NETWORK TECHNICAL LOSSES PRECISE EVALUATION USING DISTRIBUTION MANAGEMENT SYSTEM AND ACCURATE NETWORK DATA

Gianluca SAPIENZA
Enel Distribuzione SpA – Italy
gianluca.sapienza@enel.com

Christian NOCE
Enel Distribuzione SpA – Italy
christian.noce@enel.com

Giovanni VALVO
Enel Distribuzione SpA – Italy
giovanni.valvo@enel.com

ABSTRACT

EU Member States shall ensure that concrete measures and investments are identified for the introduction of cost-effective energy efficiency improvements in the network infrastructure.
A precise evaluation of the distribution network technical losses is crucial to plan efficiency actions on the network. For this reason, Enel Distribuzione, the main Italian distribution system operator, customized its Distributed Management System and integrated it to other Corporate Systems in order to get accurate and reliable results on losses calculation.
Accuracy and reliability is really important because these data, officially communicated to the Italian electrical market regulator, are used to plan the grid operation at "minimum energy losses".

INTRODUCTION

It is well known that the optimal grid operation and planning are very important because their impacts on several key performance indicators (KPIs). One of these KPI is represented by energy losses.
Total energy losses are defined as difference between bought and sold energy. These losses can be divided into technical (cupper and iron) and non-technical (caused by other reasons - non synchronized measurements, thief, losses during short faults, etc).
The reduction of energy technical (TL) and not technical losses (NTL) play an important role in the network efficiency improvement, that is a provision of several Electricity market regulations around the world [1].
With reference to TL, a first problem is to have an accurate evaluation [2]. The use of tools such as load flow (LF) is required for proper evaluation. This implies necessarily having a lot of information about lines, transformers and equipment, which can be hard to obtain. Furthermore, load variations are a very important factor to evaluate these losses.
So TL are influenced by the grid topology, grid characteristics, presence of distributed generation (DG) and active/reactive load distribution. In order to plan the grid operation at "minimum energy losses", all of the previous factors must be taken into account.
For this reason, in order to get accurate and reliable energy losses results, Enel Distribuzione (ED) customized its Distributed Management System (DMS), developed by the Schneider Electric DMS NS (Serbia), and integrated it to its Corporate Systems.
It is important to underline that TL results, calculated by ED using the ED DMS, are officially communicated to the Italian Authority for Electrical Energy and Gas (AEEGSI).
Results accuracy and reliability are evaluated by a comparison between ED DMS output and real data obtained by the ED Automatic Metering Infrastructure (ED AMI).
Results are calculated for all 28 ED Operative Centers (COE), distributed on the Italian national territory. Each COE is equipped by the ED DMS.
This paper will present the results of the ED DMS in the calculation of energy technical (TL) losses for the ED MV distribution network.

ED DMS STRUCTURE

As reported in the previous paragraph, all ED COEs are equipped by the ED DMS. Where is used for operation, operation planning, simulation and analysis for the entire ED MV distribution grid.
The ED DMS is integrated with the main ED corporate systems (figure 1):

- the ED SCADA;
- the Corporate Asset Management System and network component DB (ED AUI);
- the ED Geographic Information System (ED GIS);
- the ED AMI.

A standard ED DMS is composed by several operator clients (normally two), i.e. DMS clients, and a centralized server. The server performs on-line calculations and it is always-on with the ED SCADA. ED DMS clients shown the grid topology with the same graphic/symbols of the ED SCADA (see figure 2). It can work in on-line mode or in simulation mode. When the DMS client is in online mode the operator can only perform a grid monitoring. Indeed, when the client is in simulation mode, the operator can do all manipulations, simulating several scenarios and getting output results. A focus on how the ED DMS work to calculate output data will be given in the following paragraph.

DMS main features

The core of the ED DMS is a LF engine which works with a real-time state-estimator algorithm. The LF is calculated taking into account:

- the real-time grid topology, in order to get these data, the ED DMS is real-time connected to the ED SCADA;
- the grid electrical characteristics, in order to get these data, the ED DMS is integrated to ED AUI;
- the load and the generation, in terms of active and reactive power curves, in order to get these data, the ED DMS is integrated with the ED AMI database and with the generation forecast system (ED MAGO [3]). E.g. figure 3 shown an active power daily curve for a solar distributed generator, derived from the AMI database.

