



Smart power grid and cloud computing[☆]

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ABSTRACT

As a consequence of rapidly increased CO₂ emissions, humanity is facing global warming. Electricity generation accounts for almost half of the emission; besides, conventional electrical production based on fossil fuel is becoming more and more expensive. One approach to significantly slow down global warming is to drive our society away from the current fossil fuel fiesta and use only renewable power such as solar and wind energy. Another approach is to improve the management of energy production, transmission, and distribution. Part of the latter solution is on the supply side, where one possible solution is to develop continent-wide smart power grids and energy storage systems. However, an equally important part of the solution is on the demand side, where technologies and applications that can work with this type of unpredictable energy consumption are becoming necessary. The smart power grid with new sources of data, fast growth of information, and proactive management requires new strategy for business and operational management. In this paper we discuss how Cloud computing model can be used for developing Smart Grid solutions. The Cloud computing model is based on the delivery of computing as a service, whereby storage, software and information are provided to computers and other devices as a commodity over the Internet. The advantages of Cloud computing – reduced costs, increased storage, on-demand performance, and better flexibility – have motivated many companies in recent years to move their IT operations to the cloud; the same advantages can be used to achieve the most important future goals of a large-scale Smart Grid, such as energy savings, two-way communication, and demand resource management.

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1. Introduction

It is almost impossible to imagine the world we live in without electricity. Economic development and sustainability of humanity is conditioned by industrialization that constantly requires more

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and more energy. In the last decade of industrial development, the world economy is moving away from cheap energy to consumption of expensive energy. Awareness of the relative limitations of the traditional exhaustion of energy resources on the one hand, and limited energy supply from renewable energy sources have a dual effect on the energy and economic development, but also on the environment.

Electricity is a pivotal element for understanding global energy challenges. It is an energy carrier, a sort of intermediary, between the supply of primary energy sources (e.g. coal) and the demand for energy-using services (e.g. transport, heating, and lighting). Electricity is, in fact, the main energy carrier used around the world for residential, commercial, and industrial processes next to fuels and heat. The climate challenge related to electricity stems from the fact that over two-thirds of global electricity production is generated from the combustion of fossil fuels [1].

Globally, it is expected for residential/commercial demand to continue shifting toward electricity and away from the primary fuels used directly by consumers. The need for energy to make electricity will remain the single biggest driver of demand. By 2040, electricity generation will account for more than 40 percent of global energy consumption [2].

In the past decade, electricity demand was rising more quickly than utility companies could keep up with. Besides, conventional electrical production based on fossil fuels is becoming more and more expensive, while at the same time consumers are becoming increasingly concerned about greenhouse gases resulting from fossil fuel energy production. Consumer demands are also responding to economic and environmental pressures by demanding a granular view of their real-time usage and time-of-day pricing.

Energy based on fossil fuels was developed a hundred years ago, and it is unlikely that it will appear more economically feasible than new technologies in the near future. That “old” energy will not just as easily give way to new energy due to environmental protection [3]. The current approach to invest in large scale centralized fossil fuel power plants is obviously not working anymore. The cost of main natural resources of conventional grid power (coal and copper) is rising, while on the other hand the cost of renewable energy sources such as solar panels and LEDs is falling down even faster. Therefore, investing in large scale centralized energy production, particularly coal plants, seems relying on the wrong tool for much of the job, not to mention the waste of scarce resources. That leaves us with many reasons to invest in the alternative—distributed, clean, and renewable energy access.

The growing importance of energy sustainability imposes the need to monitor and control the optimal usage of energy assets. Smart power grids with their support for real-time, two-way communication between utilities and consumers come to a rescue. Although the term smart power grid cannot be uniquely defined, it usually implies a network able to intelligently connect all users involved (generators, markets, service providers, distributors, customers, appliances etc.) to deliver sustainable, economic, and secure electricity supply. The smart power grid is a melting pot of different technological trends and engineering platforms; furthermore, since the concept itself is relatively new and evolving, the relevant terminology is not yet settled down. Smart grids offer many advantages, among which the most notable are increased energy efficiency, information availability, better fail recovery, and the possibility of using alternative energy sources.

Cloud computing is also a general term, referring to convenient, on-demand network access to a shared pool of configurable computing resources (networks, servers, storage, applications etc.) that can be quickly provisioned and released with minimal management effort or service provider interaction [25]. Cloud

installations can use techniques such as virtualization to separate the software from the characteristics of physical servers. Using this approach it is often possible to optimize servers and reduce energy costly features. The emergence of cloud computing is providing a fundamentally different IT model in which a cloud provider might be responsible for a range of IT activities, including hardware and software installation, upgrades, maintenance, backup, data storage, and security.

Cloud platforms can play important role in software architectures that allow more effective use of smart grid applications. Specifically, cloud computing services can address needs for large scale real-time computing, communication, transfer and storage of data generated by Smart Grid technologies.

This paper provides information on recent developments in application of Cloud technologies with the existing power grid. We present a broad overview of the state of the art in this area and discuss possible research directions to achieve better interaction between Smart Grid and Cloud computing model.

The remainder of this paper is organized as follows: Section 2 presents a system view of the Smart Grid. Section 3 details the design and developmental issues of Cloud computing. Section 4 presents state of the art in applying Cloud technology in Smart Grids. Finally, Section 5 concludes with a discussion of future trends of the Cloud in the smart power grid environment, and discusses key problems to be solved. This paper closes with a glossary of the relevant terminology.

2. Smart grid

To better understand the term smart power grid, which means different things to different people depending on the perspective of their own area of expertise or interest, we should look at it as a whole. Before we continue with the explanation of the new paradigm, we present a short overview of the conventional power grid. We continue with highlighting the differences and advantages of smart grid over conventional electric grid, and then conclude with discussing two important smart grid design features where Cloud platforms can be efficiently applied, namely integrating time-dependent renewable resources (virtual power plants) and controlling the load.

2.1. Conventional electric grid

Electric power systems (EPS) are real-time energy delivery systems. Real-time means that power is generated, transported, and supplied the moment the light switch is turned on. Electric power systems are not storage systems like water systems and gas systems; instead, a power grid is a perfect just-in-time system where generation and demand must be balanced at every instant.

The system starts with generation, by which electrical energy is produced in the power plant and then transformed in the power station to high-voltage electrical energy that is more suitable for efficient long-distance transportation [6].

High-voltage power lines in the transmission portion of the electric power system efficiently transport electrical energy over long distances to the consumption locations. Finally, substations transform this high-voltage electrical energy into lower-voltage energy that is transmitted over power lines that are more suitable for the distribution of electrical energy to its destination, where it is again transformed for residential, commercial, and industrial consumption. The distribution network includes medium-voltage (less than 50 kV) power lines, substation transformers, pole- or pad-mounted transformers, low-voltage distribution wiring and electric meters. The distribution system of an electric utility company may have hundreds of substations and hundreds of

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