Economic Dispatch of Generalized Multi-source Energy Storage in Regional Integrated Energy Systems

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Abstract

The development of low-carbon technology has strengthened the linkage among various energy vectors in regional integrated energy systems (RIESs). For the sake of economy and stability, grid-level energy storage is in urgent need. To address this issue, a novel approach called generalized multi-source energy storage (GMSES) is proposed, taking advantage of synergies and complementary benefits of different energy systems. This paper focuses on the electricity-gas RIES, and two typical types of GMSES systems are studied based on the energy hub concept, while three modes of GMSES are modeled and analyzed, including charging, standby and discharging status. On this basis, an economic dispatch solution of GMSES is investigated along with steady-state multi-energy flow analysis, facilitating economic and stable operation of RIESs. Numerical studies show the applicability of the proposed method in this paper, and GMSES systems can be operated in a flexible way.

Keywords: generalized multi-source energy storage (GMSES); regional integrated energy systems; multi-energy flow; economic dispatch.

1. Introduction

Driven by the diversity of energy demand and environmental policies, energy systems are experiencing a significant transformation [1]. The development of low carbon technologies provides the foundation of energy integration, and
various energy sources like electricity and gas are tightly integrated. Energy vectors can be operated and controlled in a simultaneous way in regional integrated energy systems (RIESs), promoting both economic and security benefits [2]. The reliability of RIESs is challenged due to the intermittency and uncertainty of distributed generation (DG), thus there is an increasing need for energy storage. Energy storage also plays an important role in economic dispatch and energy balance service. Therefore, optimal energy storage management is crucial for RIES operation [3].

Traditionally, energy storage can be mainly classified into electrical, mechanical, thermal and chemical technologies [4]. With the development of demand response (DR) technology, end-use controllable loads can be used as the virtual energy storage to provide energy ancillary services. In addition, technologies focusing on synergies among various energy vectors (e.g. energy hub [5]) also provide a new way of understanding in energy storage.

To the best of the author's knowledge, two kinds of problems of RIES energy storage are not well solved yet. One is that large-scale energy storage is not in full application due to high cost, geographical restrictions and other factors. Another problem is that the synergies among various energy vectors are not well exploited, the flexibility of energy management can be enhanced by energy conversion and dispatch.

To address this issue, a generalized multi-source energy storage (GMSES) is proposed, which includes three kinds of available resources in RIES: convertible and dispatchable resource, conventional energy storage and DR resource. From a point of view of energy management, GMSES can be used for day-ahead scheduling (DAS) and intra-hour scheduling (IHS), as shown in Fig.1 (a). The IHS part mainly utilizes DR and conventional storage technology to provide fast response service. The convertible and dispatchable resource is mainly discussed in this paper, where the bi-direction multi-energy flow is addressed.

The rest of this paper is structured as follows. In section 2, two typical GMSES systems in DAS are modeled. The discussion of GMSES economic dispatch is described in section 3. Section 4 discusses the case study part. Finally, the paper is concluded in Section 5.

2. System Modeling

With the help of the concept of energy hub, energy demand can be classified and treated in a unified way. Combined with multi-energy flow analysis, this concept makes a contribution to the modeling of GMSES. The flexibility of energy conversion and dispatch shows that energy systems can be optimized in a simultaneous way [6].

From the perspective of electric power system (EPS), electricity can be absorbed and released via energy conversion and dispatch in response to different targets. This characteristic of bi-direction multi-energy flow has not been studied adequately. Meanwhile, constraints of energy networks and equipment capacity should be taken into account. On this basis, the model of GMSES in DAS can be established.

GMSES is coupled to various energy vectors, and status of charging, standby and discharging can be switched flexibly through the synergistic use of energy components. GMSES is characterized by its ability to achieve large-scale bi-direction energy flow without changing the state of the energy networks, nor installing additional high-cost energy storage devices. Two typical types of GMSES are presented in Fig.1 (b).
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