THE PORTUGUESE GRID UNDER-FREQUENCY LOAD SHEDDING (UFLS) PLAN – THE DSO ROLE

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ABSTRACT

The high level of interconnection of the European electricity system makes them more dependent on national electrical systems and susceptible to disturbances. The Under-Frequency Load Shedding (UFLS) as its main purpose contributing to the balance between production and consumption in case of lack of generation, thus avoiding the collapse of the system. The objective is to develop a new methodology with focus on clear and transversal criteria not forgetting the restraints and needs to cope with the operational implementation
This paper presents the approach taken by EDP Distribuição, as a DSO, in assessing and reviewing the actual UFLS, aiding the DSO in the transition to the new guidelines in order to respond positively to the requirements, both by ENTSO-E and by the Portuguese Regulator.

INTRODUCTION

The main purpose of the Under-Frequency Load Shedding (UFLS) national plan is to help to avoid a power system blackout by shedding load in case of a generation deficit. The purpose of this plan is to be used as a tool for the safety and control of the European Electrical System in case of an exceptional disturbance. The TSO has the responsibility of coordinating the UFLS plan in partnership with the DSO, whose role is extremely important, insure an optimized selection of the loads to shed and to avoid shedding critical loads (ex.: hospitals).

Until 2010, the UFLS was based on the recommended practice from the Union for the Coordination of the Transmission of Electricity (UCTE). This stated that a 50% shed of the total load, making use of automatic devices allowing the definition of multiple steps of load shedding (49,5 Hz – Load shedding threshold (pumped-storage power plants), 49,0 HZ – 1st frequency step, 48,5 HZ – 2nd frequency step and 48,0 HZ – 3rd frequency step). The generation groups directly connected to the National Transmission Grid operated by the TSO and to the High Voltage Grid and to the Medium Voltage busbars in primary substations (managed by the DSO) should not be disconnected for frequencies between 47,5 Hz e 51,5 Hz. Until then, the DSO objective was assure that 25% of the load would be shed in case of a frequency drop below 49 Hz, and another 25% the frequency continued to decrease until 48,5 Hz.

In 2010, the ENTSO-E Operation Handbook [1] was re-evaluated, bringing significant changes to the UFLS. This plan should assure, likewise, the shed of 50% of the load, for a frequency variation between 49 Hz and 48 Hz. The frequency steps should not be greater than 200 mHz. In Portugal a program comprising 5 under-frequency steps was adopted: 49 Hz, 48,8 Hz, 48,6 Hz, 48,4 Hz and 48,2 Hz.

Table 1 - Load Shedding Frequency Bands

	Generation		*DSO*	
Frequency [Hz]		Timing [Seconds]	Load	Timing [Seconds]
49.5	Pumped Storage Plant	0.00		
49,2			Interruptible clients	0,00
49.0			10%	0,00
48,8			10%	0,00
48,6			10%	0,00
48,4			10%	0,00
48,2			10%	0,00
48,0				
47.5	Generators	0,00		

The new guidelines require a complete assessment of the current UFLS, which implies that the DSO must develop a new plan that abides by Policy 5 guidelines and current Portuguese regulatory status, namely the Quality of Service Regulation [2], establishing clear and transversal criteria for load selection.

The main objective in this paper is to assess the actual UFLS and to define a plan for the DSO's transition to the new guidelines. The analysed themes may be structured in 6 vectors:

- Current status;
- Criteria Definition;
- Main difficulties;
- DG influence;
- Operational restrains
- Operational implementation.

UNDER-FREQUENCY PROTECTION

Under-frequency protection functions are based on the grid's frequency measurement and comparison to a preset value. Algorithms for frequency measurement can be prone to have high measurement errors especially in the instant of a fault inception. The classical approach to avoid the unwanted trips is to increase the observation time thus filtering instantaneous network events, such as faults. However, this approach leads to higher operation times by the protection unit. Table 1 shows the typical operating time for the under-frequency protection of 4 different vendors.

Vendor A	~100ms
Vendor B	~85ms
Vendor C	~75ms
Vendor D	-120ms

Table 1 – Typical algorithm intrinsic delay time for under-frequency protection units

Most vendors use under-frequency protection algorithms that display a typical minimum intrinsic delay of 100ms as a response to a step variation of frequency.
The relay intrinsic delay time adds to the time the opening order takes to reach the circuit breaker and the time this takes to open. In the case of an under-frequency the frequency will drop before the circuit breakers open. Figure 1 shows this added frequency drop before the load shedding program removes load.

