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Energy management by generator rescheduling in congestive deregulated power system

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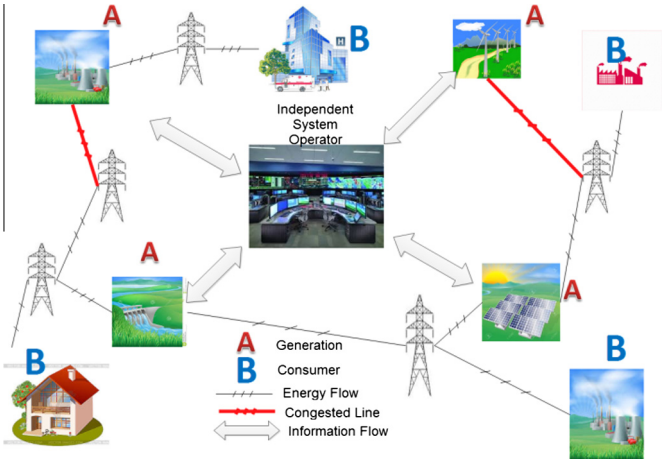
HIGHLIGHTS

- Optimal RES/NRES based generator rescheduling is performed for energy management during congestion by applying Cuckoo Search Algorithm for optimization process.
- Several real time congestion scenarios are investigated by incorporating both day-ahead and hour-ahead schedule.
- Case study is conducted on IEEE 30-bus system and practical TamilNadu (TN) 106-bus system.
- Simulation results show a significant reduction in energy loss, usage of coal, CO_2 emission, energy rescheduling cost and generation cost.

GRAPHICAL ABSTRACT



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ABSTRACT

Optimal energy delivery and energy consumption is vital in electric power systems as large amount of electricity cannot be stored in its electrical form. As part of upgradation, power systems are undergoing deregulation. One among the key issues of the deregulated power system is overload on a transmission line, also referred as congestion. Congestion is not acceptable as it increases the energy price and threatens system reliability and security. In this paper, a method of energy management is presented to remove congestion on transmission lines by rescheduling generators with the objective of minimizing energy rescheduling cost on day-ahead and hour-ahead basis. Usually, optimization methods are useful to achieve maximum gain. The Cuckoo Search Algorithm is employed in this article in order to get the optimized result. Numerical analysis of modified IEEE 30-bus system and real time application for TamilNadu (TN) 106-bus system is presented to provide evidence of the performance of the energy management measure. The realistic cases of base load, peak load, bilateral and multilateral power transactions, generation failure, and transmission line outages are considered and their corresponding energy generation, energy consumption and energy savings are obtained and are compared with the results of Particle Swarm Optimization. The discussed results show that the presented approach of energy management can reduce energy rescheduling cost and energy generation cost. In addition to that, the rescheduling of generators based on Renewable Energy Sources (RES) can further reduce the congestion cost, system energy loss and the usage of fossil fuels. The presented algorithm takes less computational time to achieve their optimal energy rescheduling cost when compared with Particle Swarm Optimization.

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1. Introduction

The energy mix of renewable energy resources should be increased in the existing generation portfolio and this is a promised solution to reduce the usage of fossil fuels as well as to become an Eco-friendly generation and Sustainable development. This becomes possible as the power system is restructured in almost all developed and developing nations and any people can set up renewable energy resources farm and can give their power output to the grid. In restructured power systems, electricity is being viewed as a trading commodity where the buyers and sellers are involved in direct contract or through power brokers. The main outcomes of restructuring the power system are maximum exploitation of energy resources and flexibility without compromising system security. But, as transmission system is being operated by a single Independent System Operator, there are certain issues faced by transmission system operators like energy management during congestion, efficient electricity pricing and reducing energy losses. As more renewable energy sources are being added to its potential sites as well as bilateral and multilateral power transactions are being encouraged, the congestion cases are rising as the existing transmission lines are supposed to carry out all the obliged power transactions. But, the power transactions may increase near the generator whose generation cost is cheaper than which generators whose generation cost is more, which makes the sensitive transmission line to overload [1]. Congestion in a transmission line is not allowed as it threatens system stability, increases energy price and may cause cascaded outage or blackout if not recovered in a limited time of few minutes. Thus, energy management is one among the challenging tasks of the Independent System Operator (ISO). The existing use of conventional generation based on fossil fuel is accounted for considerable release of carbon dioxide and other greenhouse gases. Alternatively, nature driven generation technologies, which are continually replenished on a human timescale, are viewed as environmental friendly and clean energy for unlimited period of time. As the renewable generation portfolio is considerably increasing in the restructured power sector, opportunity can be given for RES to manage congestion.

