MONITORING AND CONTROL OF ACTIVE DISTRIBUTION GRID

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ABSTRACT

Enel Distribuzione and Siemens are developing a new system called "MAGO" (Monitoring and control of Active distribution Grid Operation) to collect and process data regarding distributed generation. The scope of the project is forecasting the distributed generation (DG) on MV networks, aggregating data according to the different sources (solar, wind, hydro, thermal and others).

Forecasted production data and real-time measurements will be provided to the operators of Distribution and transmission (TSO) control centres to help them in "Active" network operation.

INTRODUCTION

The increase of distributed generation (DG) from renewable sources (solar, wind, thermal, etc.) also at domestic level, is leading to a radical change in energy distribution.

The network control systems must be upgraded to integrate, manage and control energy flows coming from both, conventional power plants and medium and small generation at local level.

The electrical grid will no longer be an unidirectional channel transmitting and distributing energy from the conventional plants to the final users, but will be a Smart Grid enabling the interaction among producers and users, forecasting the demand and balancing the production and consumption of electric energy, taking into account dispersed generation located in the lower levels of the network.

Pushed up by these needs, Enel and Siemens started the development of "MAGO": a new engine to collect and process data regarding DG in order to provide real-time measurements and short-term forecasts (36 hours ahead) of produced energy from the deep of the distribution network.

The application must be fully integrated with the Distribution Management System and use information from different systems and Data Bases (e.g. network connection status, measurements, data coming from electronic meters, weather forecasts provided by third parties, etc.).

Several methods and algorithms can be applied to produce forecasts depending mainly on available input data. For example, in the case of solar power plants, it is possible to develop models taking into account solar-panel performance, orientation and technology, the solar average radiation, etc.

There are even more complex models mixing forecast model, local measurements and local statistics [1], but the most of these methods do not comply with network control requirements asking for a real-time forecasting at one-hour intervals.

THE MAIN FEATURES OF THE SYSTEM

MAGO system provides a real-time monitoring of active power generation coming from Medium Voltage (MV) and Low Voltage (LV) generators.

The production data and forecasted ones are divided according to the different source of energy: solar, wind, hydro, thermal and "others" kind of sources and are available in each selected point of the network, thanks to a function that dynamically aggregates the relevant generation values in the requested point.

Since it is integrated with the remote control systems (SCADA), production measurements and forecasted values are directly available on the operators' screen during their ordinary and emergency work in the distribution control centres. The system follows the evolution of the network connection status, due to standard operations and fault management, and presents the requested data on operator demand.

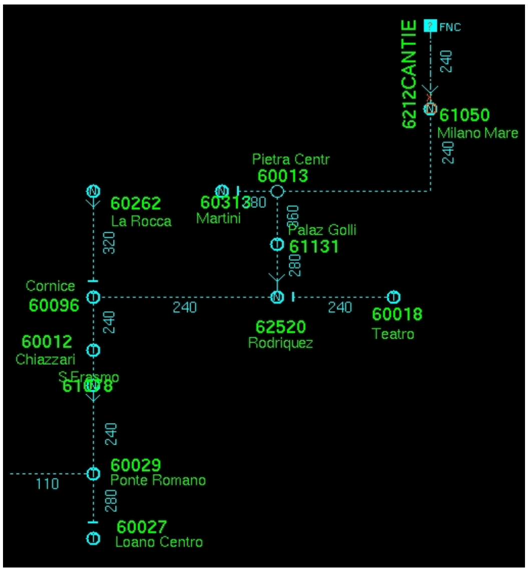

Fig. 1 - Network diagram from the present Distribution Management System (SCADA) in which MAGO information will be integrated

