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Harnessing business intelligence in smart grids: A case of the electricity market

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ABSTRACT

This paper discusses analytical aspects of smart grids and offers insights into the development of a business intelligence solution for the electricity market. The goal is to design a system that provides an emerging electricity market with the necessary data flows and information for forecasting, data analysis and decision making, leading to better business results and more control over the market. By employing a methodology specifically suited to the electricity market domain, we designed a business intelligence solution for the Serbian electricity market operator "Elektromreža Srbije". The research results show that the proposed approach leads to more effective market management in data-rich smart grid environments, while still being dynamic enough to adapt to frequent rule changes in the still developing grids and their markets.

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1. Introduction

Throughout history, as well as in modern times, the energy sector represented a key factor for accelerating economic growth and achieving sustainable development. Nowadays, the energy industry constantly needs to seek new ways to achieve higher levels of energy efficiency in order to answer the ever-increasing demands of consumers, businesses and governments. The key factor in achieving optimum energy efficiency is surely the development and adoption of smart grid technologies [1].

Smart grid technologies bring many innovations to the electric power industry, as well as changes to market structure, business models and services. As operators strive towards implementation of smart grids and accompanying technologies, they are faced with various problems concerning the ever-increasing consumer needs [2]. In order to succeed and thrive in this constantly changing business environment, electricity market operators must constantly seek to expand their access to operational data, and more importantly, improve their ability to convert the huge amounts of data into intelligence relevant to the operation of the grid [3]. In turn, the adoption of smart grid technologies must lead to consequent changes in companies' information systems. The dynamic nature of the energy business would serve as the perfect grounds for implementing analytical systems capable of meeting these requirements [4]. Business intelligence (hereinafter: BI) and knowledge management infrastructures have existed in business environments for many years, and their importance is an established fact. The necessity for such infrastructures in large energy systems has been recognized, as well.

BI in smart grids is considered to be one of the essential mechanisms of maximizing the "smartness" of the grid. A business intelligence model suited for the needs of a smart grid must offer a way to generate immediate business value from the new disparate data sources, including modern metering and supervisory data. The focus on the utilization of newly acquired data implies that the grid and market operators that are still in the process of smart grid adoption could gain the most from the implementation of a BI solution. This provides an opportunity to influence the future development of the metering infrastructure, allowing the grid to evolve into an information-rich environment where any decision could be based on actionable intelligence [5].

On the other hand, the majority of electricity markets in the developing countries still do not operate in the smart grid ecosystem. In order to adapt to the expected changes, it is necessary to design the current projects in such a way that they can be easily adapted to future smart grid expectations. Taking this into

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account, this research aims at proposing a bottom-up approach for developing BI solutions that support future developments of the deregulated electricity markets in the developing countries. Energy markets in this new environment will need to adapt to the newfound flexibility in energy demand, as well as to the consumers, who will become market participants and take an active role in energy generation [6]. Under these conditions, the energy systems still need to remain stable, in the sense that energy demand must be equal to its supply. Stable energy systems require adequate management of energy supply, and to some extent, of the demand, as well, in order to meet the optimum operational plans. For this purpose, it is necessary to develop and use analytical and BI applications in the markets. However, the literature does not offer much information about methodologies and best practices for designing BI solutions that incorporate all the specifics of rapidly evolving energy markets.

With the idea of making a contribution to filling in this gap, the focus of the research was placed on designing BI models capable of supporting an emerging electricity market. The models were specifically shaped for the electricity markets of the developing countries, which are in the process of grid modernization and migration to a smart grid. The developed BI model includes the required analytical data structures, as well as a set of key performance indicators (hereinafter: KPI) specifically suited for the three core processes of an emerging energy market: Balance Responsibility, Balance Mechanism and Allocation of Cross-border Capacities. While the energy market rules may differ from one country to another and from one market to the other, these processes remain largely unchanged. For this reason, other emerging markets can easily adjust the model presented here to fit their market rules.

The proposed approach was developed and evaluated within the Public Enterprise Elektromreža Srbije (hereinafter: PE EMS), a Serbian transmission system and electricity market operator.

The paper includes four sections. The second section provides a theoretical background of the business intelligence systems and data warehousing technologies from the perspective of an energy transmission system operator. The third section offers insights into the project itself, the methodology used, as well as the specifics of the conducted project. A subset of notable key performance indicators is also presented in this section. The fourth section analyses the achieved results for each of the distinct business process groups that were identified. The fifth section contains the discussion and the conclusion of the paper.

2. Theoretical background

The importance of smart grid concepts for the energy industry is a well-established fact [7]. Smart grid is a complete information architecture and infrastructure system that encompasses the entirety of energy-related activities in the field of power generation, transmission and distribution [8]. Smart grid strives to optimize the delivery of electricity through bidirectional communication between the grid and its users. End users in the smart grid environment act interactively and are allowed to adapt their energy consumption according to their needs, preferences, environmental concerns or other characteristics [9].

The basic concept of the smart grid and its effects on the electricity market stakeholders are outlined together with the conceptual model described in the NIST Framework and Roadmap for Smart Grid Interoperability Standards [10]. This model describes communications across the smart grid and offers a framework for the identification of actors, their interactions and their potential capabilities. In addition, this model can offer a new view on the potential sources of data that need to be integrated into the BI system of electricity markets. The identified potential data sources are:

- Electricity producers generate electricity from various forms of energy. The use of energy production data allows for smart generation and load balancing.
- The transmission and distribution of electricity to the customers is achieved through transmission and distribution operators. The use of distribution and transmission data allows for advanced prediction, minimization of transmission losses and ultimately the actualization of a self-healing grid.
- Residential, commercial and industrial customers are the end users of electricity. In smart grids, they are also able to produce and distribute energy, and are therefore able to participate in the retail market.
- Markets manage wholesaling, retailing and trading in electricity. They connect service providers, operators and customers, and often act as a connection point where data from various elements of the smart grid must be exchanged. Market data allows for detailed market analyses, trend and pattern recognitions and advanced forecasts.
- Service providers perform customer management, billing, and installation and maintenance services. They are often the link between the markets, operators and customers. Service provider data enable insights into customer behavior at a higher level of aggregation.

The use of BI systems in the energy industry has a potential to bring new value to business models and become the leading influence in the empowerment of the energy industry [11,12]. The use of a BI solution, coupled with a data warehouse, allows the market operator to collect data from heterogeneous systems and translate them into KPIs and analytical models that could be further analyzed. For this reason, data warehouses are commonly regarded as a basis for BI and decision-supporting systems [13].

BI solutions based on data warehousing technology are becoming a standard in the electricity markets. The most frequent way these systems are used is facilitation of faster report-drafting, as well as serving as a common integration point for data originating from different systems [14]. While highly useful, these conventional applications of BI technologies are not sufficient to enable a smart grid, and for this reason, further analytical aspects of these systems need to be considered. Many electric utilities have decided to harness the benefits of business intelligence systems and advanced analytics capable of supporting data-driven decision making and planning [15]. Table 1 shows the taxonomy of smart grid analytics based on literature data [16]. These main areas draw their analytical capabilities both from the technical data and the business/user-oriented data.

Analysis of the literature shows that the existing BI solutions in the energy industry are mainly focused on the fields of data warehouse design, forecasting and customer relationship

Table 1
Smart grid analytics taxonomy [16].

Field	Applications
Operational analytics	Operational effectiveness
	System performance
	Asset management
	Load trends and forecasts
Business analytics	Demand profiles
	Market segmentation
	Nonlinear load parameters
	Demand response behavior/forecasts

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