



A comprehensive review on microgrid and virtual power plant concepts employed for distributed energy resources scheduling in power systems

Seyyed Mostafa Nosratabadi, Rahmat-Allah Hooshmand*, Eskandar Gholipour

Department of Electrical Engineering, Faculty of Engineering, University of Isfahan, Isfahan, Iran

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ABSTRACT

Due to different viewpoints, procedures, limitations, and objectives, the scheduling problem of distributed energy resources (DERs) is a very important issue in power systems. This problem can be solved by considering different frameworks. Microgrids and Virtual Power Plants (VPPs) are two famous and suitable concepts by which this problem is solved within their frameworks. Each of these two solutions has its own special significance and may be employed for different purposes. Therefore, it is necessary to assess and review papers and literature in this field. In this paper, the scheduling problem of DERs is studied from various aspects such as modeling techniques, solving methods, reliability, emission, uncertainty, stability, demand response (DR), and multi-objective standpoint in the microgrid and VPP frameworks. This review enables researchers with different points of view to look for possible applications in the area of microgrid and VPP scheduling.

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1. Introduction

Electrical energy can be supplied in various ways, but the consumers want it with the highest quality, the lowest cost and the highest reliability. Microgrids and virtual power plants (VPPs) are two remarkable solutions for reliable supply of electricity in a power system. Since these structures include distributed energy

* Correspondence to: Dept. of Electrical Engineering, University of Isfahan, P.O. Box: 81746-73441, Isfahan, Iran.

E-mail addresses: sm.nosratabadi@eng.ui.ac.ir (S.M. Nosratabadi), hooshmand_r@eng.ui.ac.ir, Hooshmand_r@yahoo.com (R.-A. Hooshmand), e.gholipour@eng.ui.ac.ir (E. Gholipour).

resources (DERs), scheduling of these resources is then very important [1,2]. Microgrids and VPPs share some important features like the ability to integrate demand response (DR); generation of distributed renewable energy; and storage at the distribution level. It is estimated that some market participants share a lot of activities with these two platforms; however, there are some differences [3,4]:

- Microgrids may be in the grid-tied or grid-connected form, but VPPs are always in the grid-tied one.
- Microgrids can pose themselves as an island separated from the larger power grid but VPPs do not recommend this type of contingency.
- Microgrids normally require some levels of storage; however, the presence or absence of storage in VPPs is possible.
- Microgrids depend on hardware innovations such as smart inverters and switches, whereas VPPs heavily depend on smart metering and information technology.
- Microgrids include a fixed set of resources within a limited geographical area, whereas VPPs can combine a wide variety of resources in large geographic areas, and match them together.
- Microgrids are normally traded only in the form of retail distribution, while the VPPs can build a bridge to the wholesale market.
- Microgrids face legal and political hurdles, while VPPs can now be performed on the current structure and legal tariffs.

Given the lack of current standards, a variety of microgrid and VPP models are therefore on the increase. Some of them focus on their reliability, while other models concentrate on the maximization of the economic opportunities by selling the excess energy services to the larger networks [3,5]. So, this is very important to perform a comprehensive review by focusing on DER scheduling from different points of view.

Recently, some literature reviews have been published in the field of microgrid and VPP concepts by focusing on DERs to overcome concerns in power systems. Some of them are reviewed as follows.

Some features of microgrids are investigated in [6], and a literature review on the stochastic modeling and optimization tools for a microgrid is provided. The description of microgrid design principles considering the operational concepts and requirements arising from participation in active network management is presented in [7]. The paper proposes the application of IEC/ISO 62264 standards to microgrids and VPPs, along with a review of microgrids, including advanced control techniques, energy storage systems, and market participation. Reference [8] describes the developed operational concepts of microgrids that have an impact on their participation in active network management for achieving targets. The paper addresses the principles behind island-detection methods, black-start operation, fault management, and protection systems along with a review of power quality. Since the concept of smart controlled DER merits consideration, reference [9] reviews some VPP ideas and gives a general overview of VPP. Reference [10] reviews the challenges and the problems caused by charging/discharging of plug in electric vehicles and investigates their capabilities as a solution to integrate the renewable energy sources and DR programs in power systems. In [11], a review on uncertainty modeling methods for power system studies is given that makes sense about the strengths and weakness of these methods. The literature review in [12] reveals that the integration of DERs, operation, control, power quality issues, and stability of microgrid system should be explored to implement microgrid successfully in real power scenario. Reference [13] gives an idea about different optimization techniques, their advantage and disadvantage with respect to a wind farm. The main objective of [14]

is to give a state-of-the-art description for distributed power generation systems based on renewable energy and to explore the power converters connected in parallel to grids which are distinguished by their contribution to the formation of the grid voltage and frequency. The study performed in [15] is aimed to review the basics of wind energy and pumped storage plant system along with their current status, applications, and challenges involved in their operation under deregulated market and optimization techniques used in the scheduling. Reference [16] reviews the concept of hybrid renewable energy systems and application of optimization tools and techniques to microgrids. In this reference, a framework of diverse objectives has been outlined for which optimization approaches were applied to empower the microgrid. A review of modeling and applications of renewable energy generation and storage sources is also presented. In [17], the technical literature on optimization techniques applied to microgrid planning is reviewed and the guide lines for innovative planning methodologies focused on economic feasibility are defined. Also, some trending techniques and new microgrid planning approaches are pointed out. Reference [18] presents an overview of the literature on residential DR systems; load-scheduling techniques; and the latest technology that supports residential DR applications. Furthermore, challenges are highlighted and analyzed to become relevant research topics with regard to the residential DR of smart grid. The literature review shows that most DR schemes suffer from an externality problem that involves the effect of high-level customer consumption on the price rates of other customers, especially during peak period. In [19], a review of different failure modes occurring in various microgrid components is presented and also a review on various fault diagnosis approaches available in the technical literature is provided. Reference [20] presents a literature review on microgrid central controller. The evolution and advancement of microgrid central controller technology is explored and presented in a compact form. The classification of microgrid central controllers based on the outcomes found in the process of review is proposed. The role of central controller in the domains of microgrid protection, stability, and power quality are also summarized. In [21], a review of existing optimization objectives, constraints, solution approaches, and tools used in microgrid energy management is presented. The contribution of [22] is to apply the literature review to the power quality problems and to test them in a real distribution system that has plug in electric vehicles and photovoltaic panels. The results show that a coordinated delay charge mode reduces loading on transformers at peak hours and improves voltage regulation. Additionally, it is shown that photovoltaic panels introduce a power factor reduction during daytime in the main feeder. Reference [23] offers a review of the research work carried out in planning, configurations, modeling, and optimization techniques of hybrid renewable energy systems for off-grid applications. This paper presents a review of various mathematical models proposed by different researchers. These models have been developed based on objective functions, economics, and reliability studies involving design parameters. Reference [24] provides a survey of control strategies for the converter interfaces of the DERs and shows detailed figures of the control schemes. In [25], scheduling methods are reviewed and categorized based on their computational techniques to integrate plug in electric vehicles and then, various existing approaches covering analytical scheduling are surveyed. Reference [26] proposes such strategies for integrating hybrid micro-generation power systems into the grid through homeostatic control as a means to reconcile power supply and DR management. These strategies can be designed and implemented in the microgrid supervisory control system for the purpose of eliciting energy efficiency and thriftiness in consumers to build energy sustainability in the system. Topologies and control strategies

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