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A Review on Optimal Generation Techniques used in Microgrids

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***Abstract*— Results of a literature survey done on optimization of generation thought that there is plenty of research study. With the depletion of conventional energy sources and increasing of load demand, there is a need of alternative energy sources, therefore non-conventional energy sources and distribution generation technologies continue to gain popularity. As non-conventional energy sources are intermittent, complete dependence on these sources also makes us to face difficulties such as availability of the electricity generated, weather conditions, cost of the equipment, reliability, power quality, voltage profile etc MG, which is a cluster of distributed generation sources, storages and loads that cooperate together in order to improve the power supply reliability, power quality and overall power system stability. It also integrates the advantages of power generation from alternative energy and non-conventional energy power generation systems connected to the grid. This paper presents different optimization techniques developed in recent days for minimization of cost, over emissions and curtailment of loads.**

Keywords*— Conventional Energy, Non-Conventional Energy, Distribution Generation, Power Quality, Voltage Profile, Reliability, Optimization techniques, Curtailment of loads, over Emissions, Literature Survey.

Nomenclature

MG	: MicroGrid
DG	: Distributed Generation
DER	: Distributed Energy Resource
DSM	: Demand Side Management
PCC	: Point of Common Coupling
PV	: Photovoltaic
WT	: Wind Turbine
PQ	: Power Quality
MILP	: Mixed Integer Linear Programming
PSO	: Particle Swarm Optimization
MOGA	: Multi-objective Genetic Algorithm

I. Introduction

These years because of the industrial development and increase in population, there have been a tremendous raise in global energy demand. The government provides subsidies on the Electricity supply, theft of electricity, mounting transmission losses, overwhelming power dues, lack of maintenance of the units, administrative incompetence enormous gap between supply and demand have resulted in the worst ever faced power crisis. Energy deficit in many states have not only adversely impacting the agriculture sector but also the industrial production is being decreased. The cause behind the severe power deficient situation is lack of new investments and also modernization attached with the large transmission losses.

Environmental issues associated with the centralized electric power generation, technological advancements in small-scale power generators, lack of adequate transmission capacities, and volatility of fossil fuels prices have introduced the concept of MG. MGs are subsystems and are defined as a cluster of distribution generation capacities, storage devices and controllable loads. They all cooperate together to improve power supply reliability and overall power system stability. It can be operated as a single controllable system which is either connected or isolated from the utility grid. In MGs distribution generation resources are of two types: Dispatchable and Non Dispatchable resources. To operate MG reliably there is a need of consideration of Dispatchable resource like diesel generator, Micro turbines, Battery Energy Storage units etc., which can be controlled, but it is cost effective. Hence Non Dispatchable resource like Renewable energy sources which are uncontrolled must be considered. As renewable energy sources are discontinuous in nature there is requirement of energy storage system.Boilers are non-dispatchable generators that burn diesel fuel to serve thermal loads.

MGs based on renewable energy sources are an already well known concept in off-grid remote electrification systems like telecommunication stations, lighthouses, submarines etc. Before a MG concept could become a commonplace in residential, commercial and public buildings, a number of technical and regulatory issues have to resolve.

Some of the technical issues that need to be resolved include the question of the MG power link design (AC or DC technology?), power link voltage (or frequency) regulation, power flow optimization etc. The latter is especially important in order to improve the MG reliability, as well as the economics of energy trade with electricity markets. In order to be able to perform a power flow optimization on a MG components level, power production and load profile prediction, energy storage systems state-of charge (SoC), and terms of energy exchange with the utility grid have to be known, as well as technical limitations of MG components.

When power grid is integrated with the distributed-renewable power generations such as photovoltaic (PV) or wind power, the dynamic pricing policy is extremely useful for balancing the power supply and demand at different locations so as to perform proper frequency regulation. In this way, such distributed renewable power generation facilities can be effectively integrated into the smart power grid despite their intermittent nature.It is concerned that installation of small-scale DGs to the distribution grid may cause voltage instability and power quality problems to customers. To handle these problems islanded mode of operation is proposed.

The economic and environmental benefits of MGs can be further increased by employing mathematical programming concepts. Thus, the operation of different devices within a MG can be optimally coordinated by a real-time optimization-based controller. Optimization techniques are required to improve efficient usage of available sources, scheduling of generation, minimizing running costs, emission of greenhouse gases, power losses etc.

