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**BOLOGNA**

# MICROGRID CONCEPTS AND MODELS FOR THE ELECTRICAL GRID OF AN INDUSTRIAL DISTRICT

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## SUMMARY

The paper is aimed at describing an on-going project for the definition, modelling and implementation of a microgrid within an industrial district. The project intends to facilitate the integration of renewable generation sources in existing energetic districts including industrial and tertiary service companies. The behaviour of generation, load and storage systems will be modelled and studied in order to understand, propose and test strategies for the integrated participation to the electricity market both in terms of energy supplied and of ancillary services provision.

The microgrid is modelled by means of a software tool that allows to simulate the behaviour of the electrical system and the combined action of generators and loads and to propose and test possible management strategies. The architecture proposed for a DMS – Distributed Management System, that allows to control the industrial district, is also presented. Adopted optimization tools and methodologies are described.

Some scenarios useful for individuating future test to be performed on field are presented and simulation results are provided and commented.

**KEYWORDS: microgrid, distribution networks, distribution management systems, smartgrid,**

## INTRODUCTION

Electric distribution networks are rapidly evolving from completely passive systems (i.e., systems with almost no local generation or with non-dispatchable generation) to system with significant percentages of generation mostly of the renewable type and with medium to small scale generation. This fact poses severe problems in distribution system management and requires a re-thinking of hardware and software structures for network automation [1]. Moreover the fact that most of distribution generation is of the renewable type requires that a coordinated control involving different resources such as generators, loads and storage systems has to be realized so that a unique entity is interfaced with the rest of the grid. Aggregation of both generators and customers is thus expected to improve the participation of medium and small scale generators, as well as loads, to electricity markets.

New automation architectures for electric distribution network management and control in the context of active distribution systems, i.e. electric distribution networks with significant percentages of distributed generation (DG) are required. DMS – Distribution Management System is the term used for indicating the distributed control centres that are required for managing electric grids at sub-transmission and medium voltage levels.

The evolution from structures typically used for large Energy Management System (EMS) adopted in Transmission Networks to Distribution Management Systems [2] that manage and control electric distribution networks is sketched in Figure 1 [1].

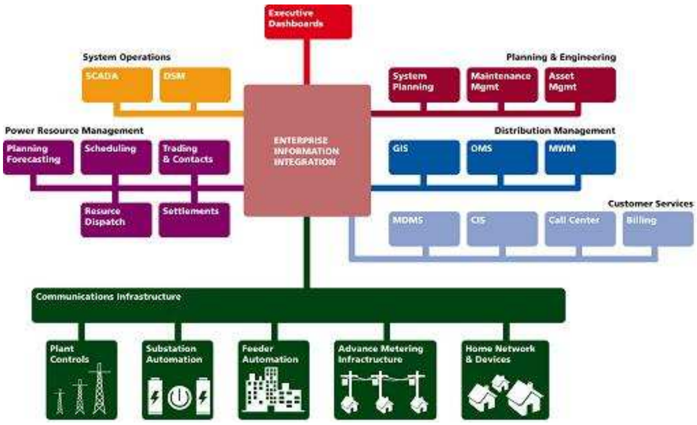

**Figure 1 - Description of key elements in a modern DMS architecture [1]. MWM = Material World Modules; OMS = Outage Management System; GIS = Geographical Information System; MDMS = Maintenance Data Management System; CIS = Customer Information System; DSM = Demand Side Management.**

An immediate challenge faced by operators of electricity distribution networks (DSO – Distribution System Operator) in the transition from passive to active networks is the integration and connection of distributed resources (DG – distributed generation) in the distribution networks [3], [4].

In the "passive" approach the solution to DG integration requires the creation of strong enhancements of existing facilities resulting in significant investments that, however, are not compatible with the resources of Distributors and may constitute economic barriers.

