ENERGY BALANCE IN LOW VOLTAGE NETWORK CONSTRAINTS AND OPPORTUNITIES

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ABSTRACT

Energy losses are a very important issue in EDP Distribuição, given its commitments to energy efficiency. This work attends this problem by trying to map the total energy losses in each Medium Voltage / Low Voltage (MV / LV) substation, using the available data about energy delivered, produced and consumed, as well as the model of the LV network. It also analyses this results to classify the values that are considered normal, identify possible causes to justify the abnormal values and suggest corrective actions.

INTRODUCTION

The work presented in this paper rises from the need of identifying energy anomalies, frauds or thefts, to reduce the commercial energy loss in the distribution network. The main goal is to identify regions with a high level of total energy losses, which have a greater probability of having higher commercial energy losses.

METHOD

The principle applied in this work was very simple. It consisted in calculating the difference between the energy delivered by each MV / LV substation, plus the energy produced by LV clients, and the energy consumed by the clients connected to each MV / LV substation, obtaining the energy balance.

Formula

The formula used to represent the energy balance is:

$$Balance\ (\%) = \left(\frac{Energy\ supplied}{Energy\ consumed} - 1\right) \times 100$$

The energy supplied is the sum of the energy delivered by the MV / LV substation and the energy produced by the clients connected to the LV network.

Energy delivered

With the deployment of Automatic Meter Reading (AMR) at the MV/LV substations, it became possible to know the total power delivered in a particular network, detailed by intervals of 15 minutes. This system measures the power flow in two directions, MV to LV and vice-versa.
After the installation of the metering equipment, several tests are made to validate the data. The information used in this work was gathered always after the conclusion of this validation process.

Energy consumed

Given that smart metering in LV clients does not yet cover an extended region in Portugal, it was necessary to apply methodologies that helped transform largely spaced readings (typically 3 months) into more detailed data, adjustable to the time interval of the energy balance.
Linear distribution by day does not reflect the seasonal behaviour of clients, which results in high error in consumption estimation.
Consumption profiles, detailed by intervals of 15 minutes, for LV clients, are built yearly, depending on their contracted power and consumption, and they are calculated based on a sample of LV clients with AMR. These profiles are national, hiding the specific traits of each country region, which also result in a high error in consumption estimation, when applied to a small area.
The third option considered, which this work applied to add resolution to the energy consumed, used the energy delivered by the MV / LV substation to profile the energy consumed by the LV clients connected to the MV / LV substation. This allows the estimation of consumption based on a local profile (the energy delivered by the MV / LV substation), maintaining seasonal and regional traits.
The MV / LV substation profile was used to split consumption between two readings and to estimate past and future consumption relative to a real consumption measured.

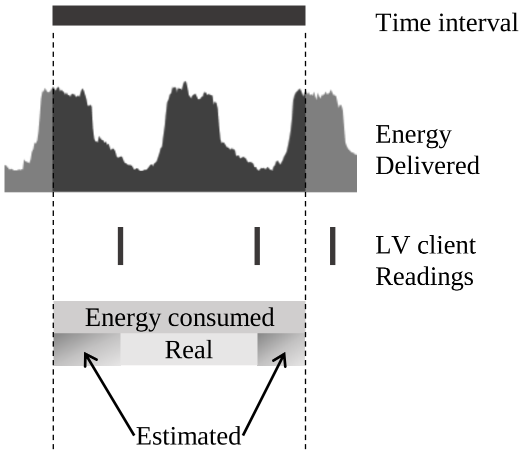

Figure 1 Schema of information used to calculate the energy balance in a given time interval

Readings go through a rigorous validation process, to insure that consumption calculations do not have errors. Only the data validated by this process was used in this work.

Energy produced

For energy produced, there is no profile available. Therefore, the average daily energy production was used to add resolution. No back or forward estimation is made, assuming zero production when no readings are available.

Network information

Due to the dynamics of the LV network, the clients connected to a MV / LV substation are not always the same. This method used quarterly snapshots of the network model, to identify the clients connected to each MV / LV substation in a given time interval.

Tools

Due to the volume of data and the diversity of file formats of the gathered data, this work was developed in Microsoft SQL Server.