This paper is further organized as follows: 1) Different optimization problems associated with MGs are outlined in Section II; 2) Optimization techniques are then described in Section III; 3) Simulation results of reference papers are discussed in Sections IV 4) finally; conclusions are drawn in Section VII.

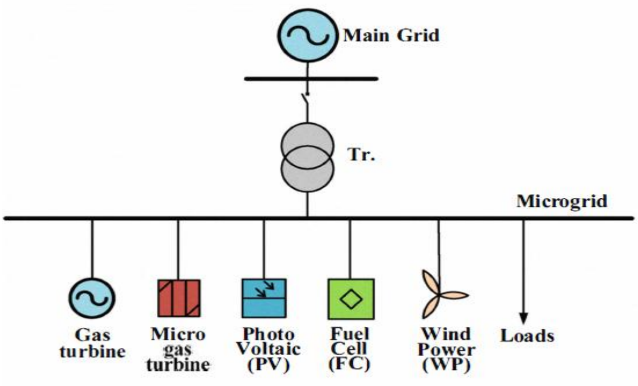

Figure 1 The base structure of Smart MicroGrid

II. DIFFERENT OPTIMIZATION PROBLEMS ASSOCIATED WITH MGS

It is hard to determine optimum renewable generation capacities and provide enough reserve margin to meet the target reliability in MG [1].The impact of generation diversity and various load growth on system adequacy were analyzed using sensitivity analyses. Finally, the optimum capacities of wind and PV systems are calculated in order to minimize the total cost of generation and unserved energy for different types of load sectors, subject to a certain reliability target.

The main objective is to study the effect of optimal determination of SSVR location and size and DG production capacity. Multi-objective optimization is composed of active loss, reactive loss and voltage profile indices and a combination of all weighted indices (Weights have limitations). With the proposed strategy, objective function indices including active and reactive loss index and voltage profile index are optimized while overload conditions and different operation modes conditions of the grid are satisfied [2].

The multi-objective energy management problem of the designed MG contains two non-commensurate competing objectives: cost and emissions. Cost objective function depends on the cost of five different energy sources i.e. operation cost of electrolyzer, high power battery operation cost, fuel cell operation cost, ICE(internal combustion engine) operation cost and boiler operation cost. Emissions objective function is composed of the emissions that are produced from the natural gas used to fuel the ICE and the boiler. The energy management optimization problem contains one equality and two to four inequality constraints depending on the operating state of the system [3].

The decomposition method was used to decouple the problem to a normal operation problem and a resilient operation problem. The objective of the normal operation problem is to minimize the MG operation cost including the operation cost of dispatchable units and power transfer from the main grid and the inconvenience cost realized by consumers subject to equality, inequality limits. The objective of the resilient operation problem for an islanding scenario s is to minimize the power mismatches subject to equality and inequality constraints [4].

The objectives of the system are to simultaneously maximize the power availability and minimize the costs which optimize the system sizing of the PV panel, wind turbine, battery storage and the power imported from grid with highest possible availability. The hybrid system parameters are life cycle of the project, battery life cycle, inflation rate, interest rate and escalation rate. Usable roof area, desired lifetime and desired availability of power limits on maximum imported grid power are considered as the design constraints for the objective functions [5].

The main objective is to optimize the MG operations; this can be achieved by minimizing the operating costs. Objective function includes costs associated with energy production and startup and shut-down decisions along with possible earnings, curtailment penalties and also operative and maintenance costs of DG units, subject to equality and inequality constraints [6].

A term neural network could be summarized as a mathematical function with a number of parameters that are fitted in a way so that difference between target y_t and neural network output y_{MLP} is minimized by certain criteria (i.e., cost function) for the given set of input-target pairs for training. Mean Square Error (MSE) is used as a Cost-function for NN training. Input candidates in local network are lagged load, meteorological and time data. These candidates are chosen heuristically, but for the more realistic information input variable selection (IVS) analysis required [7].

The power grid controller sets the pricing signal and cloud controller performs resource allocation among data centers. The main objective of the power grid controller is to maximize its own profit and also to perform load balancing among power buses that is minimizing power flow from one power bus to others, while the objective of cloud computing controller's to maximize its profit with respect to the location dependent pricing signal [8].