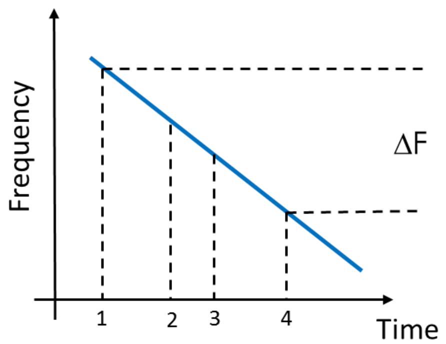

Figure 1 – Time to open the circuit breaker after an under-frequency event

In Portugal most substations are equipped with a centralized frequency relay which trips the preset circuit breakers. This adds roughly 50ms to the total time.

Considering a circuit breaker opening time of 100ms the total time between the instant where the frequency reaches the set point and the circuit breaker opens is roughly 250ms. According to [1] the maximum operating time, including breaker operation, is 350ms. Therefore the DSO under-frequency load shedding systems comply with this requirement.

METHODOLOGY

In order to successfully plan a strategy to respond positively to the requirements, either by ENTSO-E or by the Portuguese Regulator (ERSE), it was necessary to survey the current state the UFLS plan.
The survey pointed out several aspects that should be improved, in particular the positive differentiation between priority and non-priority clients, geographical optimization of load distribution, the role of distributed generation, the technological capacities of substations and the available load that can be shed in this plan.

Criteria Definition

To address the issues highlighted in the survey, it was necessary to determine exactly the available load value to shed. Thus two types of criteria were developed.

Technical criteria
Were considered all the primary substations with the UFLS system of acting at the medium voltage feeders, either by a centralized automatism or by individual protection units

Civilian criteria
The civilian criteria were selected in accordance with the Article 63º of the service quality regulation[2], which defines priority customers as those who provide security services or basic health to the community and for which the supply interruption electricity causes serious changes to their activity, therefore, MV feeders that supply these specific customers were not taken into account in the load shedding scheme.

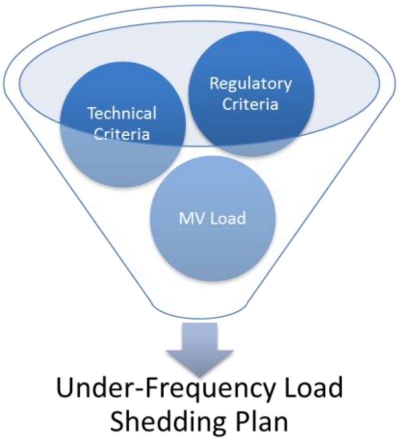

Figure 2 - Simplified methodology scheme

Load Distribution

Based on the objective of shedding 50% of the load, equally divided in five steps, the following challenge was to combine the loads from the MV feeders within the five frequency steps. Due to the magnitude of the problem (more than 3500 MV feeders to combine), the approach taken in order to reduce the scale of the problem was to downgrade it from a national level to a transmission substations level, thus reducing a complex problem into multiple problems of smaller complexity.
The geographical imbalance of the consumption density in Portugal led to a need to find a plan that would allow for a safeguard of the most densely populated areas (quality of service areas defined Quality of Service Regulation[2]) without however causing geographical imbalances.

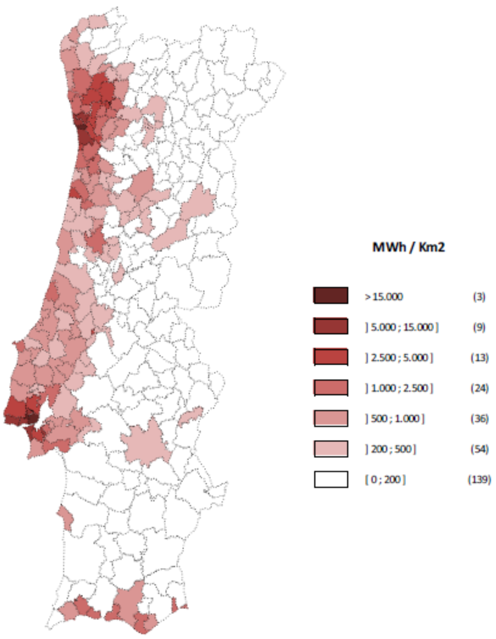

Figure 3 - Distribution of consumption by density classes MV + LV by municipality, year 2013

The model is based on the following criteria:

- Loads zones C on the 1st, 2nd and 3rd frequency step;
- Loads zones B in all 5 steps,
- Loads zones A in step 4th and 5th frequency step;

For each transmission substation and taking into account the available loads per quality of service zone, the load distribution for each frequency step is given by:

$$Pn = \sum \frac{\%\ Installed\ power\ QS\ Zone\ x \times Available\ Load}{N^{\underline{o}}\ Frequency\ Steps\ with\ Zone\ x}$$

n = step number;
x = QS Zone considered.