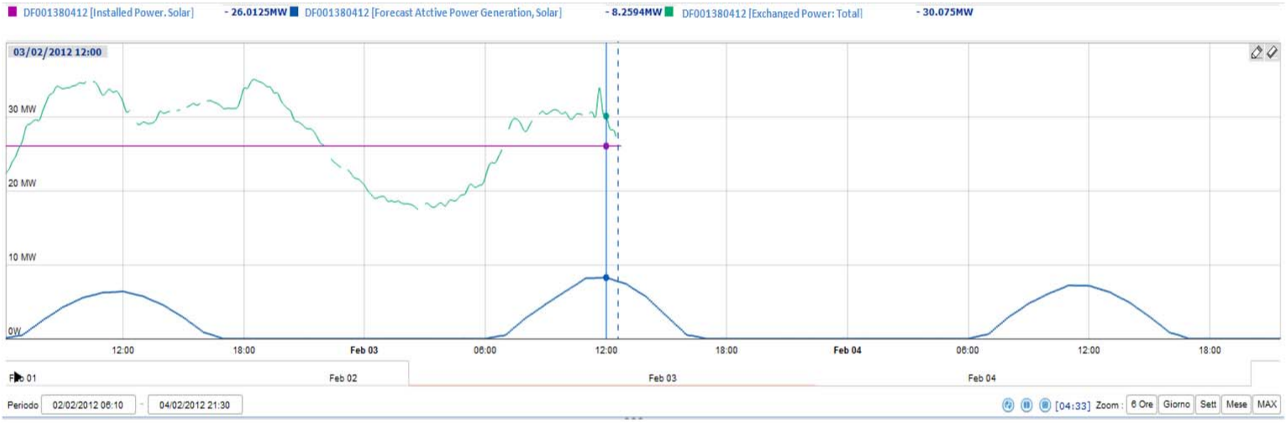

Fig. 2 - MAGO: forecasting of active power generation (bottom blue line) compared to other measures (web-based interface)

To be more precise, MAGO has a double output interface: the Distribution Management System (Fig. 1), used by network operators, and a web-based interface (so called "MAGO web") (Fig. 2) to carry out analysis and reports in the back-office activities.

"MAGO web" allows to display measured data and forecast ones in a graphic or tabular format and get reports of Power or Energy generation according to the different source of energy.

According to the organization of Enel Distribuzione, that uses a 28 Control Centres, each operating at regional level on the Italian territory, MAGO is replicated 28 times from HW and SW points of view.

This means that each application runs on the regional network data base and operates on a wide but limited amount of distributed generators.

THE FORECASTING ALGORITHM

MAGO implements a real-time forecasting of active power generated on MV network using the following input data:

- weather forecasts;
- electrical network connection status;
- installed power of single power plants directly connected to MV feeders;
- aggregation of generators for each MV/LV distribution transformer in case of DG located on LV network;
- historical recordings when they are available.

Each single generator or aggregation is categorized according to 5 different generation sources: solar, wind, thermal, Hydro, other.

Weather forecasts of each local administration units (about 8.000 in Italy) are available with a resolution of one-hour interval along a temporal window of seven days and include solar radiation, temperature, wind direction and speed.

The forecasting algorithm is designed paying attention to both: accuracy of results and performances.

Weather data are updated every 12 hours and consequently each local MAGO system have to reevaluate all the forecasts with the same frequency; this means calculations involving several hundreds of producers. LV producers under the same MV/LV transformer are located in geographically limited area with a similar weather characteristics and can be replaced by an aggregate. This aggregation allows to reduce data processing time and save memory space without losing in accuracy.

The algorithm can provide forecasts even without any measurements from the field: this is possible because each type of MV producer or aggregation of LV generators is modeled by a characteristic curve that correlates the weather parameters (solar radiation, wind speed for wind plant) with active power generation.

At the system startup each curve is defined with models initialized with default parameters (typical curves). These default parameters are updated as soon as the system begins to collect measurements from field so as to make the model more and more accurate.

For solar power generation the best forecasts are obtained updating the producer models using both, active power and solar radiation, recorded together for a long time span (Fig. 3).

If solar radiation recordings are not available, it is possible to make a trial using a forecast of solar radiation as replacement of measurements. In this case there is a phenomenon of data dispersion that produce a resulting curve not reliable (Fig. 4).

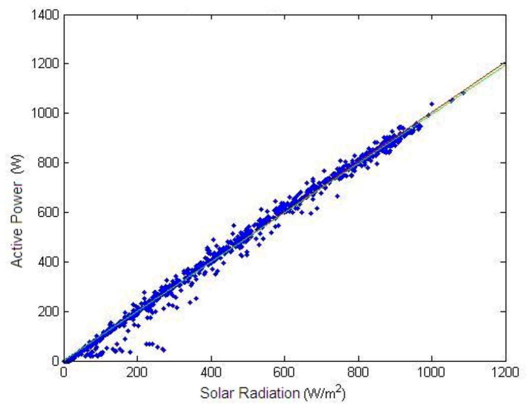

Fig. 3 - Comparison of active power generated and data of solar radiation a posteriori

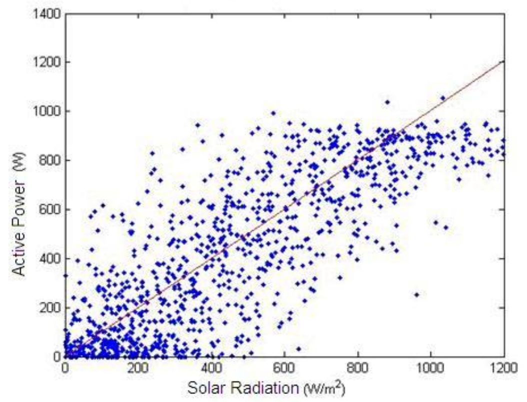

Fig. 4 – Comparison of active power generated and solar radiation forecasting

Therefore when the historical data of solar radiation are not available and the weather forecastings don't give good fitting, the "clear-sky" solar radiation model is adopted.
The clear sky solar radiation model calculates solar radiation at the Earth's surface when there is the ideal condition of cloudless-sky (in absence of atmosphere).
As result, the characteristic curve of each producer can be calculated from the envelope of data points (Fig. 5).