Assuming that the low forecasting precision can incur high costs due to the cost of the balancing energy we aimed at quantifying the increase of costs for one particular setup of prices and policies in the MG market model [9].

MG economic operation optimization in grid-connected operation can minimize system operation cost and pollution discharge when the system load demand and reliability are satisfied. Cost function involves local available energy resources, the technical performance of distributed power supply, load demand, environment protection expenses, and operation and maintenance expenses of MG power supply. Besides, electricity transaction between the MG and external power grids should be considered, namely, system electricity purchase and sales. On other side MG in isolated grid operation, electricity transaction with external grid will not be considered. Objective function is subject to equality and inequality constraints [10].

The development and management of the Dongfushan MG system is a multi-objective problem, which has two major objectives. 1) Minimize the Power Generation Cost: The power generation costs of the diesel generator and the renewable energy sources are included. 2) Minimize the Batteries Life Loss Cost: The total batteries life loss cost is included. Power generation and consumption should always be kept balanced [11].

The objective of wind turbines, in terms of Control and operation, in a large interconnected power system has been, conventionally, to extract maximum power output from wind flow, since its operation, production cost are almost negligible compared to fossil fuelled power plants [12].

The optimal energy dispatch problem for MG is modeled as a cost minimization problem (fuel consumption cost and interaction electricity cost between MG and main grid at time t) with the output constraints of controllable micro resource adjusted by prediction errors, the ramp rate, time-of use price and other factors. Then this model is transformed into a bi-objective optimization problem in order to deal with the constraint boundary better [13].

In the probabilistic small-signal-stability analysis, uncertainties concerned may include but not limited to Nodal loads (forecasts), including levels and shapes; Operation status of units; Change of market dispatching rules; Timing and location of new generation resources; Transmission network parameters, e.g. line impedance and resistance; and Parameters of various controllers [14] .

Multi-objective function is used to minimize three reliability indices: system average interruption frequency index (SAIFI), system average interruption duration index (SAIDI) and energy not supplied (ENS) [15].

Objective function includes low carbon forms of energy use (wind turbine, photovoltaic array, energy storage device) and other high-carbon energy use (mainly for thermal power units, gas turbine), consider the EPE analysis model, set object of minimizing the power grid full life cycle costs, while reliability meet the requirements of the user [16].

To minimize the power losses in the system, power grid has to adopt changes in power production and power demand and the control problem will to helpful to exploit the available information of power grid [17].

The objective of this paper is to minimize the frequency excursion of MG for a power imbalance between the load disturbance and power generation by keeping controllable sources power output within the limits [18].

The objective of the proposed MG-based planning problem is minimizing the total planning cost all over the planning horizon and it includes investment and operation costs associated with new generating units, transmission lines, and MGs, in addition to the cost of unserved energy [19].

The deterministic variables of the optimization problem for the MG are charge/discharge of electric storage at each time [20].

Minimizing the total electricity cost is the main objective. The variable cost of electricity in EIE MG, describe the characteristics of batch production load scheduling and power generation scheduling and is composed of fuel cost for self-generation, the net electricity charge buy (sell) from (to) the utility and additional cost like overtime payment of employees, penalty fee of gas emission and other miscellaneous charges [21].

The objective of generation schedule is to maximum the difference between intermittent energy integration capacity and power curve fluctuation punishments [22].

Although revenues can be grasped by selling at the day ahead or feed-in-tariff or system reserve market, costs can be occur due to generation costs of thermal or CHP units buying at the day ahead market or capacity fees. Thus the objective is to minimizing the total costs of the system [23].

Objective to discuss some practical limitations regarding the storage modelling that might be experienced in a real-time MG optimal control and to propose a feasible solution to address them. The proposed solution is included in pre and post-processing units to modify the commands issued by the MG controller such as storage stop/start or to change some input parameters such as the initial capacity of the storage [24].

Critical decision variables like the PV array size, number of wind turbines, fuel cell size, presence of hydro system, number of batteries, converters size, dispatch strategy, generators size is given due weight in the optimization process using data from NASA's meteorological department [25].

The environmental protection and economic dispatch of smart micro grid is to adjust the output of existing DG unit in the MG. This can be done by minimizing the generating cost and greenhouse gas emissions cost subject to the power balance and load demand constraints [26].

