually to the transmission system operator the status of the under-frequency protection scheme that sheds loads. Fingrid agrees to the same procedure with network users that represent the industry and who want to select the demand to be tripped themselves.

In order to best combine the power measurements reported from different distribution networks and the industry, Fingrid requires that the following power values be reported to it in the format of Table 1:

The annual average demand of the demand covered by the under-frequency protection scheme and hourly average power values at 0800–0900 on 1 February and 1 July.

As regards to the customers' radial power lines that are included in the under-frequency protection scheme and are tripped at the main grid level, Fingrid obtains the required measurement data from its own systems.

7 Guidelines and recommendations for DSOs

It is possible to use the same sites for the under-frequency protection scheme as in the existing power-curtailment plan of each network company. The least important consumption is selected for the first trip stage (48.8 Hz).

The costs of implementing under-frequency protection are the responsibility of the implementing organisation. In the main grid, this is Fingrid and in the distribution network it is the DSO. This requirement is due to legislation and should therefore be taken into account in the Energy Authority's regulation model, although the Energy Authority has final say in this matter.

Careful planning is necessary to avoid incorrect trips. Under-frequency protection must not trip in transient faults or exceptional situations that are not the result of an actual system-level power deficit. Examples of such transient situations are voltage dips and changes

caused by short circuits and earth faults, voltage-free intervals during automatic reclosure and other switching situations.

The under-frequency protection scheme must be prevented from operating in an under-voltage situation, for example, during a fault or the voltage-free interval in an automatic reclosure. The recommended under-voltage setting range is 0.4-0.6 * U_n. Rapid voltage fluctuations cause an error in frequency measurement, which creates the risk of unnecessary triggering of the under-frequency protection scheme.

Zero sequence voltage blocking might have to be used in some cases. Distributed power stations in an area disconnected by the protection scheme might maintain voltage during the intended voltage-free interval of reclosure, while the frequency keeps dropping. In earth fault cases, this situation is also associated with a rise in zero sequence voltage, which means that unnecessary triggering of the under-frequency protection scheme can be prevented when zero sequence voltage is present.

After the under-frequency protection scheme has operated, restorative switching is performed manually after a permission has been obtained from Fingrid's Control Centre.

8 Implementation options

DSOs can build a protection scheme that trips individual medium-voltage lines, entire distribution network substations or radial 110 kV lines. These options are shown below, with X indicating a target controlled by an under-frequency control scheme.

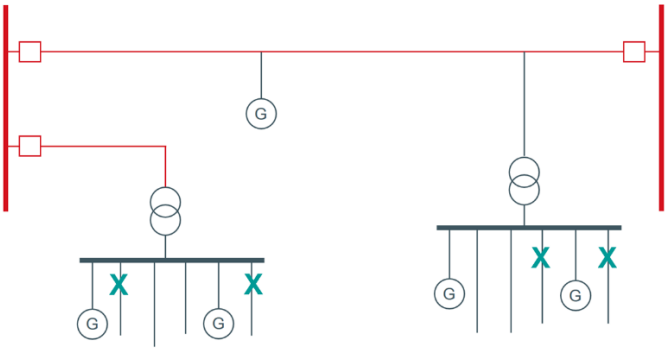

Figure 1. Implementing an under-frequency protection scheme in medium-voltage lines.

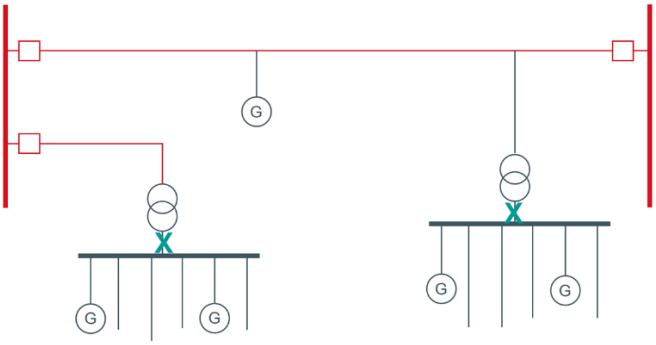

Figure 2. An under-frequency protection scheme that trips substations in the distribution network.

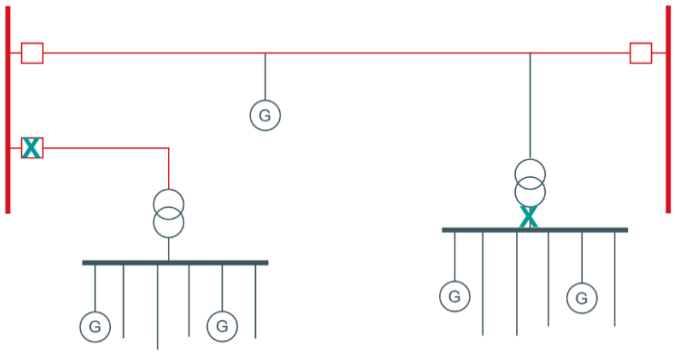

Figure 3. An under-frequency protection scheme that trips distribution network substations and radial 110 kV lines.

Annex S22440L2 presents two example figures that serve as a starting point for implementation planning. Naturally, each operator designs their own practical solutions.