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Economic evaluation model for the energy Demand Response

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A B S T R A C T

The need for new solutions for the generation, transmission, and distribution of electricity has become apparent with advancements of technology worldwide. This disposition has been revealed by the deregulation of the electricity market, the technological processes in constant evolution, the focus on environmental problems, and the need to manage and protect energy loads that are more sensitive to disturbances in the grid. Numerous significant research and development efforts, involving a large number of technology areas and requiring a highly interdisciplinary design vision, have led to the emergence of a new concept called "Smart Grids." In this context, attention is emphasized toward the Demand Response (DR), a particular tactic for the intelligent management of users' electrical loads. This paper aims to present an algorithm that helps the aggregator of energy loads in carrying out its daily decisions, using an economic objective function. A mathematical model for this goal was developed, and a heuristic solution was used to calculate the configuration of load distributions. Conclusively, the model was tested to understand its effectiveness and to determine the capability of an aggregator to have revenues from the application of a DR tactic.

1. Introduction

The term "Smart Grid" indicates an active system that is independently, efficiently, and intelligently capable of making decisions by itself to maximize efficiency. Basically, it refers to a power grid that can integrate the behaviors and actions of all its connected users to ensure sustainable supplies of electricity in an efficient, economical, and safe manner.

The electricity grid for most parts of the Western countries has a *modus operandi* based on a structure that can be defined as unidirectional and passive. In fact, it relies on the presence of a limited number of production plants that focus on the production of electricity using fossil fuels and nuclear power, where the generated energy is transmitted in a large dorsal of high voltage capacity. From there, grid lines branch from the dorsal to utilities that absorb energy. With the increase of the national energy demand, the first problem for the traditional grid was to manifest itself in keeping standards of reliability in the load energy supply. The electrical grid bases its operation on the perfect balance between demand and supply of energy over time. This balance is a crucial aspect of the delivery operation as it is the operational constraint that ensures each user is connected to the grid and may have a certain degree of delivery reliability. Over the years, electrical companies have enforced the capacity of the grid structure to establish stability in service and reliability for clients. The most logical choice to ensure the supply to consumers was to intervene by increasing the capacity of production and, thus, increasing the amount of energy available on the grid. This choice was made based on several reasons: (i) energy consumers are geographically distributed over large areas; (ii) the control stations of energy flows had a limited interconnection capacity; and (iii) the production was entrusted to a few large power plants. Therefore, a number of additional installations have been developed, most of which are carried out according to the geographic distribution of generation sources (places near coal mines and water sources). These interventions were carried out considering the logic of economies for production, where centralized systems have been installed in increasingly large proportions that allow a more profitable investment and a greater availability of production capacity. With the augmentation of the amount of energy produced, the flow of energy to operate on the grid has increased. Therefore, the transmission and distribution of electricity has tried to keep up with this capacity development to balance the change on the production side.

The result of this evolutionary process is the current structure

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with a pattern of strong vertical integration. To meet further increases in energy demands, the installation of new power plants requires grandeur investments. Furthermore, with the enhanced flow of data and information available from the grid, the current transmission structure has revealed enormous difficulties in their control and management owing to the presence of obsolete and unintelligent devices. Besides, it is inefficient from the management's view of the electrical flows since the grid requires a large number of steps that the energy flow has to respect to supply the final user. In addition, a well-defined structure is inherently static, as the flow of energy travels a unidirectional path from the place of production to the consumer. In this context, the end user is solely a passive load on the network. A brief characterization of the traditional grid is reported in Fig. 1.

There are many disadvantages associated with the use of this type of network structure, in particular the following points:

- High joule losses suffered along the connecting line from large power plants to utilities;
- Inability to effectively manage the energy flow to convey the energy where it is needed (this is due to the lack of protocols in the dynamic management of energy flows);
- Difficulty to fully use renewable energy sources like wind and solar power;
- Response time is too long in the event of a blackout, with an inability to stem the cascading effects in the voltage drop and consequent interruption of energy flow.