An optimization problem determines the output power of the generators such that the total hourly cost and/or emission are minimized [27].

The formulation of the multi-objective, multi-constraint MG power management problem begins by identifying the attributes of the MG. These include the MG capability to:

- Meet consumer load demand within given voltage and frequency standards.
- Reduce or defer distribution and transmission capacity additions.
- Reduce line losses, provide VAR support, and stimulate power market opportunities for trading ancillary services to the utility grid.
- Facilitate customization as load composition, diversity, and profile vary (example: urban vs. rural).
- Allow the integration of stable and adaptable control system behaviour for seamless "plug-and-play" implementation and sensible load control [28].

The function must minimize a global mathematical cost function, selecting on-line the most efficient way to adapt production to demand and to minimize running costs and greenhouse emissions in the MG [29].

To obtain feasible power system operating point through an acceptable transient stability level, minimizing the costs associated with power rescheduling has to be done [30].
Objective is to minimize the total generated reactive power [31].

In this the optimization problem designed for the particular household with PV, wind and lead-acid battery storage. The optimization problem is made up by using cost of generation by RES, cost associated with grid and penalty cost. Violating boundary conditions such as underutilization of a generation unit causes the penalty costs [32].

The scheduling method in practice mainly focused on how to satisfy the daily load demands by distributing monthly contract electricity into each day while the daily reserve capacity and reliability are ensured [33].

III. Optimization Techniques

In computer science, operations research and mathematical optimization is the selection of the best element from some set of alternatives, available.

Let's take a simple case, an optimization problem that consists of minimizing or maximizing a real function by choosing systematically input values from within an allowed set and computing value of the function. The simplification of optimization theory and techniques to other formulations requires a large area of applied mathematics.

A. *Genetic Algorithm*

It is a meta-heuristic technique inspired by genetics and evolution theories. During the last decade, it has been successfully applied to lots of power system problems, especially to unit commitment problems

B. *Linear Programming*

It is an exclusive case of mathematical programming or optimization and also it is a technique for the optimization of linear objective function that is subjected to linear equality and linear inequality constraints and its feasible region will be a convex polytope, which is a set defined as the intersection of finitely many half spaces, each is defined by a linear inequality. A LP algorithm finds a point in the polyhedron where this function has the smallest or largest value if such a point exists.

C. *Particle Swarm Optimization*

This algorithm is one of the modern heuristic methods. It is a general minimization method which can be used in problems whose answers are a point or area in an N-dimensional space.

D. *Modified Particle Swarm Optimization*

Particle Swarm Optimization (PSO) is a one of the new optimization algorithms, that is applied in many a number of fields widely. But the original PSO is likely to cause the local optimization with premature convergence phenomenon. By using the idea of simulated annealing algorithm, a modified algorithm is proposed which makes the most optimal particle of every time of iteration evolving continuously and assign the worst particle with a new value to increase its disturbance. By testing of classic testing functions, conclude that the modified PSO algorithm has the best performance of convergence and global searching than the original PSO.

E. *Robust Optimization Method*

It is a field of optimization theory which deals with optimization problems in which a certain measure of robustness is required against uncertainty which can be represented as deterministic variability in the value of parameters of the problem itself and/or its solution.

F. *Mixed Integer Linear Programming*

Energy and power flows are represented as continuous variables, and the discrete features of the micro grid components are captured by using binary decision variables. The behavior of the micro grid system, its components may be described by both differential or difference equations and the logical statements. So, we need to construct a prediction the system. The statement G-system, its components are described by both differential or difference equations like storage dynamics and the logical statements like control statements of the form if-then-else.

$$f(k) \geq 0 \Longleftrightarrow \delta = 1$$

$$\text{is true if and only if} \begin{cases} -m\delta & \leq f(k) - m \\ -(M+\varepsilon)\delta & \leq -f(k) - \varepsilon \end{cases}$$

similarly

$$y = \delta f(k) \quad \text{is equivalent to} \begin{cases} y \leq M\delta \\ y \geq m\delta \\ y \leq f(k) - m(1-\delta) \\ y \geq f(k) - M(1-\delta) \end{cases}$$

Where is a function upper and lower bounded by M and m, respectively, δ is a binary variable, y is a real variable, and ε is the small tolerance (typically the machine precision). ε is needed to transform a constraint of the following form $y<0$ into $y \leq 0$, and we know MILP solving algorithms especially handle non strict inequalities.