On the contrary, the "active" management approach of distribution networks can maximize the utilization of the existing network by taking advantage of the dispatching of generators, the control of the voltage profiles through transformer ratio and voltage regulators, the control of reactive power and of the topologic reconfiguration of the power system.

The priorities in developing smart grids identified by [1] are:

- Optimizing Grid Operation and Use
- Optimizing Grid Infrastructure
- Integrating Large Scale Intermittent Generation
- Information & Communication Technology
- Active Distribution Networks (New Market Places, Users & Energy Efficiency)

For the development of advanced electric power systems automation, it could be of interest to develop hybrid EMS/DMSs as pointed out by [3] some years ago in a timely vision. Such a system would require high-level analysis functions such as, for example, state estimation and contingency analysis, which are typical EMS functions, and the optimization of losses and voltage profiles. Security applications, state estimation and dynamic synoptic reporting should allow the safe real-time operation. These functions must be tailored so as to adapt existing systems and to integrate the functions of distribution systems with new managing and monitoring components.

DMSs help operators and engineers in evaluating the electrical behaviour of the network providing fast and efficient tools. These tools usually work “off line” on snapshots of the system, although some of them may switch to “on-line” operation, thus providing the results of the performed calculations directly on the operator synoptic and updating monitored diagrams when changes occur in the measurements coming from the field. In particular, the main DMS functions are [4], [5], [6]:

- real-time measurements
- state estimation
- power flow calculation
- performance indexes calculation
- short circuit calculation
- voltage control
- losses optimization
- configuration switching optimization
- control of local Distributed Generation
- control of dispatchable loads
- energy storage devices control

A further possible important aspect is the provision of ancillary services to transmission and distribution networks by the local distributed generation. Along with the primary energy supply service, the market provides the supply of a number of services that are considered ancillary to the transmission of electricity from producer to customer, even though many of these services are not necessarily tied to transmission and can be supplied by third parties, different from network operator. These services include, in general, dispatching and control services such as, for example, frequency and voltage regulation, reactive power supply and reserve provisioning [5], [6], [7]. The services can be separated and, therefore, provided by more than one operator in a competitive manner. The final user must carefully determine what specific services are needed and then determine which suppliers can ensure that service at lower cost.

In order to illustrate the potential flexibility of Distributed Generation, the possible fields of action can be:

- assist in the distribution network management through voltage support and coordinated control of power flows;
- use of GD for a better management of the zonal imbalances associated with daily trading of energy;
- use of interruptible and/or controllable loads, such as air conditioning systems as a potential “virtual energy accumulator”, with potential benefits in both fuel consumption reduction and elasticity of demand.

## DESCRIPTION OF THE NETWORK

To study the impact and the concept of microgrid, a real portion of MV network has been described. The MV grid, shown in Figure 2, is made up of two feeders connected to the 132 kV sub-transmission network by means of two 132/15 kV 50 MVA transformers. Even though the two feeders can be closed in a ring by mean of a switch, the grid is normally operated in a radial way. The MV distribution grid is made up of 21 MV/LV substations and 23 lines.

Both MV loads and LV public distribution networks are connected at the different nodes. Every line's parameters were set according to the cable/line type.
Two distributed generation plants are already present in the grid, other may be added:

- A 500 kVA photovoltaic field connected at the LV_PV_10 node,
- A 350 kVA synchronous generator connected at the LV_CHP_21 node.

There are 10 LV public distribution grids, connected to the MV grid by 15/0.4 kV transformers of different rated apparent powers.

