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Article

Synthesis of modeling and optimal management of smart grids

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Abstract: Smart grids may be characterized as the amalgamation of electrical grids, communication networks, specialized hardware, and computational intelligence (algorithms). This integration aims to oversee, regulate, and coordinate the generation, distribution, storage, and utilization of energy. Indeed, smart grid technologies have the potential to facilitate the distribution of substantial quantities of power generated from renewable sources. For this purpose, a comprehensive modeling approach is employed to simplify and enhance the feasibility of the task. It introduces a highly intricate system where modeling the components and relationships between entities proves challenging. Optimal energy management is necessary in this case. This paper provides a summary of an investigation into the modeling and optimal management of smart grids. In fact, this work allows a discussion of a hybrid system. Then we briefly introduce the domain of conceptual modeling within the enterprise.

Keywords: smart grids; modelling; hybrid systems optimal management; dimensioning; energy

1. Introduction

The smart grids are mainly offered as the suitable solution in the operation and technological communication to improve the reliability of the grid and to allow the integration of various resources, such as renewable energies, as well as the satisfaction of the energy demand, the electrical storage, and transport [1].

The emergence of the smart grid results from a convergence of a more challenging business environment and newfound technological possibilities. Systems that were financially unattainable just a few years ago can now be constructed with relative ease [2].

Modeling constitutes a crucial stage in the reengineering process, involving the presentation of the real-world dynamics within the enterprise [3].

In response to competition and evolving circumstances, an enterprise needs to be both responsive and flexible. It is crucial to consider upgrades or industrial reorganization to achieve a continuous improvement goal. In this context, there is a growing demand for enterprise modeling to streamline the analysis of a production system's performance in relation to both its internal organization and external environment.

The use of hybrid systems combining multiple sources, such as renewable energy systems, the national distribution grid, or conventional energy sources and storage systems, is generally seen by all as a solution of the future, and by virtue of what has been said, the integration of a smarter network becomes necessary [4].

This paper delves into an examination of the smart grid to evaluate various components of the electrical system and formulate an energy management strategy. Following that, we introduce the field of conceptual modeling.

2. Presentation of physical and conceptual modeling

Several approaches, such as systems engineering, have proposed methodological approaches associated with tools providing simplified representations of reality. The aim is to master the understanding, design, development, and operation of complex systems [5].

Throughout the system design and development process, the joint use of physical and conceptual modeling is both synergistic and complementary.

Physical modeling involves creating a detailed, tangible representation of a system, focusing on its physical components, their characteristics, and their interactions. Its main objective is to faithfully reproduce the physical reality of the system, integrating details such as shape, size, materials, and connections between components. In engineering and science fields, physical modeling can take a variety of forms. This may include making physical models, prototypes, performing three-dimensional (3D) computer simulations, or other tangible representations aimed at capturing the physical aspects of the system under study.

Conceptual modeling is a process aimed at representing in an abstract and graphic manner the concepts, relationships, and entities of a system or idea. It focuses on fundamental aspects, avoiding technical details. The goal of conceptual modeling is to visualize the conceptual structure and interrelationships of a particular domain, often with the goal of facilitating understanding, communication, and planning prior to concrete implementation. This approach is frequently used in various fields, such as computer science, engineering, project management, and other disciplines, to clearly represent the underlying ideas and concepts.

The implementation of modeling processes requires the adoption of appropriate modeling methods. In the context of the analysis and modeling of complex systems, various categories of classical methodologies are available, each suited to a multitude of specific application areas [6].

Thus, it is essential to select the appropriate method for our system, whether for physical or conceptual modeling, in order to guarantee the success of our modeling approach.

3. Generalities on smart grids

Smart grid technologies, as illustrated in **Figure 1**, have the potential to facilitate the distribution of substantial quantities of power generated from renewable sources, thereby contributing to the decarbonization of the electricity sector [7].

Integrating smart grid technologies into the industry can enhance various performance indicators across all segments, including generation, transmission, distribution, and end-use consumption [8].

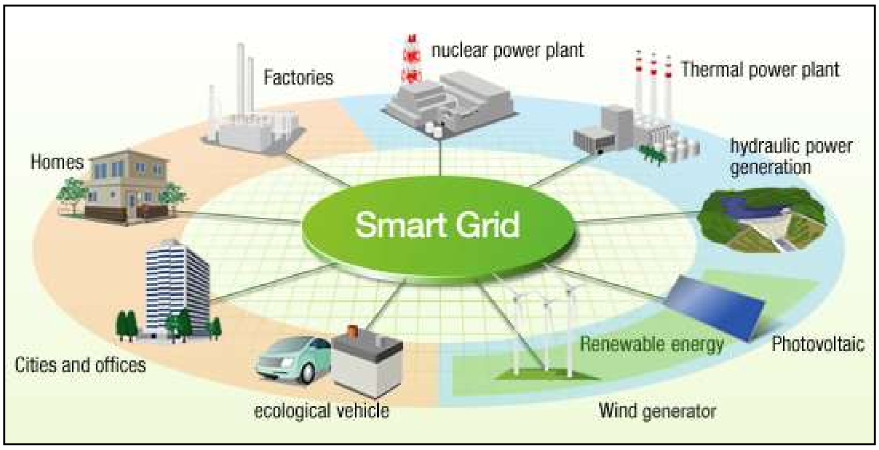

Figure 1. Smart grid technologies.

The architectural structure of smart grids (**Figure 2**) can be categorized into three levels [9–12]:

- The initial infrastructure layer comprises equipment designed for electricity transmission, including lines, transformers, and other related components.
- The second level consists of communication architectures, encompassing multimedia and multiple technologies, which gather data from various network sensors.
- The ultimate level comprises applications and services, including monitoring systems, remote intervention capabilities, and the automation of electricity demand responses through real-time information.