G. *Non Dominated Sorting Genetic Algorithm II (Also Called NSGA II) Or Multi-Objective Genetic Algorithm (MOGA)*

Multi Objective Genetic Algorithm (MOGA) which is commonly called Non-dominated Sorting Genetic Algorithm-II (NSGA-II) [18], [29] is used as an optimization algorithm or search method to find a set of equally good solutions for the objectives as a form of a Pareto frontier. However other optimization techniques can be used, but this method has been one of the most popular heuristic search methods are used for multi-objective optimization. Genetic Algorithm is a well-known non gradient based search method that mimics the natural evolution process.

MOGA uses Genetic Algorithm (GA) as its core with two important new concepts in order to achieve good multi-objective optimization. These two concepts are non-dominated sorting and crowding distance. By using these two concepts and GA principle, MOGA algorithm can be formed which is called Non-dominated Sorting Genetic Algorithm-II (NSGA-II)

H. Simulated Annealing (SA)

SA is generic probabilistic meta heuristic that can be used for the global optimization problem of locating good approximation to the global optimum of the given and required function in a large search space. It is frequently used when the search space is discrete like all tours that visit a given set of the cities. For some problems, simulated annealing is more efficient than exhaustive enumeration — provided that the goal is merely to find an acceptably good solution in the fixed amount of time than the best possible solution.

I. Bacterial Foraging Optimization (BFO)

BFO is an algorithm that belongs to the field of Bacteria Optimization Algorithms and the Swarm Optimization and is more broadly to the fields of Computational Intelligence and Metaheuristics. It is related to other Bacteria Optimization Algorithms such as the Bacteria Chemotaxis Algorithm [Muller2002], and other Swarm Intelligence algorithms such as Ant Colony Optimization and Particle Swarm Optimization. There have been various extensions of approach which attempt to hybridize an algorithm with other Computational Intelligence algorithms and Meta heuristics like PSO, GA and Tabu Search.

J. Chaotic Quantum Genetic Algorithm

Quantum Evolutionary Algorithm (QEA) has developed from basic quantum of information science and is an evolutionary algorithm that is based on the quantum computing concept. This includes the concepts for instance superposition state and others in quantum computing and this also adopts the unique coding format in order to achieve a better experimental results on combinatorial optimization problems. However, when we are dealing with Multi modal function optimization through QEA, like, high dimensional multi modal function optimization problem, it has prone to fall into local optimal and its computational efficiency that is not high.

In the above noted deficiencies of QEA, this research integrated global optimization ability of genetic algorithms, local searching capability that is based on quantum probability model, or sensitive dependence of chaotic algorithms to initial value, traverse of the search space to establish a new improved quantum evolution algorithm is "Chaotic Quantum Genetic Algorithm".

K. Homer

(Hyper geometric Optimization of Motif Enrichment) is a suite of tools for Motif Discovery and next -gen sequencing analysis. It is a collection of command line programs for Unix-style operating systems written in Perl and C++. HOMER was primarily written as a de novo motif discovery algorithm and is well suited for finding 8-20 BP motifs in large scale genomics data. HOMER contains many useful tools for analyzing ChIP-Seq, GRO-Seq, RNA-Seq, DNase-Seq, Hi-C and numerous other types of functional genomics sequencing data sets.

IV. OPTIMIZATION TECHNIQUES USED IN PARTICULAR AREAS

PSO is employed on top of the MC calculation to calculate the optimum capacities [1].

PSO algorithm is employed to improve voltage profile and to reduce active and reactive power loss in MG systems and also to determine the optimal capacity of distributed generation and optimal location and size of SSVR in both grid-connected mode and island mode of operation of MG [2].

Energy management of the designed MG is presented using a modified multi-objective particle swarm optimization (MOPSO) algorithm. The proposed MOPSO finds the optimal power to be generated by each source at any time to provide the desired power to the loads, considering the two objectives of minimizing cost and emissions over a 24-hour period. Because the two objectives are non-commensurate and competing, a Pareto front, i.e. a set of solutions is obtained among which a trade-off solution can be picked. Modified MOPSO performance was compared with the MO`GA optimization tool available in the Matlab optimization toolbox [3].