It is important to underline that the integration with the ED AMI has been done developing the Enhanced Load Profile Generator [4] (application to create DMS load curves), that elaborate the data coming from the ED AMI system and provides to the ED DMS the load curves for all the customers (active and passive). This functions was one of the first customization required in order to exploit the potentiality of the ED AMI, that is one of the most appreciate in the world [5]. Thanks to this function and the application of Electronic Meters to all the ED MV and LV customers, each MV customer and each MV/LV transformer can be represented with load profiles reproducing the effective load during the day, taking into account all the variations due to time, holidays, seasons, etc.

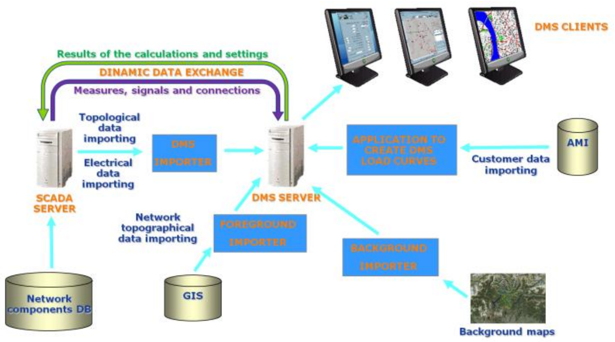

Figure 1: ED DMS architecture

With reference to the MV customers load curves; each passive load is taken into account using 24 daily load curves:

- active power (P): 4 seasons per 3 day type (working day, Saturday, Holidays);
- reactive power (Q): 4 seasons per 3 day type (working day, Saturday, Holidays).

If the load is passive and active, even during the same day, it is necessary to use 48 daily load curves , 24 representing the active load and 24 representing the passive load.

With reference to the MV/LV trasformers load curves; all the contributions (passive and active) are taken into account using 24 summarized daily load curves:

- active power (P): 4 seasons per 3 day type (working day, Saturday, Holidays);
- reactive power (Q): 4 seasons per 3 day type (working day, Saturday, Holidays).

All the load curves are 96 sample daily.

Moreover all available real-time measures (P, Q, V, I), coming from HV/MV substations and from MV/LV substations are taken into account in calculation: these measurements feed the state-estimation algorithm, which “tune” LF results minimizing the error, in all measured points, between calculated data (from the LF) and measured data. Using this technique, the DMS is able to give calculated data (P, Q, V, I) in all points of the grid, with a minimized error. The difference between calculated and really measured data is visible in all measured points, e.g. at the feeder head, as reported in figure 4, where the calculated current is 32.3 A and the measured current is 31 A.

Real-time results calculated by ED DMS are sent to the ED SCADA and they are available to operators in order to perform an accurate grid operation.
The combined LF and state-estimation mechanism described above, runs when the ED DMS terminal is “on-line”. However, when the terminal is in simulation mode, the system uses the last updated historical data.
The DMS Energy Losses calculation function (DMSEL) and the DMS Network Reconfiguration function (DMSNR), which gives an optimum grid topology at minimum energy losses, are available in this mode.

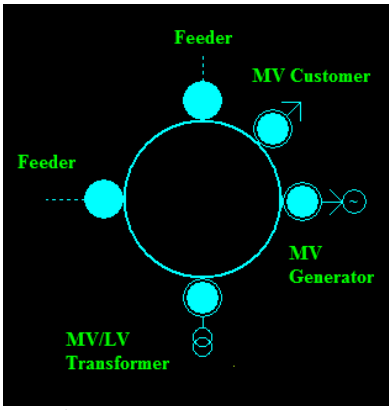

Figure 2. Example of MV/LV substation graphical representation in ED SCADA and in DMS.

