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A Review of Optimization Techniques for Power and Energy Supervision in Micro Grids

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Abstract
Increased penetration from renewable energy sources needed for the effective use of distributed energy systems. Multi-energy systems and microgrids play a critical role in integrating renewable sources. Optimal supervision of Distributed Energy Resources can be achieved by energy management and provides significant economic and environmental benefits. The superior confrontation for the efficient utilization of these resources is the intermittent nature of RESs. To ensure the grid to operate in a reliable state, it takes full advantage of renewable energy sources by optimally dispatching stable fossil-fuel generation and/or battery storage. For economic feasibility, and development, traditional power grids power, and energy management must be addressed. A microgrid possesses independent controls and intentional islanding that take place with minimal service interruption. Power and energy management of a microgrid is a complex process due to existing alternatives, constraints, and undetermined targets. It can respond to change in the load while decreasing the feeder losses and improving local reliability. During the scheduling process, different optimization problems can be applied for the effective supervision of power and energy targets. Microgrids are reliable when there is an event of grid failure or outage. This paper begins with an overview of microgrid control and reviews various classical, evolutionary, and hybrid optimization algorithms in terms of objectives, constraints in microgrids, and typical problems that they may be used to solve and various challenges that a microgrid researcher may face.

Keywords: *Multi-energy systems, Microgrid, distributed technology, optimization*

1. Introduction

In a microgrid for balancing the power and optimal energy allocation, an effective supervisory system is needed. In today's world, the power sector is facing many difficulties in microgrid integration. With increasing loads, environmental factors energy efficiency is low and there is a requirement of high power quality. The emergence of smaller generating systems such as PV, wind, fuel cell, microturbines has opened new possibilities for on-site distributed power generation. Various types of DGs and ESs in the microgrid help to reduce the burden from the conventional power system.

Microgrid aids for conducive energy saving, emission reduction, and also significantly helps for the sustainability strategy [1-4]. Due to various intermittent RESs integration reliability problems such as power quality disturbances, brownouts, and blackouts arise. Good energy efficiencies can be achieved by Energy management in grid integration by optimizing production and consumption[28].

A broadway to classify optimization algorithms is to identify them as either Stochastic or Deterministic, in terms of their solution dynamics (Venter, 2010). The deterministic algorithms were designed in such a way that they can obtain the optimal solution but their stochastic counterparts cannot guarantee the optimal results but could solve larger and more complex problems within a relatively short time [31]. By combining various controllers in a hybrid microgrid system, overshoot can be eliminated and quick response can be achieved[33].The stochastic optimization techniques which are usually Nature-inspired Algorithms (NAS) simulate the harmonious cooperation and competition in nature resulting in amazing solutions to seemingly impossible human problems NAs can be classified as Bio-inspired, Environment-based or Physics/Chemistry-based (Binitha & Sathya, 2012). Nature-inspired Algorithms (NAS) simulate nature's way of solving its problems and this has opened a new vista in computer science. Nature-inspired stochastic algorithms could be to categorize them as either population-based or trajectory-based (X.-S.Yang, 2009b). Population-based optimization techniques solve problems using several search agents which also result in obtaining several solutions in a particular iteration[31]. Such population-based search algorithms are usually designed in such a way as to permit elitism which enables the algorithms to select the best solution amongst the several generated solutions [31][32].Variation can be observed between population and trajectory-based methods as in former several agents are used in generating solutions and in the latter single search agent generates single solution per iteration.

The rest of the paper is organized thus: section two attempts a classification of NAs, highlighting the working of some of these algorithms and their areas of successful applications, strengths, and weaknesses; section three discusses the findings of this review; section four concludes the study.

2. Literature Survey

2.1 Classical Optimization Methods

For optimal scheduling of microgrid the most important factors for the supervision of power and energy are the uncertainty of demand and intermittent nature of renewable resources, sudden outage of DGs, unwanted islanding leads to various power quality problems. A multiple chance-constrained scheduling model is used for power management in the microgrid [4].Various scenarios are generated based on uncertainty which makes larger problems in the case of two stages and multi-stage approach. It can be decomposed to smaller problems solved by different optimization algorithms. It is often chosen to approximate the bounds on a possible solution. Some of the conventional and nonconventional methods are proposed to give approximations [5]

Conventional methodologies:

- Exhaustive enumeration
- Priority listing
- Dynamic programming
- Branch and bound
- Integer programming
- Simulated annealing
- Lagrange relaxation
- Tabu search
- Interior point optimization
- Bender Decomposition based algorithm

Some of them are explained as follows:

Integer L shaped algorithm: The main idea of the Integer L-shape method is to replace the feasibility and optimality cuts points of the previous L-shape algorithm by suitable equivalents. In this method, optimality cuts represent the value of the integer solutions that have been processed, and hence it's very weak. Local branching cuts algorithm is added to extend the range of optimality cuts. Usually, one needs to add lower bounding functional derived from partial solutions to obtain good results on larger instances.