A robust optimization method is employed to account for uncertainties in load and generation forecast. The benders decomposition method is employed to decouple and coordinate the normal operation and the resilient operation problems. To model the normal operation problem, mixed integer programming was used and for resilient operation problem, linear programming was used [4].

In this Non-dominated Sorting Genetic Algorithm-II (NSGA-II) which is also known as Multi-Objective Genetic Algorithm (MOGA) is used and it considers high temporal resolution insolation data taken at 10 seconds data rate instead of more hourly data rate. Pareto Front, an engineering trade off analysis is used to choose the unique design from the set of feasible designs based on particular preferences [5].

Combination of Model Predictive Control (MPC) approach and Mixed Integer Linear Programming (MILP) is employed. MPC-MILP is the feedback control law computed through the MPC control scheme. In this a certainty equivalence approach is applied i.e. predictions are assumed to be perfect in the MPC problem, unaffected by errors. The uncertainty is then compensated by the feedback mechanism. Least-square SVM (support vector machines) is applied to compute control strategy renewable power and demand forecasts [6].

For NN training (i.e. parameters tuning), a gradient-based Levenberg-Marquardt algorithm is used [7].

Using convex optimization and simulated annealing techniques, two players in Stackelberg game i.e. the near-optimal or suboptimal strategies can be derived with backward induction method [8].

An agent based simulation environment is implemented in which many parameters can be individually varied [9].

Isolation Niche Immune Genetic Algorithm (INIGA) is used to compare with some other optimization techniques that are usually used to solve Optimization Operation problem and the Energy Management and also to confirm the validity and accuracy of the mathematical through some real examples. It demonstrates the usability and superiority of this approach [10].

The NSGA-II algorithm was used to find solutions for a multi-objective problem to minimize the generation cost and to minimize the battery life loss [11].

To enhance stability margin and damping ratio of critical modes, simulated annealing algorithm is used [12].

Improved PSO algorithm with simplex crossover operator is proposed to improve the overall efficiency of optimization [13].

Stability of the power system is optimized using the PSO technique [14].

The PSO-based multi-objective function (MOF) will be applied for optimization problem [15].

The modified particle swarm method is used to solve the optimization problem includes three situations: low-carbon scene, equilibrium and high-carbon scene, [16].

Dynamic optimization methods are used to implement a dynamic control policy to optimize the performance of the power grid by assuming power demand information is available at the power producer side [17].

Many powerful mathematical optimization techniques are using to tune the parameters and to tune the control parameters the most reliable are population-based optimization methods includes particle swarm optimization (PSO) genetic algorithms (GAs), and bacterial foraging optimization (BFO) [18].

MG-based co-optimization planning is a mixed-integer programming (MIP) problem [19].

Optimization problem of a stochastic operation cost model is formulated by stochastic scenario and then solved by a method of PSO [20].

A unified electricity management method based on integrated optimization of both power generation and batch production load scheduling for EIE MG is proposed. Linearization techniques are introduced to convert the problem into a MILP model [21].

An active power dispatching model is solved by a linear programming optimization algorithm [22].

The Lagrange Relaxation is applied as an iterative optimization [23].

Power generation optimization in this study is formulated in separate unit commitment and linear optimal dispatch problems; hence, the decision variables such as the storage charging powers are not controlled by complex constraints including binary variables in the framework of a mixed integer linear programming model. Therefore, some of the computational tasks are performed by pre and post processing units [24].

The task of evaluating and optimizing different system configurations in the design of an off-grid MG is simulated using HOMER [25].

The Chaotic Quantum Genetic algorithm adopted the quantum bit coding is adopted for the coding of the problem itself [26].

To identify the optimal MG configuration and the corresponding optimum dispatching in each of the aforementioned cases, HOMER software package has been employed [27].

A framework has been developed for utilizing the promising ACO heuristic technique for implementation in a MG power management controller [28].

This research is focused on finding a new algorithm (cost function based algorithm) for active-power dispatch in connected-to-the-grid mode. Based on electrical generation cost functions of micro sources a heuristic approach algorithm is designed to minimize the cost objective. [29].

Constrained global optimization problem is solved by a mixture of PSO and ANN [30].

Using Genetic Algorithm (GA) procedure reactive power generation limits and/or bus voltage magnitude limits are specified as allowable range of values of these variables [31].

