ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

Methods Adopted for Management of Distributed Energy Resource (DER)

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ABSTRACT*:* Micro-grid is a combination of multiple distributed generators (DGs) and/or storage units which provide energy to comparatively small local communities Micro-grid (MG) is formed by renewable sources. MG is a small scale network of low voltage distributed renewable energy resources (DER).This paper reviews the optimal energy management for a MG under various constraints. This paper emphasize on the different methods adopted by various authors to optimize fuel cost, manage peak load and reduce gas emissions by scheduling generation of DERs in each hour or for particular time 't'. MG model includes battery as a storage device; hence the battery life also becomes one of the constraints. Mainly DERs are wind and solar source and are dependent on climatic conditions. The authors have used deterministic method to address aforesaid costaints.

KEYWORDS: DG sources, Energy management, optimal power

I. INTRODUCTION

Micro-grid is a combination of multiple distributed generators (DGs) and/or storage units which provide energy to comparatively small local communities and smart Grid is an automated and distributed advanced energy delivery network that includes Conventional Generators, Renewable Generators, Industrial Loads, Residential Loads, Storage Units, Electrical Vehicle Charging Stations, etc. Micro-grid (MG) is a grid formed by renewable sources. The renewable sources are distributed energy resources (DER). A MG gives clean energy. MG can have two operational modes; the islanded mode and grid connected mode. DERs are installed to establish green and smart distribution system with the use of renewable energy resources. The source mostly used in DERs are wind, solar, micro-hydro, bio-gas etc which are non-controlled energy sources with diesel generator, fuel cell, micro-turbine, and energy storage system (ESS) According to the US Department of Energy [1], relying on the advanced communication tools and power electronic control devices, the utilization of DERs is potentially in favour of increasing the energy utilization efficiency, mitigating the power flow congestion in distribution system, improving the system stability and reliability, providing more benefits in both economic and sustainability reasons, and strengthening the centralized control for grid operation.

As compare to large power grid, a single and small DER is considered as a non-regulated energy resource. If such source is integrated into the power grid, there are voltage fluctuations and it may affect power quality. Also if the fault occurs in the main grid single DER needs to be disconnected instantly. This is the main disadvantage and it limits the performance of DER to a large extent. Therefore a MG concept is introduced. In energy management system of a MG it needs to optimize the model in terms of cost also it needs to plan a Generation schedule for each unit in each hour on the next day, minimize harmful gas emissions, improve energy utilization efficiency, maximize MG operation profits under different operational conditions.

To achieve these goals the constraints are total power supply should be equal to the load demands in each time interval and each DER unit should operate within its minimum and maximum limits.

The state variables are power generated by the forecasted wind and solar generation in each hour on the next day, the forecasted market electricity price on the next day and also the load demand forecasting.

II. DISTRIBUTED ENERGY RESOURCES

Smaller energy sources in a MG are called as Distributed Generation (DG) units, and form part of the Distributed Energy Resources (DER). Generally non-conventional energy sources such as solar, micro-hydro and wind sources are

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most commonly used. Stand alone units like wind, solar, water are already in operation at many places. Islanding operation is costly and not reliable. Hence hybrid energy system is formed. A system with combination of different sources provides balance and reliable and stable supply. The main aim is to provide 24h quality power in remote areas. In this system solar photovoltaic (PV) array, wind system and micro-hydro system is considered along with the battery as a energy storage system (ESS). Different system developments in hybrid energy system are published in [2]. A simple numerical algorithm was used for unit sizing and cost analysis of stand- alone wind, solar PV system is explained in [3]. In [4] linear programming techniques was developed for optimal design of hybrid system. In [5,6] various aspects of hybrid power system including optimal sizing and operation is detailed. A probabilistic performance of stand-alone Solar PV, wind energy system with several wind turbines with same and different sizes and PV models with battery storage system has been presented [7].
This paper attempts to develop a general model to find an optimal hybrid system among different renewable energy combinations, minimizing the total life cycle cost of DER by guaranteeing reliable system operation. The aim is to find the suitable component sizes and optimal operation strategy for integrated energy system to get economical power supply as well as to manage peak load shading.
The optimal operation plan for the hybrid system is
to minimize the annual operating cost computed based on operating cost for the particular time interval " t" in a day as

$$Cot = \sum_{1}^{365}\left\{\sum_{1}^{24}\left(C_{oh}(t) + C_{ow}(t) + C_{os}(t) + C_{og}(t) + C_{ob}(t)\right)\right\}$$

Where $C_{oh}(t), C_{ow}(t), C_{os}(t), C_{og}(t), C_{ob}(t)$ are the, operating costs of hydro, wind-turbine, solar, diesel and battery unit with the constrained depending on weather conditions. Cot is total operating cost
The capital cost is Cc is

$$Cc = \sum_{h=1}^{Nh} C_h + \sum_{w=1}^{Nw} C_w + \sum_{s=1}^{Ns} C_s + \sum_{g=1}^{Ng} C_g + \sum_{b=1}^{Nb} C_b$$

Where Nh, Nw, Ns, Ng, Nb are the total numbers of hydro, wind, solar, diesel generator, and battery units respectively and Ch, Cw, Cs, Cg, Cb are the corresponding capital cost.
Unit cost of electricity by hybrid system, Coe

$$C_{oe} = \frac{C_c + C_{ot}}{El}$$

El is the load served in kWh/year .

