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A review: Agents in smart grids

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ABSTRACT

Agents are intelligent entities placed in some environment to make wise decisions and act flexibly and autonomously based on their built-in intelligence along with their previous experiences. This paper focuses on the main features of smart grid, anatomy of an agent and the applications of these intelligent agents in power grid to achieve the envisioned goal of the smart grid. A thorough literature survey of intelligent agents and smart grids relating the applications of agents in smart grids has been done. Agents appeared to be the intelligent entities best suited for monitoring, control, electricity market activities and the efficient usage of energy. They provide a market place for electric vehicles (EVs) and demand response (DR).

Contents

1. Introduction

Conventionally, Supervisory Control and Data Acquisition (SCADA) system have been used for the control and communication in power systems [1], which is centralized in nature and has required a lot of computation power to make intelligent decisions for the whole system at once, hence having much burden on the main processor. In contrast to centralized processing, distributed control is more flexible, efficient, reliable and economical. Distributed control system has the ability to divide the whole system into many self-contained control units, making each unit responsible for real-time monitoring and control of that particular part or unit. In this way, effect of any disturbance in one portion of the system would not directly affect the other portions of the system, because the distributed controls try to resolve the problem

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locally, so less information is required to pass to the upper layers.

The main objective of this research is to have good understanding of smart grid, intelligent agents and applications of agents in smart grid operations and control through an intensive literature review. The core focus is on the anatomy of the agents and to show the applications of these intelligent entities in smart grids. This review paper is organized into six sections. Section 2 starts with the details of the concept of smart grid and its vision, Section 3 focuses on the inside of an intelligent agent and its anatomy and the agent platforms and development tools, Section 4 flashes light on the smart grid agents in particular, Section 5 highlights applications of agents in smart grids from different aspects, and Section 6 concludes the survey done.

2. Smart grid: Unhide the secrets

Smart grid integrates modern sensing technologies, control methodologies and advanced communications into the existing power grid to exhibit the envisioned features into reality [2]. Fig. 1 gives a clue of smart grid technology. Distributed Generation (DG) provides us with many benefits including enhanced reliability, improved security as well as cheaper electricity [4,5]. The CIGRE and CIRED reports [6,7] has mentioned several encouraging reasons for the implementation of DG. Distributed Energy Resource (DER) systems could be implemented as a standalone system or as a hybrid system containing multiple DERs in a system; PV system, solar thermal system, wind turbine system, small bio power system, and fuel cell system [8,9]. Sargent & Lundy LLC has estimated that by 2020 electricity price using trough technology could be dramatically reduced to 6.2 cents/kWh and power tower technology to 5.5 cents/kWh [10]. Detailed applications and markets of fuel cells as a primary and back-up source of supply are presented in [11]. "A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode" [12,13]. Microgrids are best when operated as autonomous agent based power system components [14]. Department of Energy (DOE) is focusing on the applications of advanced sensing, control and communication technologies to find an optimized and dynamic way for the implementation of microgrids [15]. "Demand response is changes in electric usage by end use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized" [16,17]. Some of the empirical evidences of demand response have been discussed in detail in [18]. Clustering of several distributed heterogeneous generation units gives birth to a Virtual Power Plant (VPP) [19]. According to [20] VPP is an integral part of "Internet of Energy". Based on intelligent entities and smart decisions, virtual power plant optimizes assets and maximizes benefits for both the utility companies and end users intelligently. Agent based control of VPP is presented in [21]. For smart grid, it is the immediate identification of problems; their location and causes, necessary actions for the minimization of the adverse impacts and prompting the recovery of the system to stable state [22,23].

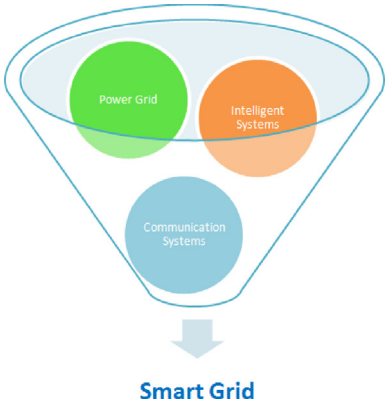

Fig. 1. Idea behind smart grid [3].

Smart grid brings the renewable energy resources into the existing grid with a more distributed nature to help reduce carbon emissions [24]. Traditionally distribution system did not provide the space for active power generation and energy storage at distribution level [25]. Electric vehicles provide a good storage option for the electrical energy and help reduce carbon emissions. According to [26] United States contributed almost 25% of whole carbon emission in the world; most of the part of this emission is because of the use of oil in transportation. Ref. [27] has presented some of the potential benefits, which we can have, from EV.

Fig. 2 gives us a broader view of the relation between the layers in power grid and communication network to integrate both the systems. Intelligent Electronic Device (IED) is used to control the flow of power and operate equipment while making some particular decisions locally [29]. Introduction of internet in power grid has improved monitoring and control of smart grid. However, in order to introduce internet to smart grid world, it has to be modified to improve the security of the network and avoid any attacks from the hackers [30]. Several types of communication transmission media are discussed in [31–35].

Smart grid focuses on the fair pricing and continuity of energy supply [29]. A study about the costs and benefits from smart grid has been done by [36]. Smart grid is supposed to recover capital invested on it from its consumers which will make it facing strong opposition from the consumers [37]. Many issues related to economics of smart grid have been raised and are well explained in [38]. Smart grid will focus on the security of the grid to make it resistant to any external or internal attacks and make it more reliable and secure [39]. Fig. 3 shows a big picture of smart grid features and the network management in smart grid is presented in Fig. 4.

3. Intelligent agent

Artificial Intelligence (AI) has surrounded almost every field of technology, ranging from medical [41], transportation, astronomy, security, navigation, entertainment and even energy usage management. However, the intelligence we seek from intelligent agents is that they can make acceptable decisions to perform actions in their environment [42]. For instance, a robotic agent [43,44] has cameras as sensors and motors as actuators. In the same manner, a software agent has encoded bit strings as sensors and effectors [45]. Agents are intelligent and rational systems [46,47], a system is rational if it does the "right things" at "right times".

Anatomy of an intelligent agent can be better explained with the help of a very simple diagram shown in Fig. 5. Intelligent Agent has been defined by [48–51] considering different aspects but the most precise definition of an agent is "An intelligent decision making system that is situated in some environment and can act flexibly and autonomously in response to any change in that environment to meet its design objectives" [42]. Intelligent agents have the characteristics of autonomy, reactivity, proactiveness and sociality [52]. Generally, an intelligent agent consists of four components: input interface, output interface, decision making system and communication system as depicted in Fig. 6. Refs. [53–56] have classified the