LP along with heuristics is used for optimization of operating cost. The heuristics can be defined based on the prior information from the Fuzzy ARTMAP based prediction module which can then be utilized to define the optimization problem within the LP paradigm [32].

GA is used in the optimization algorithm, a new technique to represent candidate solutions is introduced, and a set of expert operators has been incorporated to improve the behavior of the algorithm [33].

V. RESULTS IN CORRESPONDING REFERENCE PAPERS

To minimize the total cost of generation and unserved energy for different types of load sectors, higher wind generation capacity is chosen for residential customers, the optimum hybrid generation capacity for commercial and industrial customers includes higher PV capacities [1].

PSO optimization in presence of SSVR shows remarkable improvement in voltage and obtained results show appropriate performance of proposed algorithm and important role of the SSVR in MG operation improvement [2].

The faster simulation time and denser Pareto front showed the MOPSO algorithm to be superior and was therefore used in the 24-hour energy management simulations. The results of the energy management simulations show the trade-off between least cost and least emissions [3].

On considering an uncertain main grid supply interruption as well as uncertain load and generation forecasts, the resiliency-oriented MG optimal scheduling is studied. It suggests that accurate load forecast has a more significant role than generation forecasts. It also advocates that considering an uncertain main grid supply interruption time may result in a higher operation cost but would be more robust [4].

The proposed methodology guarantees a reliable energy supply with lowest investment [5].

Results show that MPC-MILP control scheme is able to economically optimize the MG operations and save money compared with current practice. Tradeoff between demand peak reduction and user comfort can be achieved through allowable curtailments [6].

Developed NNs performs very well for one-hour ahead prediction. However, for one-day ahead prediction NN model does not perform very well. Since a single bad prediction at the particular moment could spoil all other predictions after that moment. In order to be able to obtain more realistic information on load profile prediction, the prediction model should be extended with its stochastic description [7].

Experimental results on IEEE 24-bus Reliability Test System Shows that the effectiveness of the proposed game theoretic optimization framework on profit maximization and load balancing and simultaneous enhancement in total profit and reduction in the risk of circuit overflow can be achieved [8].

The precision model is unbiased, and the balancing energy not drastically higher than the price of energy and the resulting MG price. Future scenarios need to focus on anomaly price events and the role of price prediction in order to quantify how price forecasting and battery management can safeguard from potentially severe impact of anomaly events [9].

Compare to other common optimization methods this method can meet accuracy and promptness requirements [10].

The proposed method can effectively increase battery life and reduce generation cost via helping users obtain a set of optimal operation schemes of actual MG systems [11].

By optimizing control system parameters in different loading levels of the islanded MG operation, the proper dynamic performance of wind turbine is ensured [12].

MG operation cost of typical days calculated by using the proposed algorithm is less than the conventional PSO, and the constraint violation degree of optimal energy dispatch calculated by the proposed algorithm under the goal of minimum operation cost is also less than the one by the conventional PSO [13].

The level of stability has been increased and can be done further more when optimization increases [14].

The improvement of reliability indices in MOF, as the locations and the number of CB affects reliability of system [15].

An equilibrium point of energy consumption and carbon consumption can be achieved by considering balance scene meant for clean energy consumption [16].

The stability of the system can be achieved with the smaller energy consumption level when the power price is known than without the knowledge of power price information at the consumer [17].

It is observed that for optimal tuning of multiple parameters in nonlinear MG BFO is better than PSO, GA and classical methods [18].

MG investments in the power system can provide significant reliability and economic benefits and are viable options for system upgrades when large investments on new generation and transmission facilities are not forthcoming [19].

Although the optimal operation cost solution by the stochastic cost model may be slightly higher than that of the deterministic cost model, nevertheless, the ability of handling uncertainties of renewable generation fluctuations and load change make the stochastic method be more practical and advantageous [20].

Compare with situation without optimization, the integrated optimization model can significantly reduce electricity cost. Also, the integrated optimization model obtains a better solution comparing with strategies of only batch production load scheduling or only power generation scheduling [21].

The charging and discharging operation of the energy storage system can smooth the power output curve of the whole generation system. The total generated power curve is smooth and the power output is desirable [22].

Highest load peak occurring can be reduced by including the referring fee into the optimization, the additional benefit of considering small generation and storage units as VPPs and Cost reductions can be observed when applying all of the proposed market participations [23].

