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Real time simulator for microgrids

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ABSTRACT

Microgrids today include more and more renewable sources both for environmental and economic reasons. The advantage of microgrids is their capacity of running isolated. The presence of largely uncontrollable sources (PV plants and wind farms) makes the grid control a complex task. During the design stage it is mandatory to consider the expected variations of both loads and sources to identify proper solution for stabilizing the Microgrid when it runs isolated.

The paper presents a simulator that was developed to support the design of the Microgrid both in terms of power devices and control techniques. The main goal of this simulator is to test the automation system of the Microgrid before its site installation. The simulator calculates the dynamic behavior of conventional generators, renewable source, and loads. The model of renewable sources includes the expected power variations as well as the random profile of loads. If required, energy storage systems can be integrated in the simulator. All the control set-point of controllable equipment and the calculated frequency and voltage of the Microgrid are interfaced with the control system using a standard Ethernet-base fieldbus. Such a solution makes it possible to study different control logics and to tune the control parameters of the system using the real control system. The data exchange between the simulator and the control system is identical to the real data flow that will be found in the Microgrid. With the use of the simulator, the control system of the Microgrid is implemented during the design stage, with reduced development, testing, and commissioning times.

1. Introduction

Today economical, legislative, and environmental reasons strongly support the deployment of Distributed Energy Resources (DER) with a special attention to renewable ones. This is a common trend worldwide, but it leads to special advantages on electrical systems geographically isolated or connected to weak and unreliable grids. These electrical systems are forced to operate in islanded conditions, and they must reach a compromise between capex and opex that reflects on their efficiency and availability.

Conventional gensets are the traditional power source for this kind of stand-alone electrical systems (e.g. mining plants, resorts, small islands, etc.); this solution guarantees a high stability of the electrical system with good performances in terms of availability and reduced capex, with the drawback of high operational and environmental costs [1]. Adding renewable sources represents an important opportunity to reduce these costs, limiting fossil fuel consumption and the emission of CO_2 and noise. An electrical system that is able to run islanded and uses both conventional and renewable sources is commonly defined a Microgrid (MG) [2–4]. The higher the penetration of renewable sources (that is the ratio between the energy produced by renewable sources and the total energy demand), the higher the advantages (Fig. 1). Unfortunately, photovoltaic and wind sources introduce a partially uncontrollable element inside the electrical system due to their sometime erratic behavior. This means that an increasing penetration of renewable sources may increase the frequency and voltage variations inside the MG, with a poor Power Quality of the system and a higher risk of black-out. The mitigation of these problems requires proper power and control solutions. MGs are complex systems, and these solutions must be extremely smart, advanced and innovative to achieve satisfactory results.

Conventional and renewable generators, loads, and Battery Energy Storage System (BESS) build the MG. Every component contributes to the power balance of the system, and the overall dynamic arises from their interactions.

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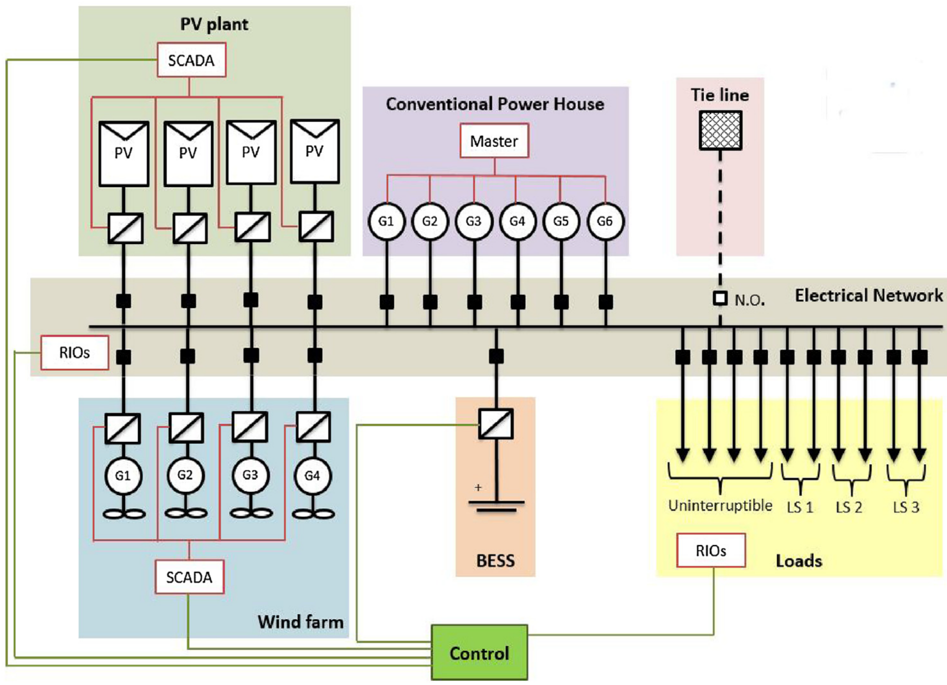