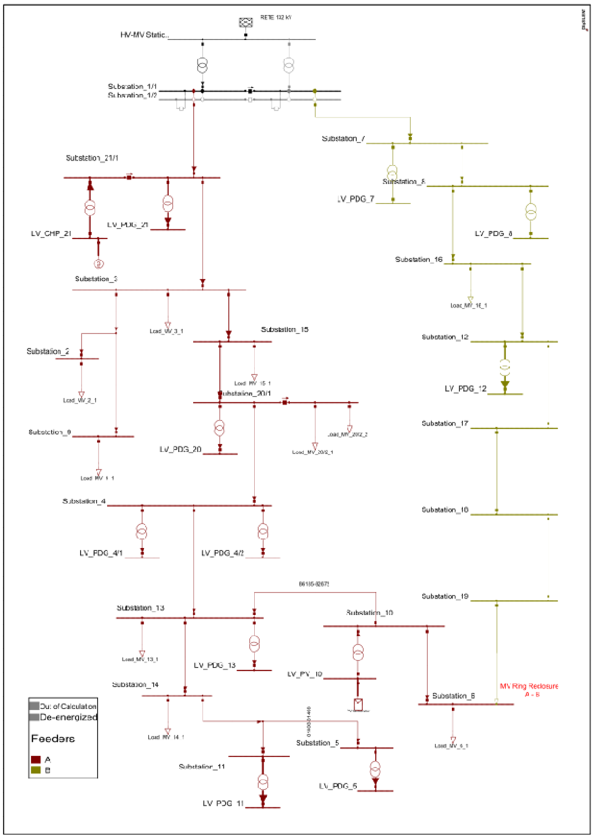

Figure 2 - MV Distribution Network - Feeders

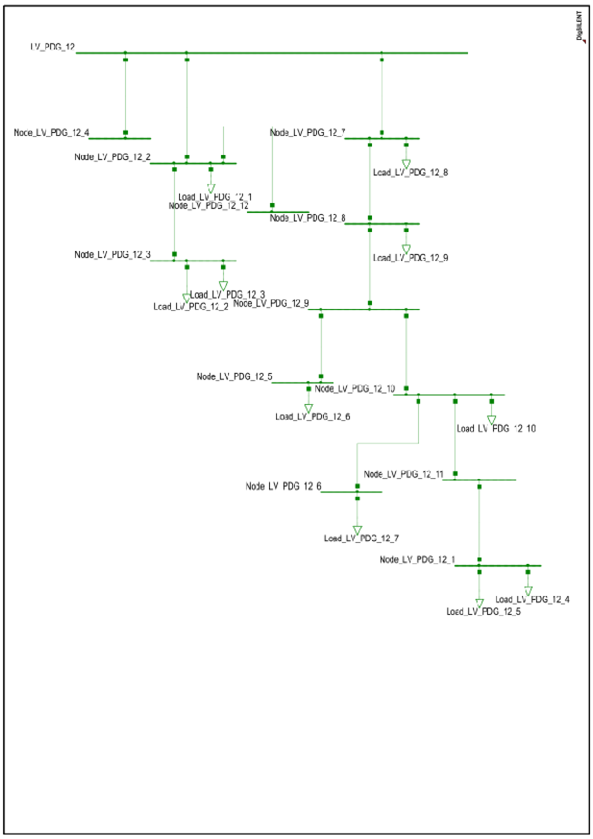

Figure 3 - LV Public Distribution Network

## LV DISTRIBUTION GRID

All the LV public distribution networks are modeled in higher detail level. An industrial and tertiary district distribution network, shown in Figure 3, is taken into account, and used as a reference network of the study.
This LV public distribution network is made up of 12 nodes and 12 lines. It has a radial structure and feeds both 1-phase and 3-phase loads of different natures. Once again line parameters were set according to the cable type.

## LOAD MODELING

Four different load types were defined: Residential, Agricultural, Industrial and Commercial. Each load type has a different load profile according to the day of the week: Weekday, Saturday or Sunday and the season of the year: Autumn, Winter, Spring or Summer. As an example the Autumn load profiles are presented in Figure 4.
The cumulate load profiles were also calculated in order to further describe the grid operating conditions. As an example the Autumn cumulate load profiles are presented in Figure 5.