RESULTS

Validation using smart grids

To measure the error associated with this method, two MV / LV substations were chosen, with all the LV clients with smart meters installed and integrated in an Advanced Metering Structure (AMI) [1].
The communication model of the AMI system, which uses PLC (Power Line Communication) protocol, was used to identify the LV clients connected to each MV / LV substation, which is sometimes different from the network model registered in the company system.
The balance using this method and the balance using the meter data from AMI system (without any estimation) were compared and showed an absolute error of about 2%.

MV/LV substation	Time interval	Balance (%)		LV clients
A	2015-01-01 to 2015-01-31	Method	2,01	3
		AMI	-0,14	
B	2015-01-01 to 2015-01-31	Method	6,07	112
		AMI	4,04	

Table 1 Results of the validation tests made to the method

Analysis criteria

Considering the manual method used to collect all the data needed from the company systems, metrics were constructed to show the proportion of data missing (for example, readings for LV clients). Only the results with at least 95% of LV clients with readings were considered.

MV/LV substation	Time interval	Balance (%)	LV clients considered (%)
C	2015-04-01 to 2015-06-30	-8,57	95,91
D		22,98	95,65
E		20,39	95,83
F		16,62	96,34
G		6,81	95,71
H		-0,78	95,18
I		7,24	100
J		179,91	95,24

Table 2 Examples of balances calculated with this method

Aggregated balance

Given the range of values obtained, the possibility of errors on the network model was raised and the need for an aggregated vision was identified. First, the balances were aggregated by proximity, using the MV / LV substations coordinates, according to the formula:

$$D = \mathrm{acos}(\sin(A_x) \times \sin(B_x) + \cos(A_x) \times \cos(B_x) \times \cos(B_y - A_y))$$

where D is the distance from MV / LV substation A to MV / LV substation B and A_x, A_y, B_x and B_y are the coordinates, in degrees, of MV / LV substations A and B, respectively.
Afterwards, the aggregation grew and became by county.

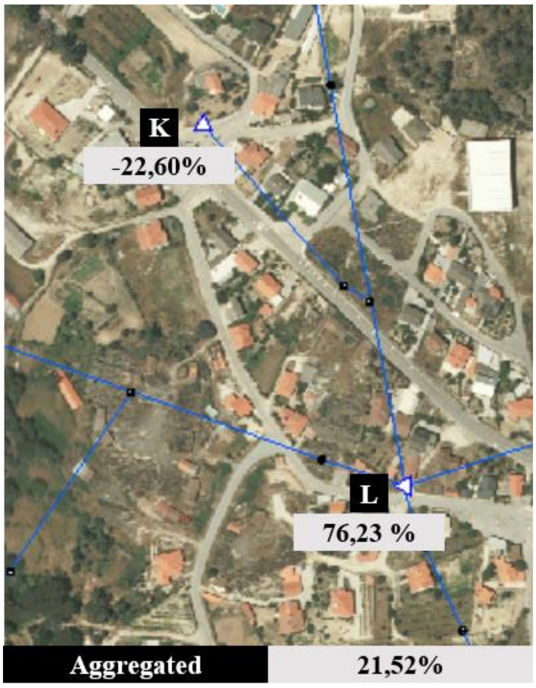

Figure 2 Example of aggregated balance of two MV / LV substations

Decision tree

The various analysis made showed that depending on the values obtained by the metrics, distinct causes were identified and, consequently, different corrective actions were advised. The following schema shows the decision tree that evolves from the analysis:

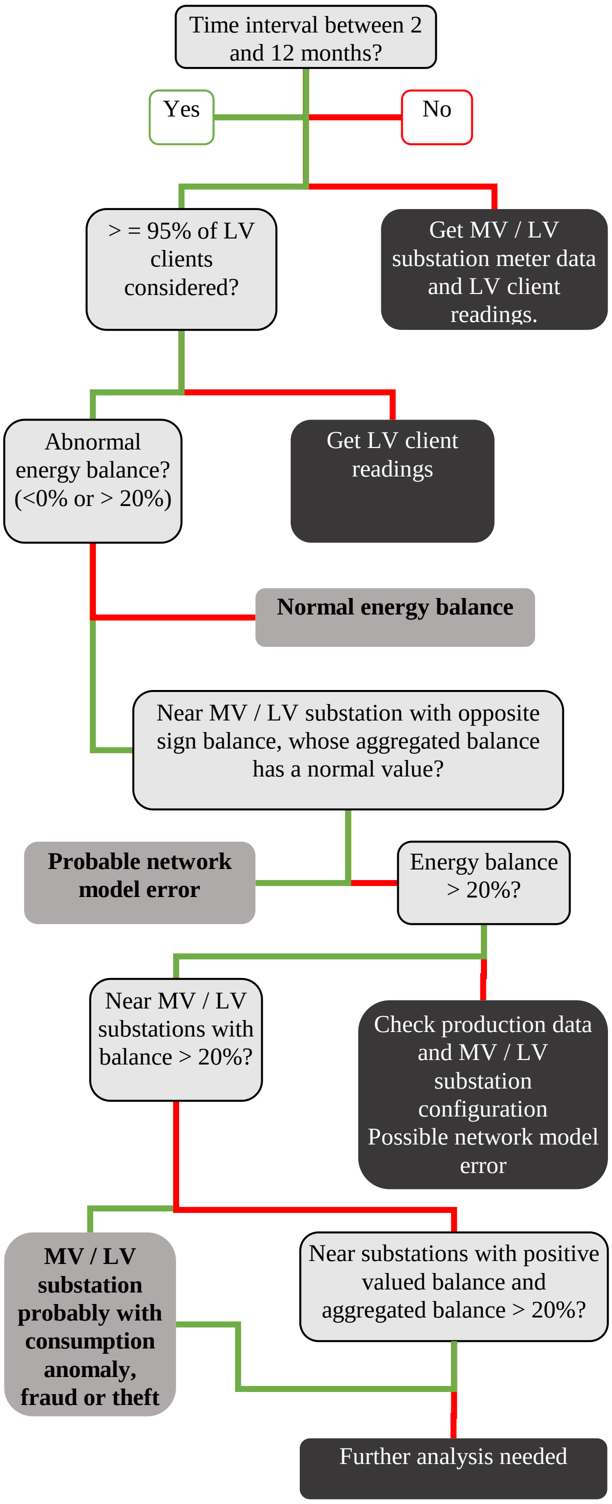

Figure 3 Decision tree

Field tests

To test the analysis made, the field teams were involved in the project. Their work was separated in two stages: the first verifies the network model and corrects it if necessary, allowing for new and more accurate values to be calculated; the second audits the LV clients connected to MV / LV substations whose network model has been validated in the first stage. The main goal of the second stage is to search for consumption anomalies, frauds or thefts and correct them. After this process, MV / LV substations with high energy losses should reduce their losses and the new value obtain should be the technical energy losses.

MV/LV substation	Balance before field work	Balance after field work
M	34,1	12,4
N	45,2	9,6

Table 3 Examples of balances corrected by field work

CONCLUSIONS

This method, when all the necessary data is available, shows an error relatively low and allows obtaining more detailed energy losses in the LV network. It also indicates several different possible problems in the data used, allowing more focused corrective actions.

Constraints

Network information errors were a big obstacle in this work, because they distort all the other calculations made. It is crucial to correct the network model to have more detailed and accurate data about the location of energy losses.

The dynamics of the network is not always reported on the network model. This also contributes to the deviations on the values calculated. It is important to consider this factor when applying this method.

With about 67 000 MV / LV substations and 6 000 000 LV clients connected [2], the volume of data is impossible to process manually. It is important to acquire tools that allow the full processing of this data, in order to have a global vision of energy losses and to structure a plan to address this issue more efficiently.

Opportunities

Using the communication model, it is possible to correct the network model. For now, this only includes a small portion of the LV clients, but, has the smart meters deployment expands, this can be a very efficient way to improve the network information, without additional field work. This method is applicable apart the expansion of smart meters and its results improve with smart meter data.

Using this work, as some MV / LV substations are validated with field tests and technical energy losses references are obtained, it is possible to prioritize interventions to MV / LV substations with higher probability of commercial energy losses. This will allow a better financial return by field intervention.

REFERENCES

[1] P. Lúcio, P. Paulo, H. Craveiro, 2011, "Inovcity – Building Smart Grids in Portugal", *CIRED 21st International Conference on Electricity Distribution* paper nº 0455.

[2] EDP Distribuição, 2014, Relatório e Contas - Rede de Distribuição em Portugal https://www.edpdistribuicao.pt/pt/edpDistribuicao/indicadoresGestao/EDP%20Documents/RC_EDP%20Distribuicao_2014.pdf.