III. ENERGY MANAGEMENT IN A MG

DERs and energy saving system (ESS) provides clean energy in distribution grid and MG which can improve the energy utilization efficiency and stabilize the system voltage and frequency. There are several types of ESS such as the flywheel, super capacitor, battery and so on; battery is most commonly used due to its low cost and its convenience of installation and maintenance. A fact emerges in MG energy management model is that the battery state of charge (SOC) in each hour depends on the SOC in the previous hour. Hence, the batteries SOCs in each two adjacent hours are correlated and the optimization model is developed. The installed EES capacity should be ~ 3% of total generation capacity. For peak shaving the required capacity of EES needs to grow beyond 8%. There are variations in Renewable energy generation, depending upon the size of the evaluated system, depending on the time scale, Microscale (seconds

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to minutes) Mesoscale (minutes to hours), and Macroscale (hours to days). Microscale fluctuations can be smoothened over a region. Mesoscale and Macroscale variations are usually cause of concern.

In microscale, large-scale integration may require significantly more regulation reserves and frequency control (~ 11%). In mesoscale, variations impact the balance between the supply and demand and may require a significantly increased amount of operating reserves (~ 47%). In macroscale, variations impact unit commitment and scheduling of conventional generators, and unpredictable variations may result in significant economic costs. (e.g., increase in system start-up costs by up to 227.2%)

Table 1
FUNCTIONAL REQUIREMENTS FOR STORAGE

Function	Storage Time	Response Time Required
Renewable Capacity Firming	6-10 Hrs	mins
Smoothing micro, meso and macroscale variations for wind; Cloud effects on PV	0.01 to 3000 Hrs	ms to s
Voltage and Frequency control	0.005 Hrs	ms
Peak Shaving, Transmission and Distribution Issues	2 to 10 Hrs	mins
Emergency Back up; Seasonal Storage	Hrs to Days	's' to min

Current Storage Solutions in the Market
Electrochemical - Batteries;
Mechanical - Compressed air energy storage, Flywheel energy storage or Hydraulic accumulators;
Electrical - Capacitor;
Chemical - Hydrogen fuels cells;
Thermal - Molten salt

Fernando A. Inthamoussou suggested control of super-capacitor if used as a energy storage system for MG [8]. S. Ashok suggested if battery is used as a storage devise, its charging and discharging period has to be considered. SOC can be calculated by

Battery discharging

$$P_{b(t)} = P_{b(t-1)} * (1 - \sigma) - \left(\frac{P_{h(t)}}{\eta i} - P_{l(t)}\right))$$

Battery charging

$$P_{b(t)} = P_{b(t-1)} * (1 - \sigma) - (P_{h(t)} - P_{l(t)}) / \eta b$$

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Where, $P_{b(t-1)}$, $P_{b(t)}$ are battery energy at the beginning and the end of the interval, here it say "t", respectively. $P_{l(t)}$ Load demand at the time "t". $P_{h(t)}$ is the total power generated by renewable sources at time t, σ is self discharge factor and ηb, ηi are battery charging and inverter efficiency respectively.[9]