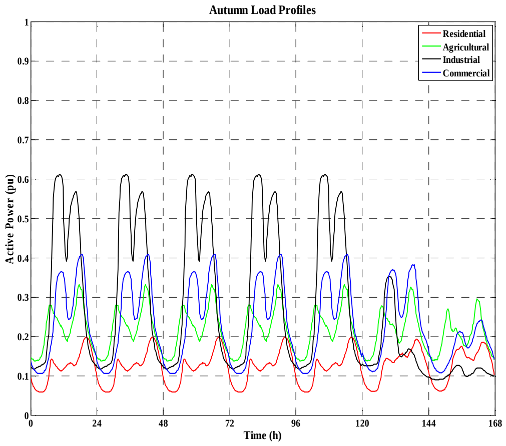

Figure 4 - Autumn Load Profile

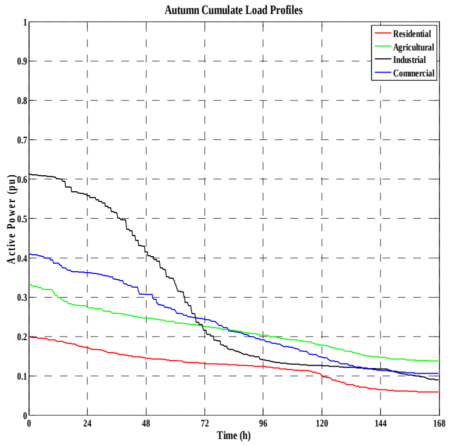

Figure 5 - Autumn Cumulate Load Profile

From the knowledge of these curves and of load rated powers (with reference to the nominal values reported in Table 1) the actual value curves can be calculated. As an example the cumulated load profiles of the LV grid in Figure 3 are presented in Figure 6.

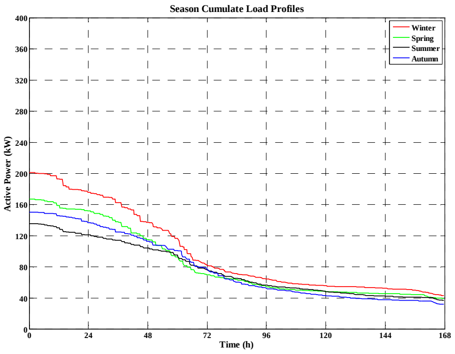

Figure 6 - LV grid Seasonal Cumulate Load Profiles

## STATIC ANALYSIS

A static analysis was performed on the system in order to evaluate the base conditions of the grid. The load flow was performed with all the DG resources producing the rated power and all the loads absorbing the rated power except for the MV loads (adsorbing 50% of their rated load) and the LV_PDG_20 loads (10%). The load adsorptions are summarized in Table 1.

Table 1 - Load Absorptions

| Name | Active Power [MW] | Power Factor | cos(phi) (ind/cap) | Name | Active Power [kW] | Power Factor | cos(phi) (ind/cap) |
|---|---|---|---|---|---|---|---|
| Load_MV_2_1 | 0.132 | 0.9 | ind. | LV_PDG_20 Aggregate | 116 | 0.9 | ind. |
| Load_MV_3_1 | 0.32 | 0.9 | ind. | LV_PDG_12 Aggregate | 313 | 0.9 | ind. |
| Load_MV_20/2_1 | 3 | 0.9 | ind. | LV_PDG_13 Aggregate | 15 | 0.9 | ind. |
| Load_MV_20/2_2 | 0.1 | 0.9 | ind. | LV_PDG_11 Aggregate | 57 | 0.9 | ind. |
| Load_MV_6_1 | 0.12 | 0.9 | ind. | LV_PDG_7 Aggregate | 0 | 0.9 | ind. |
| Load_MV_9_1 | 0.154 | 0.9 | ind. | LV_PDG_8 Aggregate | 0 | 0.9 | ind. |
| Load_MV_13_1 | 0.5 | 0.9 | ind. | LV_PDG_5 Aggregate | 53 | 0.9 | ind. |
| Load_MV_14_1 | 0.4 | 0.9 | ind. | LV_PDG_4/1 Aggregate | 174.5 | 0.9 | ind. |
| Load_MV_15_1 | 0.3 | 0.9 | ind. | LV_PDG_4/2 Aggregate | 235 | 0.9 | ind. |
| Load_MV_16_1 | 0.5 | 0.9 | ind. | LV_PDG_21 Aggregate | 204 | 0.9 | ind. |

In Figure 7 and 8 the voltage profiles of nodes along the two feeders and of a specific individual the detail of node (LV_PDG_12) – see Figure 9 – are presented.