Distributed generation influence

The imbalance between the generation and consumption results in a decrease of the frequency value, at that point measures should be taken in order to protect generation and minimize their loss. Given the importance of distributed generation(DG) in the overall load consumption, the reviewed UFLS intended to minimize their shedding.

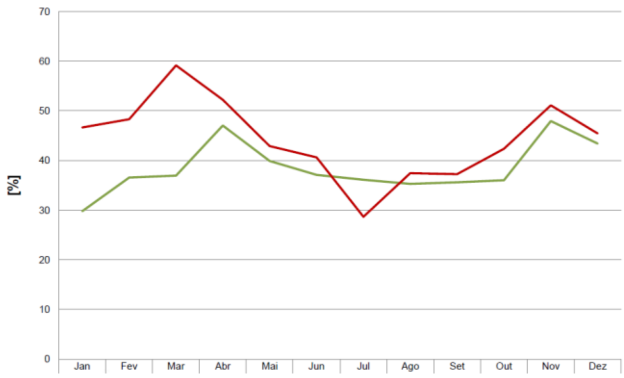

Figure 4 – [%] of load consumption provided by DG in 2012 and 2013 [3]

Therefore two types of DG were considered:

- HV and MV DG which are directly connected to the MV busbars of primary substations won't be considered in the UFLS;
- MV feeders with embed DG are considered in the UFLS, since their large majority is disconnected at 49,5 Hz.

OPERATIONAL IMPLEMENTATION

After concluding the UFLS plan the Maintenance Department was involved. It was necessary to carefully analyze each substation to proceed with the

implementation of UFSL. Some difficulties have arisen since the installed under-frequency protections span for several decades and technologies. In some older systems it was necessary to perform compliance tests, which sometimes involved the use of mobile substations to carry them out.
Another major constraint was related to existing technology in primary substations, because the implementation of the UFLS involved changes into two components - command and control (automatic frequency implementation of the algorithm) and protection functions. In some cases it was possible its implementation by command and control systems but it was not possible to implement the due to the coexistence of electromechanical protections. In other cases, it was possible implementing the frequency functions in protection but, given the local SCADA technology, this was not possible (CLP400, CLP4, RTU211, CETT, ASE400). Thus, it was necessary to break down the study by the different technologies and deploy gradually by technology.

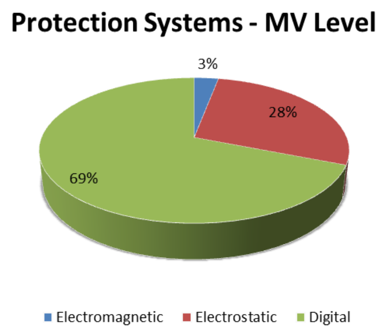

Figure 5 - Distribution of protection systems in MV Level

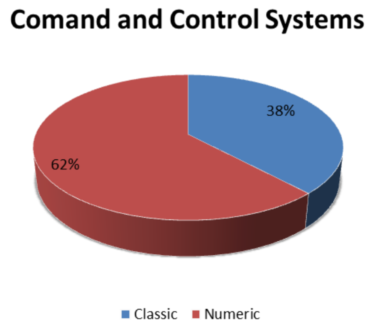

Figure 6 - Distribution of command and control systems

As seen above, this implementation required the support of a large number of human resources and time in order to carry out the necessary tests to guarantee the correct operation of the automation function. In the course of these tests several anomalies were detected, such as automatic controls that did not match the protocol used for the validation.
At the technical level some options will now be taken: the primary substations where the RTU already have automation function available, will be installed; the primary substations where the protection systems already have frequency functions new RTU will be installed.

CONCLUSIONS

The implementation of UFLS to the distribution network is still in progress due to the high operational effort required to individually implement settings in more than 3500 MV feeders. The simulation in the distribution network of the UFLS selection criteria shows that it is possible to meet the objectives proposed by the *Policy 5* thus ensuring the load values to shed, either by each frequency step or wholly of steps.

REFERENCES

[1] ENTSOE, *Continental Europe Operation Handbook - Policy 5: Emergency Operations*, available at www.entsoe.eu.

[2] ERSE, *Quality of Service Regulation*, available at www.erse.pt

[3] ERSE, Informação sobre produção em Regime especial (PRE), *available* at www.erse.pt