Fig. 1. Microgrid with deep penetration of renewable sources.

The control strategy for a MG connect to a grid is mostly aimed at maximizing the energy efficiency with the higher exploitation of the renewable sources. On the contrary, the control goal for an islanded MG should be first to achieve the higher availability of the power supply, than to maximize the penetration of renewable sources [5]. These targets can be obtained with a sophisticated control strategy (centralized and/or distributed) able to:

- reduce the instantaneous variation of generated power:
  - limiting the rate of change rate for renewable sources;
  - managing the operative condition of BESS (charge/discharge during power exceed/deficit);
- maintain a spinning reserve of conventional generators to compensate the maximum predictable power variations of renewable sources;
- avoid a load demand greater than the available capability of the available generators (e.g. by means of load shedding [6,7]).

The design of these advanced control logics requires a detailed study of the behavior of each apparatus [8–14], and then an integrated simulation to stress and validate the developed control solutions [15]. If the simulation tool runs real-time [16,21] and it is interfaced with the control system under development, it is possible to test, tune, and validate the real I/O configuration, the hardware architecture, and the application software of the control system during the design stage with important time and cost saving. In brief, it is possible to implement a project using the following two tools:

- **Software simulation**: useful to define the architecture, to size the devices and to evaluate the performances of the system (in terms of power quality, energy, economic turnover);
- **Real time simulator**: useful to Verify and Validate (V&V) the control logics, to check the I/O list, to tune the parameters of the control system and to train the operators. The simulator is basically a tool for detailed Factory Acceptance Tests, as defined in IEC 62603-1, pos. 4.11, Level 5 (full process simulation) [17].

This double approach is well-known [18,19], and it offers important benefits during the design and the commissioning of a power system thanks to the possibility of performing comprehensive tests of the control system. Several real-time simulators have been reported in technical literature, with different hardware and software architectures:

1. Fully software simulator interfaced with the SCADA (Supervisory Control And Data Acquisition system): used for training [20];
2. Software simulator of field and control interfaced with one or more Hardware In the Loop (HIL) like relays and protections [21]: used for tuning the parameters and testing the coordination of the devices;
3. Software simulator of field interfaced with the hardware of the supervision and control system made by one or more PLCs (Programmable Logic Controller) and the SCADA: used for V&V the logics of the control system [22–24].

The proposed simulator belongs to this third family. The most innovative aspects are the possibility of simulating an islanded power system with renewable resources, a high level of configurability and scalability, and a simplified and effective electromechanical model that allows to limit the computational power necessary to run real-time simulations.

Moreover, the simulator uses the same configurable model of the power system both for V&V and for HIL simulator. In other words, it is possible to replace the module that simulates the control logics with a communication module interfaced with the PLC that runs the real control logic. This feature allows reducing the validation process, and it simplifies the architecture of the simulator.

2. Solutions for modelling and simulation

A model for real time applications must fulfil two mandatory constraints:

- to evaluate properly the dynamic behavior of the electrical system;