Each of these factors contributes to an increase in the cost of energy. In reality, the operation and management of the transmission and distribution systems are granted, in most cases, by national or regional entities that have a monopoly. Additionally, the only obligation to respond to the control of the National Energy Authority is to guarantee access to the grid for all customers.

However, over the past years, we have witnessed a major change in the trend that has led the scientific community to define new strategies for the development of electricity grids. This scientific effort revealed the need to make a major breakthrough in electricity management [1–3]. In fact, this research enforcement promoted the following alternative considerations:

1. Despite the current period of financial crisis, a minimal growth in energy demand has stimulated the formulation of plans to widen and strengthen the existing electricity grids.
2. Liberalization has brought the energy market to move according to the logic of competitiveness. It is not only consumers that have the opportunity to benefit from better choices at lower prices but the whole system is also inspired to realize technological progress and continuous innovation for a steady growth in energy efficiency by the presence of economic incentives.
3. Fossil fuels began a downward spiral owing to the progressive depletion of deposits and, therefore, of available stocks. As a progressive and constant increase in energy demand has existed since many years, this factor has led to a consequent rise in prices for fossil gases and oil barrels. In recent times, this price increase is why countries have been accentuating policies to diversify the energy sources, encouraging the development of alternative energy supply systems to fossil fuels.
4. Aging transmission and distribution infrastructure in Europe is threatening the security, reliability, and quality of the energy supply.

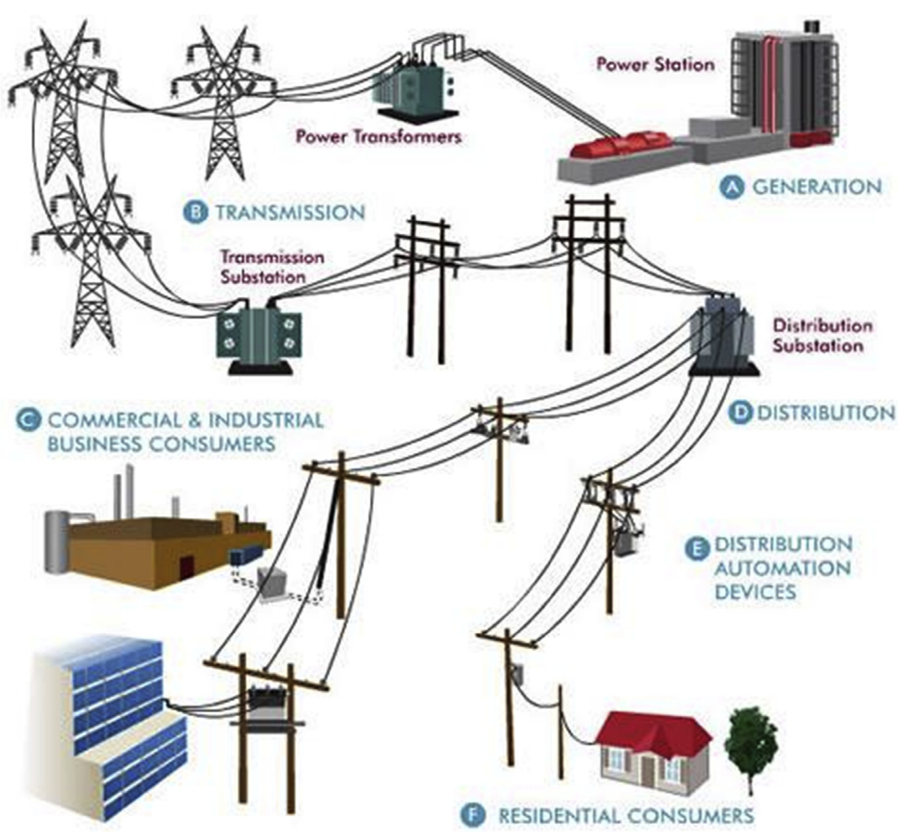

Fig. 1. The traditional energy transmission and distribution scheme.