Chapter 3

IoE–Based Control and Monitoring of Electrical Grids: A Smart Grid’s Perspective

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ABSTRACT

In many countries, renewable energy production already represents an important percentage of the total energy that is generated in electrical grids. In order to reach higher levels of integration, demand side management measures are yet required. In fact, different from the legacy electrical grids, where at any given instant the generation levels are adjusted to meet the demand, when using renewable energy sources, the demand must be adapted in accordance with the generation levels, since these cannot be controlled. In order to alleviate users from the burden of individual control of each appliance, energy management systems (EMSs) have to be developed to both monitor the generation and consumption patterns and to control electrical appliances. In this context, the main contribution of this chapter is to present the implementation of such an IoT-based monitoring and control system for microgrids, capable of supporting the development of an EMS.

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INTRODUCTION

At the end of the last century, a growing environmental concern led to the introduction of renewable energy sources throughout the electrical grids. The defined targets, such as a reduction of 80% (compared to 1990 levels) in CO₂ emissions until 2050 in Europe, has led countries, companies and public entities to search for solutions, that span from generating more renewable energy to reducing consumption.

In terms of generation, nuclear, solar, wind or biomass energy have become important sources of clean energy, allowing zero CO₂ emissions. As far as consumption is concerned, the fields where most of the reduction of consumption can happen are known and include buildings, transportation and electrical production (La Scala, Bruno, Nucci, Lamonaca & Stecchi, 2017). It is also known that cities consume 75% of the energy generated and produce 80% of CO₂, and therefore it is of great importance to act in improving their efficiency.

In order to promote the gradual replacement of outdated and inefficient equipment, the European Energy Efficiency Directive 2012/27/EU has defined that by 2020 energy savings should reach the 20% target, when compared with the estimated value for that same date without any actions.

The Mediterranean countries in particular, which have many annual hours of sunshine, can take advantage of this fact, to achieve the CO₂ reduction targets through solar electricity production. In Portugal, for instance, the average number of hours of sunshine per year varies between 2200 and 3000, depending on the region (Aiminho.pt, 2018). In addition, its geographic location, by the sea, leads to the existence of some regular and intense winds, which can be used profitably, both in coastal or mountainous regions (Costa, 2004). Wind already contributes to an electricity production ratio of 21.6% (of the total amount produced in Portugal), plus 1.6% that result from solar sources (Associação Portuguesa de Energias Renováveis APREN, 2017). Portugal has even managed to produce enough energy to feed the country for several days, using only renewable energy sources (REN, 2018).

Traditionally, the generation and distribution of electricity was done in a scheme that started in production plants, followed by transmission in high/medium voltage lines and distribution in low voltage to the final consumer. This scheme was implemented throughout the twentieth century and has remained until the present day. Although control and monitoring technologies or remote protection were included at the end of the century, they were not integrated into the entire grid, but only placed at important infrastructure points (stations, substations or high voltage) in order to allow some control and remote access (Sendin, Sanchez-Fornie, & Berganza, 2016). In general, the entire electrical grid had little automation and communication, in addition to the advanced age of many of the equipment, thus not being able to guarantee the reliability and efficiency that were intended to allow.

More recently, the introduction of renewable energy sources has created a set of new challenges for which the traditional grid had not been designed for. In this context the energy is injected by the producers at the distribution level, in parallel with the one conveyed by traditional sources, in a scheme known as Distributed Generation (DG). This trend was initially motivated by what was called micro-production, where traditional customers could also become producers, injecting the energy produced by them into the conventional grid. The concepts of micro and nanogrid were at this stage introduced, as small electrical grids, isolated or not from the main grid, that could be independently managed (La Scala, Bruno, Nucci, Lamonaca & Stecchi, 2017). In these networks, the distribution is usually done in alternating current (AC), but there are other direct current (DC) solutions that can be considered, or in some cases a mixture of the two.
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