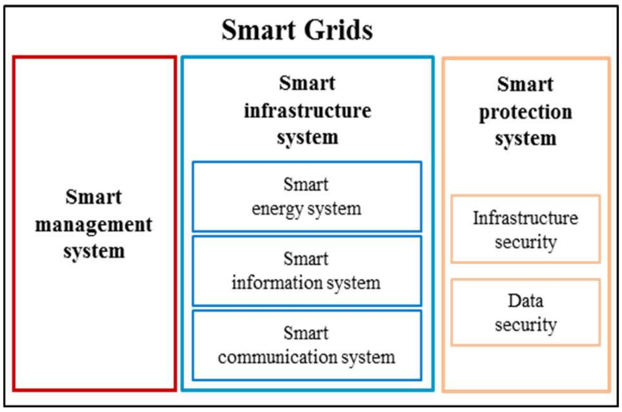

Figure 2. The architectural structure of smart grids.

Smart grids embody the digital revolution within our energy grids, and it is undeniable that they have initiated and will persist in transforming the entire value chain. Their purpose is not to replace the existing electrical network but rather to enhance it, ensuring efficient network modeling and swift optimization of energy resources.

4. Hybrid system

A hybrid system, as illustrated in **Figure 3**, incorporates renewable energy sources into an electrical system, involving more than one energy source, with at least one being renewable. This hybrid system may also incorporate a storage device [13–17].

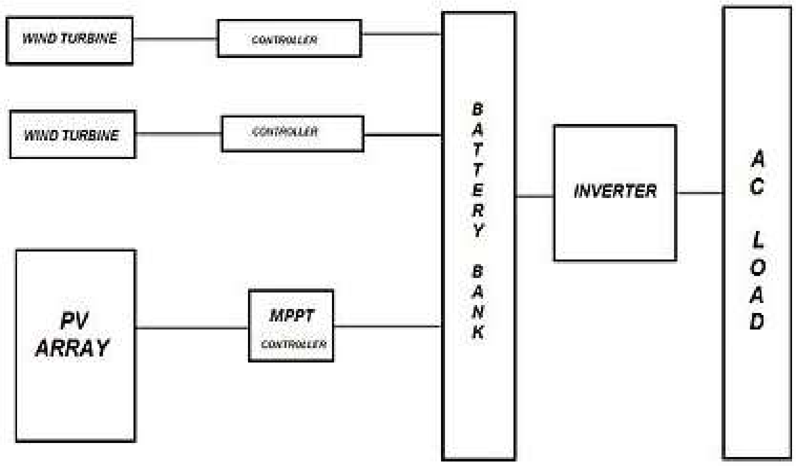

Figure 3. Block diagram of a PV/wind hybrid energy system and a wind park.

The realization of a hybrid system represents different advantages:

- Smoothing production.
- Increasing reliability.
- Reducing storage.
- Reducing production costs.

The efficiency of a hybrid system depends on many fundamental factors. The form and type of loads, the cost, the availability of energy, the storage system, and the overlook of the type of energy used to provide the electricity [18–20].

Most hybrid systems are based on wind power and solar power, which have several drawbacks.

To overcome these disadvantages, it is necessary to know the processes that take place within this system, to model the different elements, and to simulate their behavior.

Knowing that a hybrid system must meet the load demand and optimize its production in order to meet the energy demanded by the load during the intermittent period and while maintaining the quality of energy supplied. The use of smart grids is becoming essential.

5. Dimensioning and energy optimization

The objectives of smart grids include flattening the consumption curve, minimizing overall consumption, balancing supply and demand, and integrating new technologies. The challenges encompass sending energy orders/requirements, optimizing energy flow, conducting preventive maintenance, controlling permutations, and minimizing loads to optimize investments. These challenges must be addressed while managing the generation of renewable energies with erratic production and incorporating storage solutions [21–24].

Up to this point in the literature, optimization of multi-source systems connected to the network has predominantly focused on the sizing of installations and the management of storage. To enhance the competitiveness of hybrid electric technology, improvements in the design and operation of these systems are crucial to ensure reliability, longevity, and minimized installation costs. This particular system is designed based on four key aspects: study, sizing, modeling, and maximizing the utilization of renewable sources. To achieve this, the sizing and selection of component operations are conducted while considering the available energy source and the associated usage constraints [25–27].

Optimizing a complex system is a challenging task that demands a specific methodology. Here, we outline an initial resolution approach. Initially, it is essential to choose optimization algorithms that are suitable for each specific application within the system. Subsequently, the parameters of the algorithms need to be fine-tuned to enhance their efficiency. Indeed, optimizing energy management necessitates continual adjustment of energy flows, highlighting the need for a suitable approach to ensure acceptable calculation times.

The complexity of solving an optimization problem depends on the nature of the variables and elements within the model.

Based on the nature of the problem, two types of optimizations are distinguished:

- Static optimization, where the objective function depends solely on the values of the variables at a specific time;
- Dynamic optimization, in which the objective function relies on previously made decisions as well as the current state of the electrical system, and the optimization is performed over a specific time interval.

6. Conclusion

In this paper, we briefly exposed the components, mode of operation, and physical modeling of smart grids. Then the concept of enterprise modeling was presented. Then we defined the hybrid systems while citing their components, their advantages, and their disadvantages. In addition, at the end, we can mention a few studies made on smart grids using renewable energies.

Smart grids must harmonize internal emergence and self-organization while accommodating external factors to achieve the optimal balance in real-time energy distribution.

Building upon the case study presented in this paper, efforts are underway to develop simulations for smart grids, focusing on the synthesis of modeling and optimal management.

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