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A review of optimization techniques applied to solve unit commitment problem in microgrid

N.Karthik[1], A.K.Parvathy[2], R.Arul[3], S.Baskar[4]
[1,2]Electrical and Electronics Engineering, Hindustan Institute of Technology & Science, India
[3]School of Electrical Engineering, Vellore Institute of Technology, India
[4]Electrical and Electronics Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, India

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ABSTRACT

Unit Commitment (UC) is an optimization problem used to find out the least cost dispatch of obtainable generation resources to meet up an expected electric power demand over a certain time perspective under generational, technical and ecological constraints. In the midst of the momentous increase of non-conventional energy sources incorporation into the power system networks, effects caused by these system alterations to the UC are dynamically being studied and examined by worldwide researchers. This paper presents a literature review of application of several optimization algorithms to elucidate the UC problem in microgrids. Lastly a few basic challenges arising from the new optimization approaches in microgrids are addressed.

Corresponding Author:

N.Karthik,
Departement of Electrical and Electronics Engineering,
Hindustan Institute of Technology and Science,
No.1, Rajiv Gandhi Salai, Padur, Chennai, Tamilnadu, India.
Email: nkarthik@hindustanuniv.ac.in

1. INTRODUCTION

Microgrids are characterized as modest electricity networks, comprising of a collection of distributed energy resources (DER) and loads together with non-conventional energy sources (RES) and distributed storage devices [1-3]. A literature review of unit commitment (UC) is presented in [4, 5]. As a result of combining DER units into a microgrid and running them in an ecological and cost-effective proficient way, quite a lot of prospects and benefits exist equally for utilities and consumers [6–7]. Optimal operation and demand side management (DSM) are the two important functions of energy management in microgrids. Unit commitment (UC) has been repetitively offered as a hopeful approach with researchers [8-10]. With the intention of providing high-quality electric power to the microgrid, a UC approach is well thought-out to be one of the finest obtainable options. Classical optimization techniques such as dynamic programming [11], branch-and-bound [12], priority list method [13, 14], mixed integer programming [15, 16], Lagrangian relaxation [17-19] are widely used to elucidate the UC problem. The dynamic programming has the drawback of dimensionality problem.

For a large scale power system, execution time increases extremely upon the application of branch-and-bound method. The priority list approach is simple to execute and has fast execution time. On the other hand, it offers higher operation cost with suboptimal solution. As a result artificial intelligence techniques for instance tabu search [20, 21], evolutionary programming [22, 23], simulated annealing [24, 25], fuzzy logic [26], neural networks[27], ant colony optimization [28], genetic algorithm [29-34], particle swarm optimization(PSO) [35-37], expert systems [38], integer-coded genetic algorithm [39], shuffled frog leaping algorithm [40], quantum-inspired binary PSO [41] are applied to solve the UC optimization problem. The techniques listed above are population based search optimization algorithms and can seek out for the global or in close proximity to global optimum solution for any large scale system integrating all system operational limits with simplicity. K.Chandrasekaran [42] proposed a binary/real coded artificial bee colony (BRABC) optimization technique for elucidating the thermal unit commitment problem. A new binary coded ABC with revamp approaches is utilized to attain a realistic commitment schedule for every generator, fulfilling minimum up/down time and spinning reserve operating limits. Simulation had been carried out for a standard IEEE IEEE RTS 24-bus and 118-bus system. MoosaMoghimiHadji [43] proposed an imperialistic competition algorithm (ICA) for solving the unit commitment problem. In [36], an economic load dispatch method was formulated for isolated areas without taking into consideration the ecological characteristic. In [37], an economic emission dispatch is attained by merging both objective functions by presenting a price penalty factor. In [44], a generation cost and emission minimization was implemented for microgrids. This model does not take into account of sporadic non-conventional energy sources which are generally found in a microgrid. In [45], generation cost optimization was carried out by handing over the precedence depending upon the emission released by every generator. Operational competence studies comprising solar power and storage were completed in [46]. In [47-48] the overall microgrid operating cost as well as the emission cost was minimized. It is essential to note that even though there is some form of deterministic works on the efficient aspects of the microgrid systems [49–52] small concentration has been paid to the stochastic UC of the microgrid for a 24-h time period [53].