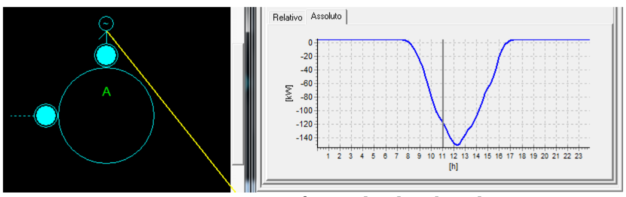

Figure 3. Active power curve for a solar distributed generator.

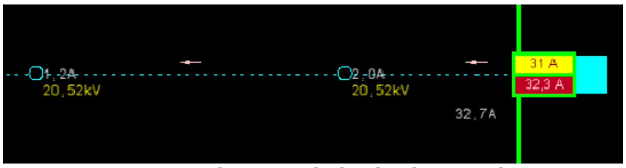

Figure 4. Comparison between calculated and measured current at feeder head.

Technical energy losses calculation in ED DMS

DMSEL deals with TL only, providing the global insight into the energy losses in the MV distribution network from HV/MV substation until LV busbars in MV/LV substations. The losses are calculated for given network state and for the specified time period; it is also possible to include/exclude the impact of DG.

DMSEL provides assessment of total and particular technical power/energy losses by voltage levels, by supply substations, feeders as well as on all network elements. For particular losses are given their participation in total TL. In this way, this function enables identification of most critical parts of the network regarding energy losses.

DMSEL perform the technical energy losses calculation using the LF algorithm of ED DMS; that is based on [6], this LF is simple, efficient and has fast convergence ability.
For the TL evaluation of one year, 35040 (96 sample per 365 days) LF must be performed sequentially; nevertheless around 5 minutes are enough to perform the calculation in one ED territorial area, with the following characteristics:

- 2000 MV feeders;
- 40000 MV/LV substations;
- 10000 MV customers;
- 30000 MV/LV transformers.

ENERGY LOSSES CALCULATION RESULTS

In this section results of the DMSEL function are presented. The calculation of TL has been performed for the entire year 2013.

Table I shows energies delivered at the HV busbars of ED HV/MV substation for each Italian Territorial Area. It is divided in order to show:

- E_DMS [MWh], i.e. the energy in MWh delivered at all the HV/MV substations, calculated by the ED DMS;
- abs(ΔE) [%], i.e. the percentage difference between E_DMS and the energy delivered at the HV/MV substations measured by means the metering system (provided by electronic meter installed on the HV/MV trasformers);
- WP_DMS [MWh], i.e. the TL in MWh calculated by the ED DMS;
- WP_DMS [%], i.e. the TL in % calculated by the ED DMS.

Table I
Technical energy losses calculation results for the 2013

ED Territorial area	E_DMS [MWh]	abs(ΔE) [%]	WP_DMS [MWh]	WP_DMS [%]
North 1	23756547	7.84%	502601.1	2.12%
North 2	43388000	2.74%	803496	1.85%
North 3	30142366	4.27%	615756.1	2.04%
North 4	27650819	3.07%	643168.4	2.33%
Center 1	20909111	5.12%	443331.5	2.12%
Center 2	17167868	2.07%	402640.4	2.35%
South 1	16431408	6.86%	371950	2.26%
South 2	15121135	6.51%	401521.2	2.66%
South 3	6539663	10.35%	163228.6	2.50%
South 4	16480431	6.20%	377322.8	2.29%
South 5	7056287	17.12%	196750.2	2.79%
Total	**224643635**	**4.00%**	**4921766.3**	**2.19%**

It is important to emphasize that the DMSEL cannot use any measures (included the registration of the meter on the HV/MV transformers), because it is based on LF. So, the comparison between metered delivered energy in HV/MV trasformers and E_DMS can be taken as a Key Performance indicator of the DMSEL results quality.
So, ED considers as valid calculated energy losses (WP_DMS) when abs(ΔE) is small.

From Table I we can observe that abs(ΔE) is small in the north-center area and become greater in the south. This phenomenon occurs also because in the south of Italy NTL are bigger if compared to the north-center area. Then measured losses are bigger if compared to calculated energy losses. ED is using ED DMS calculated data also to isolate areas where non-technical losses are relevant.
The analysis on the input data and configurations in the DMS system of south Italy are in progress, in order to detect further source of errors.
Even through NTL, the difference abs(ΔE) for the entire ED grid (row Total in Table I) is 4.00 %, and calculated losses result WP_DMS is equal to 2.19 %.
In our experience, both number can be considered as a good result.

