ENERGY RESOURCES MANAGEMENT FOR MORE SUSTAINABLE DISTRIBUTION SYSTEMS: AN INTELLIGENT APPROACH

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ABSTRACT

Energy Resources Management can play a very relevant role in future power systems in SmartGrid context, with high penetration of distributed generation and storage systems.
This paper deals with the importance of resources management in incident situation. The system to consider a high penetration of distributed generation, demand response, storage units and network reconfiguration.
A case study evidences the advantages of using a flexible SCADA to control the energy resources in incident situation.

INTRODUCTION

Power system planning and operation use optimization studies to minimize costs. Traditionally, power systems were managed mostly on a centralized way, giving place to global optimization studies that considered supply and network.
Operation in a liberalized environment changes the way optimization studies are undertaken as each player goals are to be considered. Distributed generation (DG) should also be considered as the use of DG, mainly based on renewable energy sources, is required to accomplish energy policy goals. Recent studies have proved that loads are not rigid, exhibiting elasticity that can be used for mutual benefits of power system and consumers. Demand response (DR) should be considered as an energy resource (ER) that can be used, together with other ER (generation, network, storage) to optimize power system operation.
Envisaging SmartGrids (SG) as the future of electric grids, one can say that a SG is an infrastructure able to accommodate all centralized and distributed energy resources (DER), including intensive use of renewable and DG, storage, DR, and also electric vehicles (EV), in the context of a competitive business environment [1]. EVs with vehicle-to-grid (V2G) capability, i.e. gridable vehicles, are especially interesting. SG should provide the required means to efficiently manage all these resources and to decentralize the power system control and intelligence throughout the power system.
SG should be adequate to put together all these ER guaranteeing the most adequate ER management, resulting in a complex environment. Optimization should not only consider the available ER but also their use permission, according to regulations, ownership, bi-lateral contracts and auctions.
This paper presents an ER management methodology, based on an intelligent and flexible SCADA that supports all the referred concepts. Present SCADAs are intended for the monitoring and supervision of equipments owned (or at least operated) by a very limited number of entities (one in most cases). It is assumed that there is a fixed entity to operate each piece of equipment (there is flexibility to operate at different levels, such as locally or remotely, but in the scope of the same entity such as a distribution or transmission company). In future SG, SCADA have to consider both the physical part of each power system component and its cyber dimension, which requires a SCADA based on a cyber-physical model of the power system. Figure 1 presents the relationships among the involved players in the proposed SCADA model) [2]. In this figure lines in blue represent interactions among system players to negotiate contracts; lines in red represent SCADA actions. Light yellow boxes represent Player p's components (C_{P1} to C_{Pm}). These components can always be operated by their owner, Player p, respecting technical constraints. Some or the totality of these components can also be operated by any other player if this player has a contract with Player p that regulates their use. In these cases, not only technical constraints apply. Contractual clauses must also be verified, according to the context situation. This is done at the SCADA level, using the information about the contracts established among the involved players that allow determining each equipment operation permissions, according to the context.

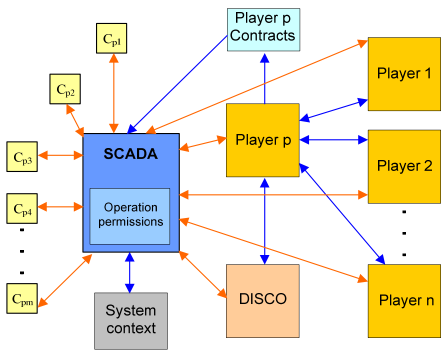

Figure 1. Proposed SCADA

The proposed ER management methodology is based mixed-integer non linear programming.
The paper will present a case-study:
- A case study using a 32 bus networks that are evolving over time, from the initial configuration in 2008 to the 2040 configuration. The use of DG, DR and storage in case of incident shows the importance of using these ER so that load curtailment is reduced and incident costs are minimized.
- A part of a SG operating in isolated mode for which the available resources, including DR, are managed.