2. UNIT COMMITMENT USING OPTIMIZATION TECHNIQUES

H. Kanchev [54] presented a 24 hour in advance microgrid optimal scheduling through the method of unit commitment with the application of dynamic programming. The microgrid system consists of twelve solar power based active generators amid three micro gas turbines and embedded storage. Utilization of the pollution free energy and emission cost of the three micro gas turbines are chosen as objective functions. Simulation results reveal that this optimization technique is efficient and a decrease in the CO_2 equivalent emissions is attained.

Juan Pablo Fossati [55] presented economic load dispatch and unit commitment problem in microgrids. Priority list and genetic algorithm was utilized to sort out the UC and ELD problem. Simulation results reveal that genetic algorithm shows better convergence when compared to priority list approach.

In [56], RezaRoofegariNejad presented a new model for optimal operation of a microgrid, comprising energy storage system, energy storage system, microturbine, wind turbine and loads. Alternatively, Monte Carlo simulation method has been applied, with the intention of modeling the uncertainties of wind power generation and energy cost of the upstream distribution system. Simulation was carried out on a typical microgrid comprising microturbines, battery bank, wind turbine and some loads. Application results reveal that upon consideration of uncertainties of wind power generation, total maneuver return of microgrid is improved from around 47$ to 54$ per day.

BinyanZhao [57] presented the optimal operation scheduling problem in microgrids with dispatchablegeberators which is used to find out the least-cost unit commitment (UC) and the linked dispatch, whilst meeting load, ecological, and operating requirements of the system. Application results reveal that the proposed technique attains a competent performance that deserves no loss of optimality with lesser intricacy than existing optimization techniques.

In [58] Bruno G.Kamdem proposed a model that evaluates the strategy and monetary allegations of the operation and implementation of microgrids. An improved Benders' decomposition technique is proposed to investigate the optimal scheduling of supply from various equipment units in the microgrid in the presence of demand and supply uncertainties. We discovered that carbon abatement strategy can be applied to encourage microgrids operators to capitalize in natural gas and fuel cells technologies when dealing with improbability.

In [59], a smart unit commitment with vehicle to grid for optimization of operating cost and emission was discussed in this paper. Harmony Search Algorithm (HSA) is applied to elucidate the unit commitment problem. Simulation results illustrate that HSA offers improved statistical results when compared to binary PSO algorithm.

JavadOlamaei [60] presented a unit commitment problem for the operation of microgrid system considering the wind power uncertainties. Operation cost of microgrids was chosen as the objective function. 2-stage stochastic programming model was used to elucidate the unit commitment problem.

SeyedMasoudMoghaddasTafreshi [61] presented a indiscriminate Unit Commitment (UC) model for optimal operation of microgrid which comprises Plug in electric vehicles (PEVs), wind turbine, microturbines, boiler, battery storage and thermal storage. The expected total profit of the UC schedule is taken as objective function. Particle Swarm Optimization (PSO) is applied to solve the unit commitment problem. To validate the model two scenarios was examined. Application results reveal that optimal integration of PEVs in the microgrid was successfully performed and the total costs are minimized concurrently.

In [62] unit commitment (UC) for the operation of microgrid which consists of wind turbine, diesel generator, photovoltaic system, microturbine and battery storage. The total fuel cost produced by the distributed generating units is taken as objective function. Priority list method is employed to elucidate the unit commitment problem. Fuel cost coefficients and the generating constraints of the diesel generators and specifications of the battery bank are considered as data to sort out the optimization problem. Quadratic programming method is employed to elucidate the economic load dispatch problem. Simulation results are attained by handing over the priority depending upon the emission released by every generating unit.