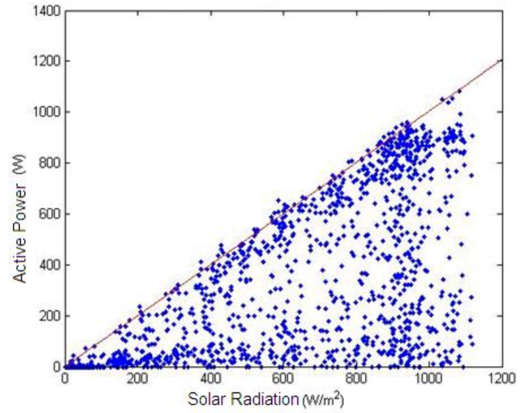

Fig. 5 - Comparison of active power generated and "clear-sky" solar radiation

For a **wind power generation** is not possible to replace wind measurements with methods similar to those used for a solar energy producer (e.g. clear-sky). Therefore, in this case, MAGO uses as input data the installed power, the plant localization, the type and the number of wind turbine and the forecasts of wind and temperature.

For the active power forecasting of **other type of producers** (e.g. thermal, etcetera), MAGO is ready to be interfaced with standard production planning systems.

The reliability of forecasting algorithms is related with the reliability and accuracy of weather forecasts and with the availability of information regarding the power production plants. For a wind energy producer the model is related to the structure of the plant and, in particular, to the number of turbines that compose the installed power.
Of course, historical data of active power can improve the reliability of MAGO forecasts very much.

SYSTEM ARCHITECTURE

MAGO system architecture can be divided into two subsystems: MAGO Back End and MAGO Front End (Fig. 6).

MAGO Back End consists of several software modules named "controllers" and implementing the required tasks:

- collecting data from "Meteo."(that is a weather forecast service), from "AMM" (that is Enel Automated Meter Management system), from "AUI" (which is the corporate Enel Data Base for the electrical network consistency);
- calculate the forecasts of active power generation;
- interfacing with SCADA.

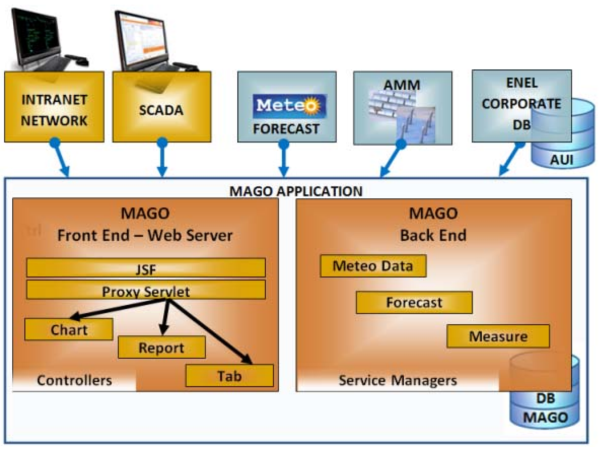

Fig. 6 – MAGO – Top level Software architecture

MAGO Front End is the software component that allows users on corporate intranet to access MAGO Back End. The graphic interface is based on different controllers and is implemented using web technologies such as JSF, jQuery, easyUI, Ajax, etc.

STATE OF THE ART AND NEXT STEPS

The road map for the full development of MAGO, involves several steps and is being carried out gradually. The goal for this year (2012) is the installation of the first version of the application in a few selected pilot sites.

Some functions are already released:

- **integration with corporate Enel Data Base:** provides installed generation for each MV producer and each MV/LV transformer (as aggregation of the LV producers connected to it);
- **forecasting algorithm** (**first version):** provides generation forecasts for solar and wind energy sources;
- **web-based interface:** reports the available data and forecasts in tabular and graphic mode.

The next step will implement the following functions:

- collection of real-time measurements (updated every 15 minutes) coming from electronic meters installed in correspondence of MV and LV producers;
- refinement of forecasting algorithm even for other kinds of energy sources that have not been included so far;
- export of forecasted production data to the systems used to operate the national transmission network by means of the already existing data connection between DSO and TSO control systems.

REFERENCES

[1] S. Bofinger, G. Heilscher, 2006, "Solar electricity forecast - approaches and first results", *21st European Photovoltaic Solar Energy Conference*, Dresden, Germany.