ENERGY RESOURCES MANAGEMENT

Future power systems in general and distribution power systems in particular are in the process of a paradigm transformation. A more sustainable distribution system requires on the one hand the study of possible opportunities offered by the available resources (including the network itself) and, on the other hand, to provide a more intelligent management of the network.

Distributed Generation

Distributed generation of electricity has a growing importance in the planning and operation of distribution systems. This is due to energy policies aiming at reducing greenhouse gas effect emissions and some subsequent governmental incentives. However, the intensive use of distributed generation presents relevant technical problems that must be solved, as the ones with the protection system.
Several technologies can be used for distributed generation, such as photovoltaic, co-generation, mini-hydro, wind, biomass, waste-to-energy, and fuel cells. Each one has different monetary incentives, concerning the initial investment or/and energy remuneration, due to the diverse maturation state of the technology and the associated efficiency [3].
In the future, generators will be seen as players in a competitive electricity market and the aggregation of several generators is necessary for a more competition capability. The evolution of the generation technologies in terms of efficiency and size will improve the competition capability of distributed generators.

Demand Response

Load elasticity has a growing importance in network management since it can be considered a very important energy resource (ER). Load elasticity leads to the concept of Demand Response (DR) that can be defined as the changes in electricity usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time [4].
The most important benefit of demand response is improved resource-efficiency of electricity generation due to closer alignment between customers' electricity prices and the value they place on electricity. Lower wholesale market prices can be originated by the use of DR since it can avoid or defer investment needs in new generation equipment and network expansion. DR can also contribute to mitigate market power .
DR programs can be classified in two major groups can be listed as Price-based and Incentive-based demand response [5].

Storage

Due to the intrinsic characteristic of electrical energy, this commodity presents difficulty of storage. Nowadays, it is possible to consider small storage systems that allow improved network operation since in a hipotethical situation of excess of DG or in periods that electricity has reduced price, that energy can be stored and used later in a most appropriate moment.
In response to the implicit effects of incorporating DG within power systems, diverse energy storage technologies have emerged which have favourable applications such as: load levelling, peak shaving, bulk energy trading, integration of intermittent renewable energy sources, island grid, spinning reserve, black start capability, uninterrupted power supply (UPS), and a general improvement to quality of power supply[6].

Virtual Power Players

The authors of this paper have been working on the management of Virtual Power Players (VPPs) [7-9] that aggregate several players with different energy resources. Considering a specific VPP that wants to optimally manage the available resources, it can make use of their own resources (i.e. of the resources owned by the aggregated players) and also of the resources that other players can make available to its use.
In order to operate in an efficient way, VPPs should have adequate decision-support tools. These must be based on the availability and processing of the required information and knowledge concerning producers, costumers, network and market operation.

CASE STUDY

This section presents a case study that illustrates the use of the developed intelligent dispatch system. Let us consider a distribution network with 32 buses, from [10]. As our aim is to study the use of demand response in the context of intensive use of DG, we have included DG in this network, considering its evolution over time, since the initial date (2008) to 2040 [11]. For this purpose, several studies have been undertaken with the aim of determining the size, technology and the location of DG in each bus, over time. Similar studies were done to determine load evolution at each bus over time. Figure 2 depicts the state of the network obtained for 2040. The dashed lines represent reconfiguration branches. All grid data is accessible through:
www.gecad.isep.ipp.pt/ies/casestudies/Baran_results.pdf