S.PoongothaiNachiyar [63] presented an unit commitment problem using Grey Wolf Optimization approach in multi microgrid networks based on battery state of charge model. Battery cost model is optimized by the application of Grey Wolf Optimization technique to face the intermittent nature of renewable energy generation. A six bus multi machine system was chosen for simulation which comprises 6 buses, 3 feeders, 1 diesel generator, 1 PV generator, 1 wind generator, 1 transformer, 3 battery storage systems and 15 loads.

Mohammed K. Al-Saadi [64] presented an energy management system for the optimal operation of microgrid. Total operating costs and emission costs are chosen as objective function. Mixed integer quadratic programming technique is applied to sort out the unit commitment problem for a hybrid microgrid system. The author investigated both isolated and grid-connected mode of microgrid. Ramp rate limits of distributed generators and operating limits of the battery are taken into consideration to elucidate the optimization problem. Simulation results reveal that the total emission and operating costs for both grid-connected mode and isolated mode is minimized.

SayedYaserDerakhshandeh [65] proposed a profit-based security constrained unit commitment (PB-SCUC) problem for Industrial microgrids (IMGs) with plug-in electric vehicles (PEVs) charging and non-conventional energy sources that comprises both microgrid factory and security constraints in addition to the PEV charging requirements. Simulation was carried out to illustrate the efficiency of PB-SCUC for an IMG comprising 6 types of PEVs and 12 factories with/without solar power generations operating in islanded and grid-connected modes.

ChristofDeckmyn [66] proposed meta-heuristic optimization algorithm for a day-ahead unit commitment (UC) model in microgrids. Operating cost and emission cost are taken as objective function. Simulations were carried out in accordance with the three UC approaches. For each approach, an added simulation was carried out comprising a congestion control signal.

RozhinEskandarpour [67] proposed a resilience-constrained unit commitment (RCUC) model which guarantees a resilient supply of loads still in juncture of multiple component outages for optimal operation of microgrid. Mixed-integer programming (MILP) was used to solve the optimization problem. Simulation was carried out using the standard IEEE 118-bus system. Simulation results reveal that RCUC model yield better results when compared to conventional security constrained unit commitment model.

MostafaFarrokhabadi [68] presented a statistical model of frequency control in isolated microgrids, which is incorporated into the Unit Commitment (UC) problem. The proposed optimization technique consider these alterations in the generation output by means of a linear model, and based on that, a modified version of Quadratic Programming (MIQP) with quadratic objective function is formulated which defers a added beneficial solution for isolated microgrids. The proposed UC model is developed based on a day-ahead with Model Predictive Control (MPC) method. To investigate and corroborate the proposed UC, an improved version of a CIGRE benchmark test system is utilized. Simulation results reveal that the proposed UC would minimize the operational costs of isolated microgrids when compared to classical UC approaches, at comparable computational costs and intricacy levels.

A.D. Hawkes [69] presented a linear programming cost minimisation model to elucidate the unit commitment problem within a microgrid. The model formulated is used to a set of United Kingdom viable load profiles. Simulation results specify that a microgrid can provide an cost-effective proposition, even though it is essentially somewhat more costly than standard grid-connected decentralised generation. The author presented conflicting optimal operation schedules among island and grid-connected systems indicating that the islanded microgird corresponds to a more inhibited system and as a result reveals a intricate cost-optimal dispatch schedule.

Robin BroderHytowitz [70] presented a co-optimization structure for a microgrid with solar power generation, transmission switching and emergency generation. In order to consider improbability inherent in photovoltaic power generation a stochastic mixed integer linear programming model is proposed to sort out the unit commitment problem. The model integrates the capability to trade energy and subsidiary services through the main grid. With the intention of managing the computational intricacies, a Benders' decomposition method was employed. Monte-Carlo simulation technique is employed to validate the projected dispatch solution beside 100 solar scenarios.

In [71], MatteoSalani presented a multi-objective optimization technique for the optimal control of bi-directional energy storages and dispatchable loads in a microgrid. The author considered two dissimilar and probably contradictory objectives: consumer energy bill tariff and the system stability as a function of the overall system's load. In this paper lexicographic multi-objective optimization technique was proposed.