Exhaustive Enumeration: It schedules generator by different combinations and from that least possible combination is chosen as an optimal solution. It is not suited for large size system but this method holds accurate result [6], [7]

Priority Listing: It schedules the generating unit based on smaller operational prices and forms the priority order and UC is solved by this prescribed order. It is also computationally efficient and it is solved in multi-area unit commitment. [8],[9]

Dynamic programming: It is the most widely used approach to solve the problem of various sizes and modified to model characteristics of utilities. The disadvantage of this model yields a sub-optimal solution. [10]

Branch and bound: It is one of the optimization techniques which has all constraints without any priority order of units. It is a more flexible and efficient method. It consists of three steps in this first step is based on the classification of subsets, the second step deals with the constraint handling condition for subset and it is eliminated based on the violation. In the third step, lower and upper bounds are checked based on constraints handling conditions. Convergence is attained only when the maximum and minimum cramps are equal to subspace limits. [11]

Tabu search: It is one of the optimization procedures that has been applied to combinatorial optimization problems it has a disadvantage of having local minima in convergence. It operates based on the iteration by comparing it with other methods. It stops the convergence if the solution has no improvement in the further iteration. Through a pliable cache, it can be applied to minimize local minima

Simulated annealing: Annealing represents the method of increasing the temperature of a solid to a high temperature by slow cooling by decreasing the temperature of the environment in steps. The unit commitment problem can be minimized and classified as a conjoining optimization problem and an abridged optimization problem and concluded that it has a long CPU time and more complex.[12]

Ant colony Search Algorithm: It is an algorithm that can be applied to conjoining optimization problems based on artificial ants that conspire with the solution of a problem by rearranging information based on the pheromone level.

2.2 Evolutionary Algorithms

The commonality is an important feature that gains attention towards evolutionary algorithms despite classical optimization methods. Huge information can be shared among many search agents with evolutionary algorithms. These are developed by imitating nature's social activity like evolution, the crowd of different types of flies, ants, swarms searching for food. From the best evolution or best-chosen position, an optimal solution can be achieved. Some of the evolutionary-based algorithms for optimal solutions are genetic algorithm [13], differential evolution [14], and flower pollination, and invasive weed optimization, etc., found in literature in which basic steps like selection, mutation reproduction, and recombination are used.

Ant colonies, particle swarm-based algorithms are also well developed such as ant colony algorithm [15], particle swarm optimization [16], shuffled frog leaping algorithm [17], cat swarm optimization, Elephant herd algorithm, cuckoo search algorithm, firefly algorithm, moth flame optimization, grasshopper optimization, Grey wolf optimization, binary whale optimization, Bacterial forging, which mimics the social behavior of searching prey uses velocity, positions, to find the optimal solution. Teaching-learning based optimization [18] which is motivated by behaviors of teaching-learning in the classroom.

2.3 Hybrid Algorithms

It is mainly based on the merging of two or more algorithms and gives a hybrid model. To utilize the benefits of both conventional and evolutionary method, many hybrid algorithms proposed in the literature like Lagrange relaxation genetic algorithm (LRGA), for solving unit commitment, cost minimization problems hybrid particle swarm optimization, hybrid harmony search, random search, hybrid particle swarm grey wolf optimization are developed to obtain more optimal solutions. Such as fuzzy PSO, hybrid priority ant, hybrid LR, hybrid GA, etc [12-13]

3. Optimization Methods

Due to the intermittent nature of renewable energies, the stability always remains a standing issue with weather conditions (e.g., wind speed, solar irradiance). Data supervision is needed to analyze data and manage the real-time system. Operational constraints can be deduced from analyzed data through which an optimization problem can be framed. In optimization problems, two conspicuous wings determine the best solution. In the first wing, objectives and constraints of generation and load powers are selected. The next wing consists of picking a suitable algorithm.
Some of these optimization techniques are discussed which determines the power and energy management in microgrids:

3.1. Two-Stage Microgrid Optimization

Jie Gao et al. [1] developed a prominent optimization algorithm used in the microgrid to obtain optimal operation of DG's. This method gives cost-efficient operation over the complete dispatch period. In variable dispatch problems, various parameters like fuel cost and power substitute cost are contemplated with the daily cost of the microgrid. Similar to standard generators, recent developments in BESS can be merged with renewable sources in various applications. Power blackout can be minimized by adjoining the needs of the microgrid through the effective use of DIG [1-2].In the premierephase, the primo location of the MG is the bus with the minimum TSSI (Total system stability index) where sizing and location are dependent on various control parameters. TSSI corresponds to the performance of the system in a day.