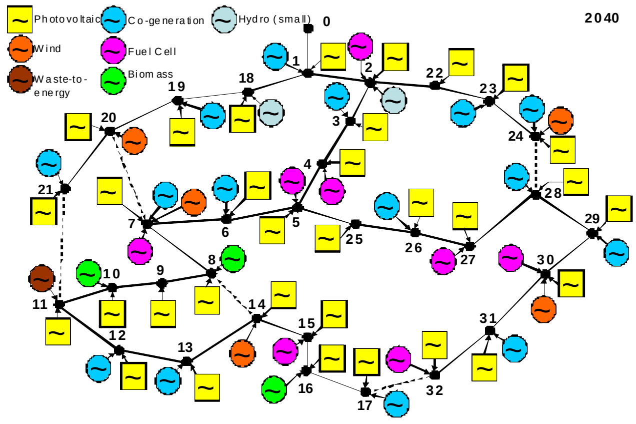

Figure 2. Configuration of the network in 2040

This network is connected to the large distribution network trough bus number 0.

For this case study, we consider a fault in line 0-1 that connects bus 0 to the distribution grid. As a result of this fault, the considered network presented in figure 2 turns to an island during 3 hours.

In the SmartGrid context, VPP can manage all resources in the Grid. In this case study, VPP manages:

- DG – Two contracts types are considered, with DG curtailment and without DG curtailment;
- DR – Three contract types are considered, Load Reduction, Load Curtailment and Critical Loads;
- Storage – Control of batteries charge and discharge periods;
- Network reconfiguration – In case of incident VPP can reconfigure network.

General Algebraic Modeling System (GAMS™) software has been used to find the optimization results [12].

Considering the normal operation in 2008, without the incident, the network operation cost is 980.04€. This value include the remuneration of DG, the remuneration of energy cheeped in electricity market (injected in bus 0) and losses.

In incident situation, the DG can't assure the complete functioning, however if we consider the control of stability in each generation bus we have the following situation:

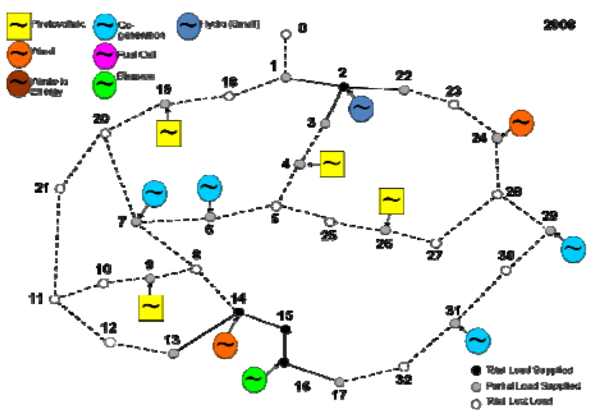

Figure 3. Network configuration in incident situation in 2008

This configuration needs the control of voltage and frequency in each bus and a flexible SCADA to open some branch (Dash Lines). Only loads 2, 14, 15, 16 (black bus) are totally satisfied, loads 1, 3, 4, 6, 7, 9, 13, 17, 19, 22, 24, 26, 29, 31 (gray bus) are partial satisfied, however it is only possible if this loads have an control to limit their consumption. In present state of the art, all this scenario doesn´t work, in practice, only loads 2, 14 e 16 because the generators can be controlled by own costumer.

Value of Lost Load (VoLL) varies among customers but is almost always greater than retail price if electricity. The accepted industry practice is to adopt a VOLL of 1.5-4 €/kWh [4]. In the present case study we consider 3 €/kWh.

Considering VoLL values, the operation cost in 3 hours incident scenario is 26,138.02€. Figure 4 shows the cost in each bus / load.