SaniyaMaghsudlu [72] presented optimal scheduling of unit commitment problem. In this paper analysis of unit commitment with wind power uncertainty was carried out to minimize the total cost. Cuckoo search optimization technique is applied to elucidate the optimization problem. Simulation is performed on a IEEE standard 10 unit test system. Monto Carlo method is applied to investigate the uncertainty of wind power. Simulation results reveal that with the integration of wind turbine total cost of the system extensively gets reduced.

Reza Jabbari-Sabet [73] presented an indeterminate model for day-ahead Micro-Grid (MG) model. The presented model utilizes probabilistic reconfiguration and Unit Commitment (UC) concurrently to attain the optimal set points of the MG's units. MG's day-ahead benefit is taken as the Objective Function (OF) and Particle Swarm Optimization (PSO) technique is applied to elucidate the optimization problem. Monte Carlo Simulation technique is used to model the uncertainties of wind power generation. Simulation was carried out on a distinctive 10-bus MG comprising wind turbine, micro turbines, battery, controllable and uncontrollable loads.

JingruiZhang [74] presented an optimal day-ahead scheduling model for a microgrid system comprising wind turbine units, photovoltaic cells, battery storage systems and diesel generators. Moreover a hybrid version of harmony search (HSDE) approach is proposed to elucidate the optimization problem. With the intention of attaining the aggressive results competently some additional attributes for instance dynamic scaling factor, crossover probability factor, distinct difference operation have been incorporated into the proposed optimization technique. Simulation was carried out for various test microgrids for implementing IEEE 9-bus, 39-bus and 57-bus systems to reveal the efficiency and legitimacy of the proposed optimization technique. Simulation results reveal that for the optimal day-ahead scheduling of microgrids, the proposed optimization technique is consistent during fault and normal conditions.

In [75], CharnonThammasorn examined a suitable battery capacity to solve the problem caused by the fluctuation of renewable energy sources in microgrid. Simulation was carried out on aIEEE14 bus system. Simulation results reveal that battery capacity was enhanced when both wind turbine and photovoltaic system were installed.

Bharatkumar V. Solanki [76] presented a neural network approach to estimate the load demand as a function of ambient temperature. This formulated neural network model was incorporated in a complete microgrid energy management systems (MEMS) framework. The MEMS framework was devised considering the unit commitment (UC) network flow and operational limits concurrently. A decoupled MEMS technique was realized by disintegrating the energy management system problem into optimal power flow and UC sub-problems to assess the benefits of the proposed MEMS technique. Simulation results revealed that improved overall dispatch results were attained, with less load curbing and improved use of energy storage systems resources.

In this paper [77], the author proposed two distinctive unit commitment strategies, one for islanded operation and another for grid-tied operation for the "natural gas generators backed" microgrid arrangement to enhance the overall system efficiency and considerably curtail the fuel consumption. In addition to describing the microgrid stability evaluation, a 3-operation mode structure had been portrayed for islanded- microgrid application and a complete four mode-unit commitment algorithm had been demonstrated for grid tied mode operation of microgrid. By means of this proposed unit commitment method, the virtual droop control has been exemplified to preserve stability for the grid tied operation of microgrid. Furthermore, the droop in the voltage and virtual frequency curves was presented for all of the four modes for grid tied operation. Simulation was performed out using Matlab software.

Daniel E. Olivares [78] presented a statistical formulation of the microgrid's energy management problem and its realization in a centralized Energy Management System (EMS) for remote microgrids. The optimal operation of the microgrid was performed using an comprehensive horizon of assessment and recourse, which consented to a apt dispatch of the energy storage units. The energy management problem is disintegrated into Optimal Power Flow (OPF) and Unit Commitment (UC) problems with the intention of avoiding a mixed-integer non-linear formulation. The microgrid chosen considered was a three-phase unbalanced system. Simulation was performed on an isolated microgrid.

