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Optimal coordination of CHP plants with renewable energy generation considering substitutability between electricity and heat

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Abstract

Combined heat and power (CHP) plants have experienced rapid development in recent years for achieving high energy efficiency. Moreover with the increasing penetration of renewable energy generation (REG), CHP plants have responsibility for providing flexible services in accommodating REG. With the development of electric heating, the extent of utilizing electricity for substituting conventional heat provided by district heating (DH) is studied. The possibility of encouraging consumers selecting different kinds of energy forms for space heating in response to particular conditions within the electricity system is analyzed. Being able to transform heating demand to electrical demand removes the heat production restriction of CHP plants and achieves the flexible operation of CHP plants for satisfying large-scale renewable energy integration. The optimization model for dispatching CHP plants to minimize overall cost while satisfying the end-users need is developed. Simulation result shows that the proposed technique can smooth the variations in net load -decreasing peak-valley ratio by 38%. And 5% operation cost can also be saved due to the overall optimization of the integrated energy system.

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Keywords: CHP plants; flexible operation; substitutability.

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1. Introduction

With environmental issue becoming increasingly serious, both developed and developing countries around world have made great progress in reducing coal consumption in electric power industry by developing renewable energy generation (REG) technology. Among all the RES, wind and solar have gained the rapidest development. Unfortunately, because of their intermittent nature, high penetration of wind and solar power brings with a number of issues in power system and requires more generating reserve capacity and balancing resources. These balancing services are mainly offered by fast responding conventional generating units, such as thermal power units and hydro-electric units. Nevertheless, as an efficient way of transforming fuels into energy services, CHP plants have experienced rapid development in recent years. As a growing important generation, CHP plants are required to provide a larger share of the balancing[1].

CHP plants are used to produce usable thermal energy and electricity to meet the demand of the consumers. Because the electricity produced can be fed into the grid, it seems that the CHP plants doesn't need any flexible operation. However, the expanding penetration of REG force CHP plants to operate in a much more flexible way. On one hand, as an increasingly important generation, CHP plants have responsibility for providing flexible services in accommodating REG; on the other hand, the intermittent REG makes electricity price vary significantly over the day, so CHP plants can achieve improved economic results if they can shift production to the hours of peak electricity prices. Therefore, there is a general consensus that flexible CHP plants serves as a more desirable option in the power system with high penetration of REG[2]. The most common way to add operational flexibility is installing thermal stores[3]. Thermal storage can partially decouple heat production from electricity generation. A lot of studies have investigated the methodologies and models to optimize the operation of CHP plants with thermal stores [4-6]. These studies illustrate that thermal storage can help to improve the economic results of a plant. Thermal stores has been proposed as a potential solution to feasible operation of CHP plants, however implementation of thermal stores may bring the additional costs and space requirements. Moreover thermal storage is most effective only lasting a few hours, and the effect is restricted by the capacity of the storage [7].

One of the primary constraints on the flexible operation of CHP plants is that the heat production has to match the heating demand. Even with thermal storage, the CHP operation is still driven by the heating demand. However, with the development of electric heating, utilizing electricity for substituting conventional heat provided by DH is feasible both technologically and economically. For example, different kinds of heat pumps (HP) have come to be price competitive alternatives to heat. Therefore the heat produced by CHP plants does not need to totally meet the heating demand while the remainder can be covered utilizing electricity. Removing that heat production restriction achieves the flexible operation of CHP plants for satisfying large-scale REG integration.

2. Substitutability between electricity and heat

CHP plants are generally regarded as a core element for energy saving and GHG reduction .Conversion from electricity to DH is crucial for redirecting the energy systems towards low-carbon and sustainability[8]. However, with the share of CHP in total gross electricity generation increasing, it is necessary to incorporate the CHP plants into the coordinating operation of the entire power system. For example, when the REG produces more electricity than expected, it will be a preferable option choice to shut down some engines of CHP plants and avoid REG curtailment. Meanwhile, customers may shift towards electric heating therefore increasing the aggregated electric demand. This way the electricity imbalance may be corrected without utilizing (or with less) operating reserves.

Especially nowadays, energy efficiency of separate systems for the production of electricity and heat are strongly improved[9]. HP has evolved to become a mature technology over the past two decades, and such electric heating can become more competitive in economy when electricity is cheap. In conclusion,