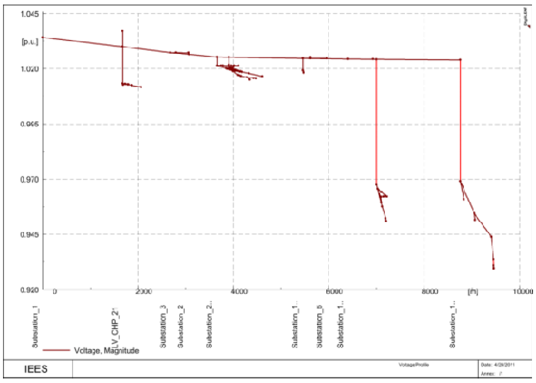

Figure 7 - Feeder A Voltage Profile

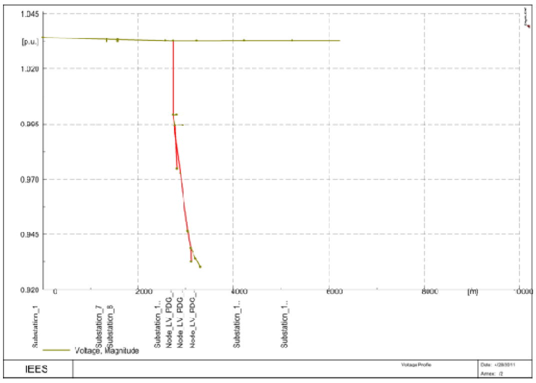

Figure 8 - Feeder B Voltage Profile

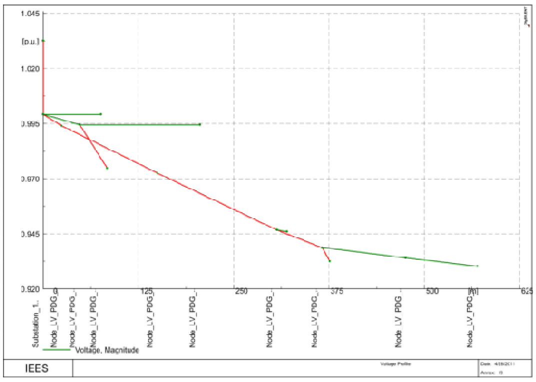

Figure 9 - Voltage Profile for node LV_PDG_12

As it is pointed in Figure 7 and 8, both MV feeders present a voltage profile heavily depressed at the end of the line. In particular the two ending LV substations, are quite loaded and present a significant voltage drop at the transformer.

For what concerns the LV reference network, it can be noticed that in the considered operating condition for several nodes, especially at the end of the feeders, the voltage drops under 0.95 p.u. – see Figure 9 – and several lines result heavily loaded.

## CONCLUSIONS

The paper presented and discussed in the context of modern architectures for electrical distribution system automation an on-going project for the definition, modelling and implementation of a microgrid within an industrial district. The activities concerning the main goals of the project are on-going. The modeling phase of the LV and MV networks and of equipment (generators, storage and control devices) are almost completed. The microgrid has been modelled by means of a software tool that allows to simulate the behaviour of the electrical system and the combined action of generators and loads. Scenarios for optimizing the integration of the above mentioned equipment and systems are under development for what concerns definition of ancillary services and related algorithms useful for implementing the testing phase.

Some initial results concerning simulation of scenarios useful for analyzing future on-site testing are presented.

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