SirusMohammadi [79] formulated an unit commitment problem for micro-grid that comprises a noteworthy number of "grid parallel Proton Exchange Membrane-Fuel Cell Power Plants (PEM-FCPPs)" by means of minimum up/down time and ramping rate operational limits. Hydrogen storage management is accomplished with the purpose of best use of numerous PEM-FCPPs. In this paper enhanced cuckoo search algorithm (ECOA) is proposed to solve the stochastic microgrid unit commitment and deterministic microgridunit commitment problem. Simulation result reveal that the proposed ECOA is efficient in offering better solutions and exemplifies a robust performance in both the deterministic and stochastic optimization problems.

Zhao Xu [80] proposed an optimal operation strategy for microgrid amid high penetration of solar power. The method is based on the rolling horizon optimization approach with the intention of reducing the total operation costs. Differential evolution optimization technique is employed to elucidate the optimization problem.

H.Z. Liang [81] proposed an improved genetic algorithm to elucidate unit commitment problem in a microgrid which comprises photovoltaic systems, wind turbines, diesel generators and energy storage devices. Improved genetic algorithm is formulated by incorporating the simulated annealing technique with the genetic algorithm to hasten the convergence. The objective of using improved genetic algorithm is to reduce microgrid’s operational cost. Simulation results reveal that improved genetic algorithm shows better convergence rather than conventional genetic algorithm.

BeiLi [82] proposed a combined optimal sizing and energy management technique for a microgrid comprising photovoltaic system, battery storage system, hydrogen storage system which is developed as leader-follower problem. The leader problem intends at choosing the optimal size for the microgrid components which is solving by means of genetic algorithm. The follower problem is devised as a unit commitment problem which is worked out by applying mixed integer linear programming technique. Uncertainties were regarded as utilizing a form of robust optimization approach. Various scenarios are modeled and simulation results reveal the efficiency of the proposed optimization technique, particularly with regard to a simple rule-based strategy when compared to classical rule-based optimization techniques.

HosseinKhorramdel [83] investigated a new unit commitment problem based on the cost-benefit analysis and Here-and-Now (HN) method for optimal sizing of battery banks (BBs) in wind power incorporated microgrids. Particle swarm optimization is employed to reduce the total cost and increase the total benefit to elucidate the unit commitment problem. The author had considered twelve scenarios in two operating modes: stand-alone mode and grid-connected with and without the presence of BBs. By means of HN method, the uncertainty of wind power is included as a constraint in all these operating modes. Application results reveal that for the proposed unit commitment problem, the scheduling of the distributed generations and the best sizes of BBs would be completely different when the accessibility of wind energy was taken into consideration in consequence of using HN method. In [84–90] unit commitment problem was elucidated by considering different hybrid renewable energy systems.

3. CONCLUSIONS

In view of the fact that the publication of the first unit commitment technique for bulk power systems, several contributions to the improvement of fundamental idea of unit commitment have been proposed to meet the requirements of numerous applications. The arrival of microgrids and then smart grids with their exceptional features and infrastructures to surmount for the most part of the operational analysis for instance unit commitment had put together a new chapter to the field of power systems. The concept of elegance in these grids assists to prevail over the drawbacks of the traditional unit commitment approaches and offers a new optimal scheduling concept. The presented optimization techniques is in no way comprehensive, but it can be used as an essential guideline for anyone entering this research field. In general, regardless of the approach used to elucidate the OPF problem, the models so far developed have at least one of the following specifications.

4. CHALLENGES IN THE UNIT COMMITMENT IN MICROGRID:

a. To alter the conventional problem formulation to integrate the intermittency of the non-conventional energy sources, emission constraints on the carbon footprint, in addition to the inaccuracy in forecasting that subsists in demand and renewable energy forecasting.
b. Application of robust and stochastic optimization technique for energy management system model beside uncertainties in the forecasting system.
c. To manage multiple microgrids within one distribution system.

d. To carry out a cost/benefit analysis to indicate the optimal spinning reserve that can alleviate the uncertainties without a considerable increase in the microgrid's operating cost in isolated mode.
e. Operation of microgrid throughout the dispatch time when the uncertainties are realized.
f. Integration of energy storage systems in the microgrid.

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