The interesting capability of the proposed method is that even with large minimum charging powers, SOC can be controlled efficiently [24].

Limitations such as requirement about 10 seconds interval for a 50% change in power output and a fuel cell requires about 10 seconds interval for a 15% change in power output for micro-turbine indicate that storage is necessary at the alternating current or direct current end to stabilise the instantaneous changes in power demand as required by the sensitive loads [25].

The algorithm used to solve the environmental EDP for Smart MG power systems is an excellent algorithm and it is economically significant and quite practical [26].

The integration of renewable energy generators and optimally-rated energy storage units into a diesel-powered off-grid site, in conjunction with an optimal dispatching strategy, can result in substantial reduction in the lifetime cost and emission of the electrified community [27].

Work addresses the complicated engineering problem of how multiple AEDGs and dispatchable loads can be successfully Work addresses the complicated engineering problem of how multiple AEDGs and dispatchable loads can be successfully controlled on a MG in a near-optimal manner using artificial intelligence concepts [28].

Cost function based algorithm sent set points to the micro sources as per the evaluation and comparison of results in steps of 5 seconds and consequently it stabilises the generation in time without the fluctuations which appeared with SQP [29].

The results show that the PSO-ANN proposed method is successfully able to adjust system operating point to improve system transient stability with minimum cost during rescheduling process [30].

Voltage settings for the generators are less than in the base case. Load bus voltages are somewhat lower than the base case but within limits [31].

DIEMS, minimizes operating cost as well as it helps to improve overall system operation. It also concludes storage always saves money compare to selling excess energy to the utility at avoided cost (wholesale-cost) [32].

The proposed GA, using new specialized operators, demonstrates excellent performances in solving this kind of problem, obtaining near-optimal solutions in reasonable time and without sacrificing the practicability of the proposed models [33].

CONCLUSION

On referring all these papers it is understood that environmental benefits, reduction of distribution losses, reliability, better voltage profile and power quality, better system stability, etc.can be obtained by using MGs.

There is prerequisite of MG operation optimization, as operating costs of MG includes generator running costs, cost of replacement of battery, cost of power imported from the utility grid etc. The technical and economic benefits offered by a MG largely depend on the presence of storage devices, which provide the energy/power requirements in different time frames constitutes Non-dispatch-able sources which are intermittent in nature. For this forecasting of load demand and Non dispatchable sources have to be done. The forecast may be long term or short term. Thus, a short-term storage device contributing in a time frame between fractions of a second to multiples of ten seconds can help to meet step load changes resulting from load-generation variations or transferring to an islanded mode of operation; this is vital for the stable operation of a MG. Also, a long-term storage device, which cans be effective between multiples of ten minutes to several hours, is appropriate for shifting the energy, and adding more economic and environmental values.

MG is a challenge for electrical distribution systems because high penetration of DG requires a change in operation strategies and design.

As increasing integration generations takes place, the power grid especially the distribution system may face some serious problems of voltage and frequency, and therefore some special measures are necessary to prevent the existing power gird from degradation., the MG that can mitigate the power fluctuation of renewable power generations by itself is a desirable way to the power grid side and be expected to facilitate the expanded utilization of the renewable energies and attaining diversification of energy resource in the late r future.

At every time step, the MG controller must take high level decisions about:

1) Unit Commitment
2) Economic Load Dispatch;
3) when should the storage device be charged or discharged;
4) when and how much energy should be purchased from or sold to the utility grid (when the MG is in the grid-connected mode);
5) curtailment schedule (which controllable loads must be shed/curtailed and when);
6) How much energy has to be stored.

There are number of optimization techniques like PSO, Modified PSO, GA, MOGA, BFO, MILP, HOMER etc., to optimize the operating costs of the MG, to reduce emission of greenhouse gases, to improve power quality, stability etc. especially multi-objective optimization is used to find a trade-off solution. Pareto front can hopefully be established for a problem with multiple objectives.

Overall studies have suggested that MGs can achieve high performance through:

1) Based on predicted future conditions and uncertainties advanced control algorithms are employed for system;
2) Demand response deployment;
3) To compensate the physical imbalances, Optimal usage of storage devices has to be consider; and
4) Applying optimal instead of heuristic-based approaches.

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