NETWORK RECONFIGURATION A MINIMUM LOSSES OPERATION

As described in previous paragraphs, the ED DMS, by means the DMSNR, gives an optimum topology asset, calculated minimizing energy losses; also load balance and interruptions optimization can included in the objective function that calculated the optimal topology.

This is possible thanks a set of options, shown in figure 4. Operators can also choose which type of breaker they want to use, e.g. remote controlled or not, under load or not. Moreover the can simulate a load increment of they can shut-down the distributed generation.
The DMSNR function gives a big number of manipulation to reach the optimal topology asset, ranked if function to the energy save benefit.

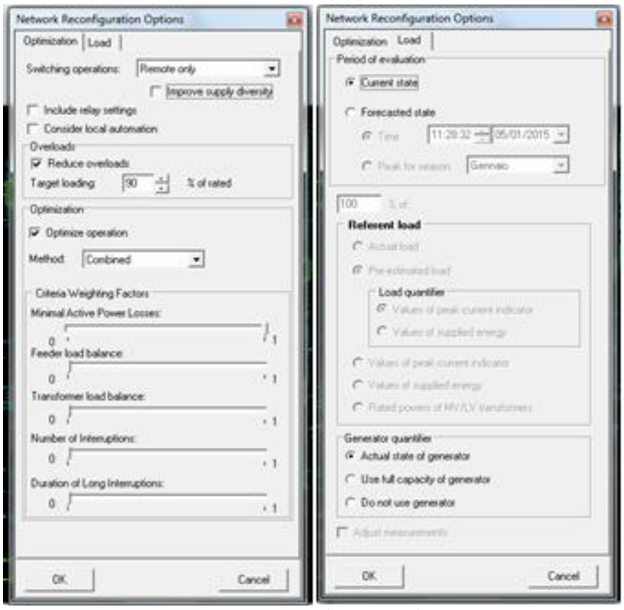

Figure 4. DMS network reconfiguration function options

ED performed several studies in order to filter the most effective manipulations. The conclusion is that applying the 20 % of total manipulations, is it possible to save the 80 % of energy losses [4].

CONCLUSIONS

DMS in ED is a key system used both for grid operation and for optimal operation planning issues, like energy losses evaluation. DMSEL and DMSNR functions are fundamental to ensure this.
Moreover analyzing DMSEL data and making comparisons with metering data, is it possible to "measure" non-technical losses entity and isolate areas where there problems are present.
This important result has been possible thanks the big customization work performed to integrate the DMS to the corporate systems and SCADA. In particular the integration with the AMI system allowed to use really metered load curve and the integration with the SCADA allowed to use the grid topology in real-time.

REFERENCES

[1] Energy Efficiency Directive (2012/27/EU) of European Union.

[2] J.E. Mendoza, M. Lopez, S. Fingerhuth, F. Carvajal, G. Zuñiga, 2013, "Comparative Study of Methods for Estimating Technical Losses in Distribution Systems with Distributed Generation", *INT J COMPUT COMMUN, ISSN 1841-98368(3):444-459, June, 2013.*

[3] C. Baldi; F. Corti; G. Di Lembo; F. Nebiacolombo, 2012, "Monitoring and control of Active distribution Grid Integration of Renewables into the Distribution Grid", *CIRED 2012 Workshop*.

[4] G. Di Lembo, P. Petroni, C. Noce, 2009, "Reduction of power losses and C02 emissions: accurate network data to obtain good performances of DMS systems", *CIRED 20th International Conference on Electricity Distribution.*

[5] Gartner "Magic Quadrant for Advanced Distribution Management Systems" by Randy Rhodes & Zarko Sumic, March 19, 2014.

[6] D. Shirmohammadi, H.W. Hong, A. Semlyen, G.X. Luo, 1988, "A compensation-based power-flow method for weakly meshed distribution and transmission networks,", *IEEE Trans. Power Syst. 3 (2) (1988) 753–762.*