Energy management during congestion is usually done by adopting one among the two ways: cost-free means and non-cost free means. ISO opts for cost free means initially to deal with congestion. The means to achieve that are: adjusting transformer taps, phase shifters and modifying parameters of Flexible AC Transmission System (FACTS) devices. At times, ISO also adapts non-cost free means like generator rescheduling, reactive power rescheduling, load shedding, and curtailment of power transactions [2]. More revenue is lost in times of congestion when the generators are unable to deliver the power to load even though it has the generation ability; the customers have the ability to purchase but there is no technical viability and so on. While analyzing the power scenario, it is clear that this is one among the main concerns of power researchers and a promising solution is required to avoid congestion.

For this reason, various studies are performed by the researchers around the world. The intermittent addition of wind power cause congestion when the addition of transmission lines was not planned accordingly and there would be fluctuations in hourly electricity price [3]. The congestion management schemes were extensively followed in England and Wales, Pennsylvania–Jersey–Maryland (PJM), Norway, Sweden, California and a unified framework was developed to evaluate those schemes. The coordination process for congestion management between GENCOs and ISO was developed using a security-constrained price-based unit commitment technique [4,5]. It was solved using Benders decomposition by splitting the main problem into master and sub problems. Congestion zones are selected based on the sensitivity of power flow in congested transmission lines and congestion management was performed by utilizing capacitors and generators [6]. Demand Side Management (DSM) is a managerial technique in which several advantages are put forth. DSM was done to curb congestion in the European electricity transmission system where various types of congestion are identified and analyzed, and the peak-load-hour congestion was effectively minimized by demand side management. Additionally, DSM was performed for home energy management systems in order to extract more energy from renewable energy supply [7,8]. Based on the energy-ratio share, strategic negotiation was performed for congestion management. The possibility of domestic load shedding for energy management system was developed with the objective of minimum electricity price and users' dissatisfaction. Congestion has been relieved by using load shedding where the customers were focused for relieving congestion. Congestion has been managed by rescheduling generators by using various optimization tools [9–16].

From the context of smart grid and off-grid power systems, energy management was done in smart grid with distributed energy resources. The decentralized energy management system was designed by using multi agent intelligent systems with the objective of minimizing net present cost of the system. Energy management was done to maximize energy savings by introducing enterprise energy management systems. In off-grid electric systems, the optimal power generation and load management were performed by using mixed-integer linear programming model. The optimal scheduling of energy generation and storage was conducted in buildings where the electricity pricing is considered. Energy management in smart homes was illustrated and various models and approaches were proposed by various researches [17–22].

However, limited emphasis has been performed on energy management during congestion with RES. The congestion effect was evaluated in Norway, after implementing wind energy, where hydropower had already been surplus there. A generalized model of congestion management for the deregulated system were discussed by considering RES as firm power transaction. Compensation from renewable sources was analyzed in order to limit the reduction to the renewable producers' revenue in times of congestion. A brief idea of giving incentives among power adjustment were also been touched. By considering the combined operation of hydro and thermal generator companies, the cost of redispatching both generators were formulated [23–26].

Various swarm based optimization techniques are used by researchers for energy management. In restructured power systems, the coordination between local load and energy storage plant was discussed for hourly-discretize energy management problem by using an Artificial Bee Colony Algorithm. For islanded mode in micro-grid, the real-time energy management study was carried out by using a Gravitational Search Algorithm. Using Particle Swarm Optimization, parabolic trough solar collector was modeled and the optical performance was compared in [27–29].

The energy management problem is a non-linear problem as the power flow is proportional to the square of the applied voltages. The authors have chosen one of the recent nature-based optimization methods, namely Cuckoo Search Algorithm (CSA). It was proposed by Yang and Deb [30] in 2009 based on the cuckoo bird's breeding nature and Levy flight distribution to determine the step size. The algorithm finds its application in various fields as reviewed in [31]. With regard to its application in power and energy systems, CSA was successfully applied to Economic dispatch, hydrothermal scheduling and multi-objective unit commitment problem. A modified CSA was used for designing energy self-sufficient farms. The hybrid Cuckoo search was being applied to forecast solar radiation in an effort to extract maximum solar

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