In the ordinal phase, maximum power delivers from a superior power grid to a microgrid with minimized cost by choosing BESS charge and discharge efficiency as 75%.To alleviate the microgrid optimum location with the minimized cost this method is used. By specifying a system stability index with voltage deviation, power loss components micro grid impingement on the distribution network can be observed. The system stability index decides the best installation and size of the microgrid. The optimal operation of the microgrid can be achieved by various DGs with determining position and size.

3.2. Mitigating Microgrid Voltage Fluctuation

Many kinds of research on BESS(Battery Energy Storage System) have been suggested for decreasing voltage deviation. The storage capacity of BESS depends on the size and location given by Yang et al. [19].The efficacy of the storage system depends on these control parameters. Optimal power scheduling and cost minimizations are two set factors in microgrid voltage mitigation. Optimal power scheduling of the BESS for mitigating voltage fluctuation proposed by Ziadi et al. [20].Solar power is one of the intermittent sources. To minify microgrid voltage fluctuation from PV, Keerachat Tantrapon, et al.[2] proposed an optimal BESS operation with the I-PSO(Improved particle swarm optimization).In the microgrid controller, I-PSO uses PSO and CSO(cuckoo search optimization) which reduces voltage deviation. This I-PSO is used to mitigate voltage fluctuation in the microgrid.

3.3. Independent smart microgrid control optimization algorithms

Bishoy E. Sedhom et al. [21] have proposed the stratified control technique identified as Harmony search (HS) optimization algorithm in which voltage and frequency of microgrid can be adjusted such that power quality can be improved by reducing total harmonic distortion (THD). The master controller works to limit microgrid voltage and frequency under various load changes. The subsidiary controller regulates voltage and frequency to their formal values after load changes. The main intent of the subsidiary controller is to compound an expedient control for improving microgrid power quality by adjusting system voltage and frequency in islanded mode. The ordinal controller is applied to reform the efficiency of the subsidiary controllers.

Harmony search (HS) method provides many applications such as solving contemporary planning problems of MG [21], improving the performance of MG [22], determining dynamic economic dispatch [23], best location and sizing of a composite MG [24], DG propellant response can be enhanced [25], assess the procurable wind power [26], analyzing and quantizing the solar cell parameters [27].Compared to the MPC method the frequency changes can be minimized and response time in the controller can be improved. Proper selection of the tuning parameters in the controller the microgrid power quality can be enhanced.

3.4. Multi-objective optimization with storage capacity ambiguous microgrid generation

In utilizing renewable sources effectively the surpassing challenge is that sources are sporadic nature. Battery Energy Storage Systems (BESS) is an impressive solution to minify the fluctuations. Fast response to power imbalances in the grid can be supported by storage systems by conserving frequency. Rasoul Garmabdari et al. [28] developed the multi-objective optimization algorithm. It comprises of the mixed-integer quadratic model to include various control parameters in the BESS capacity. This optimization model gives graded-index which is used as a measure to reduce power fluctuations and enhance stability by considering degradation factors of BESS, variable operational constraints of DGs. The graded-index is a measure to indicate the distribution of power purchased from the grid concerning its average value.

3.5. Evolutionary based algorithm for Optimal Microgrid siting of Distributed Generation Sources

Non-linear objective function with constraints type of DG allocation and sizing case is resolved using heuristic algorithms. Primarily the goals in designing these algorithms are decreasing power loss, palliate voltage stability, and cost reduction. Salcedo-Sanz et al. [30] developed Coral Reefs Optimization (CRO) algorithm, an evolutionary-based algorithm is a multi-objective approach where solution converges in a short time[29-30]. It is composed of substrate layers[31] such that the solution can be generated without degrading other objective functions.

Silvia Jiménez-Fernandezet al.[3] presented the novel and powerful algorithm “Multi-objective Substrate Layers Coral Reefs Optimization algorithm (Mo-SL-CRO)" which gives the optimum location of distributed renewable sources in the microgrid with various loads. The Mo-SL-CRO is the combination of two multi-objective algorithms, the non-dominated sorting genetic algorithm II(NSGA-II) and Harmony search. Optimal renewable generation siting in a microgrid can be driven by this multi-objective algorithm. The inconsistent objectives in this algorithm are various infrastructures, their cost, readying and power, energy losses along the lines of the microgrid.

4. Conclusion

In today’s world, there is increasing research in microgrid and renewable resources. A controllable entity for the grid is microgrid which can reduce feeder loss and increase voltage stability. The overall stability and reliability of the whole system can be improved by the proper integration of microgrids. Depending on the configuration, type, and components, the microgrid dynamics may change; and for different applications, different modeling methodologies may be required

This paper gives a review of optimization techniques and many computational techniques used for improving microgrid performance. More advanced models also give computational challenges to algorithms.

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