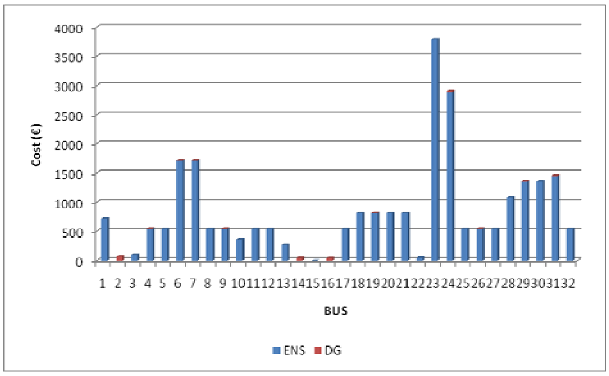

Figure 4. Operation Cost in each bus in 2008 incident scenario

In SmartGrid context, with flexible SCADA systems all resources can be controlled. To validate the proposed methodology to re-dispatch the resources, in incident mode, we develop a 2040 scenario with same contingence (fault in line 0-1). The normal operation cost is 2,120.94€. In incident situation, the DG, DR and storage assure the partial network functioning. Figure 5 show the configuration of network in incident scenario.

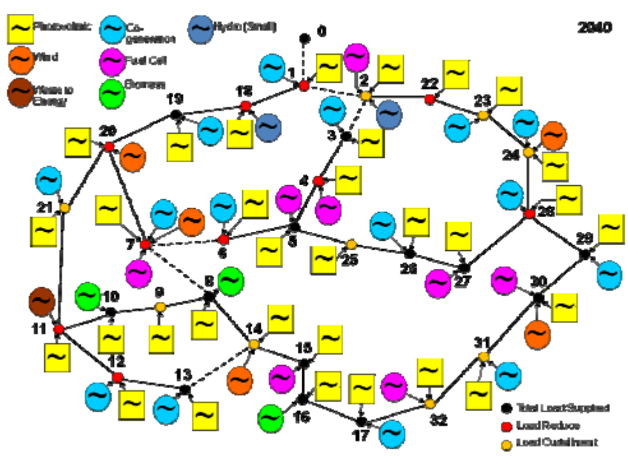

Figure 5. Network configuration in incident situation in 2040

In Figure 6 the red bus represent the bus with load reduction and the orange bus represent the load curtailment. In both situations, VPP have contracts with costumers to operate their loads. All critical loads are satisfied.

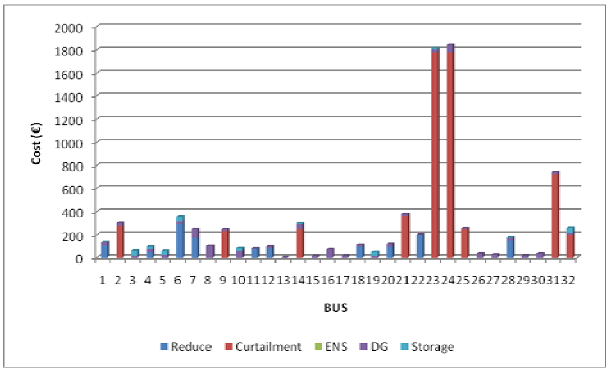

Figure 6. Operation Cost in each bus in 2040 incident scenario

In the present case study we consider a VoLL between 3-5 €/kWh. The load reduction price varies between 0,25 to 0,55 €/kWh and load curtailment varies between 0,6 to 1 €/kWh. The operation cost in this scenario is 8,307.29€. In this simulation we consider the network reconfiguration [13]; however the impact of reconfiguration is very small. If we don't reconfigure the network the operation cost is 8,318.35€.
Comparing the scenario in 2008 with scenario in 2040 we have many differences. In 2008, in incident scenario the operation cost increase 25,157.98€ whereas in 2040 increase only 6,186.35€. The major impact in this reduction is caused by demand response. The contracts to reduction and curtailment allow the reduction of 11,3MW (57% of total load), DG assures 40% and Storage 3% of total load.

CONCLUSIONS

The Energy Resources Management allows the development of new strategies to assure the correct operation of power systems. The new concept of flexible and distributed SCADA systems allows the control and management of many resources of distribution network.
The integration of DG, DR and storage in network operation allow more flexibility and a better resources management.
This paper presents a new methodology to manage the energy resources in SmatGrids context. This methodology allows studying several scenarios considering many players.
A case study considering a fault evidences the advantages of using adequate methodologies to manage the distribution network.

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