Total Hybrid Power generated at time 't' is

$$P(t) = \sum_{h=1}^{Nh} P_h + \sum_{w=1}^{Nw} P_w + \sum_{s=1}^{Nh} P_s$$

For the optimization of MG energy management various algorithms were proposed [10-15]. In reference [11], the author clearly stated the model and cost function of each type of DER. GA-based algorithms and game theory is used to obtain the optimal solution. An MRC-GA optimization module was proposed for search optimal generation schedule in reference [12] and particle swarm optimization (PSO) technique was implemented in references [13-14]. A modified dynamic programming method was considered in reference [14], but the author simplified the model by replacing some important stochastic variables with fixed values. Since the development of MG is still in an initial stage, technologies related to the optimal energy management in MG are not matured and numerous researchers have contributed diverse and valuable ideas. In some cases the model consists of the performance of the battery, some researchers used heuristic algorithms to search the optimal solution which is slow and cannot guarantee the accuracy, while some references did not include the battery in their model. The Advanced Dynamic Programming method was first proposed in 1999 by C. R. Dohrmann and R. D.Robinett [15], and later in 2005. This method was discussed in [16], and it is proved to have great results in the optimization of complex dynamic systems. In this model life of the battery is included so as to avoid overuse of battery, extend the battery service life and thus reduce the cost spent on batteries. In some papers only the capital cost of the battery is included, while in some papers the optimization is done only to reduce the fuel cost and satisfy the load demand but the life of battery was neglected. H.Z. Liang and H.B. Gooi have presented unit commitment in MG using genetic algorithm. He worked on optimization of total generating cost, while only MG is in operation.[17] C. Chen S. Duan T. Cai B. Liu G. Hu presented a smart energy management system (SEMS) to optimise the operation of the micro-grid. Their study offers power forecasting module, energy storage system (ESS) management module and optimisation module. A matrix real-coded genetic algorithm (MRC-GA) optimisation module is described to achieve a practical method for load management, including three different operation policies and produces diagrams of the distributed generators and ESS. The conclusion is that the forecasting model is able to predict hourly power generation according to the weather forecasting input. Based on power forecasting, the SEMS is developed using MRC-GA optimisation module to make an optimal operation schedule in such way that economically optimised power dispatch can be maintained to fulfil certain load demand. It is also shown that, the SEMS is beneficial to reduce energy prices for the consumers and the daily costs are reduced by 27.92% below the third policy.[18]. Thair S MAHMOUD, Daryoush HABIBI has suggested utilisation method that makes the storage Devices (SD) more efficient in supplying the electricity within a typical medium size enterprise micro-grid. A fuzzy logic based adaptive charging price is set for charging the SD based on the micro-grid's local generation price at the time of charging, and the amount of the daily SD participation in the micro-grid dispatch. A multi-objective Particle Swarm Optimisation (PSO) method is applied to optimize the energy dispatch to manage micro-grid. The results he obtained are higher amount of SD participation, and higher amount of profit with the proposed system, which reduce the overall generation cost in the managed micro-grid. A future work can be done on the demand response and the ancillary services trade considerations under competitive prices environment to the investigated optimisation method [19]. Bhuvaneswari Ramachandran and Chris S. Edrington suggested multi-agent systems for profitable operation of a Smart Grid in the energy market Fig 1. The trading strategy adopted for the auction process is a profit-maximizing adaptive bidding strategy based on risk and competitive equilibrium price prediction. The auctioneer manages the usage of DERs by receiving bids from buyers and asks from sellers. A hybrid-immune-system-based particle swarm optimization is used to minimize the fuel cost for generation assuming realistic market prices for power, distributed generator bids reflecting realistic operational costs, and load bids customized according to the consumers' priorities. With this method consumer got benefit of reduced energy prices for each type of customer. The consumer have the benefit of reduced energy prices

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Vol. 5, Issue 5, May 2016

during off peak hours in exchange for shedding their low priority loads at peak load conditions [20]. E. Sortomme and El-Sharkawi have suggested the load and generation of two micro-grids

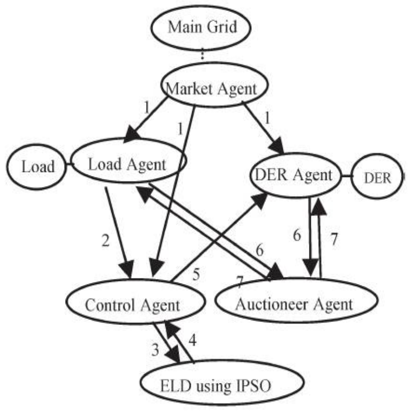

Fig 1.Agent base architecture [20]

with wind farms model to implement optimal power flow (OPF) using particle swarm optimization (PSO). The objectives are to achieve optimal dispatch of controllable loads and generators as well as effectively utilizing the battery storage of each micro-grid. With this costs could be reduced by 14% and the system load peaks could be shaved by over 10 MW [21].

IV. METHODOLOGY

The objective of the system is to minimize the fuel cost, minimize harmful gases, improve energy efficiency by providing reliable and quality power. These goals are subjected to the constraints that the total power supply should be equal to the load demands in each time interval and each DER unit should operate within its minimum and maximum limits. There are different energy management systems (EMS) that give optimized model of the MG system to fulfil the goal. EMS system is Zhou Xue et.al. have explained hybrid control method for whole micro-grid and systematic control design of micro-sources in grid connected mode and islanded mode. Control approach is by Finite hybrid Automata (FTA) for micro-grid system For single micro-grid, different control strategies are used to maintain stable output, such as PQ control, Droop control etc.[21] J.Toyoda et.al discusses the DG grouping in order to harmonize the investment of assets, quality of power supply and the co-operation of the existing power grid [22]. Also he discussed security enhancement of the multiple DGs by harmonized grouping. S.Ashok gave optimized model for energy component for rural community by minimizing the life cycle cost. This model helps in sizing the hybrid energy system.[27] H.M. Khodr and et.al. presents the methodology approach to formulate and solve the problem of determining the optimal resource allocation applied to a real case study in Budapest Tech's.[23] The problem is formulated as a mixed-integer linear programming model (MILP) and solved by a deterministic optimization technique CPLEX-based implemented in General Algebraic Modelling Systems (GAMS). The problem has also been solved by Evolutionary Particle Swarm Optimization (EPSO).[23]

V. POWER SYSTEM (HYBRID)

The hybrid system is complex because of uncertain renewable supplies, load demand, nonlinear characteristics of components. The operation methods and sizing of hybrid system are interdependent. This calls for an optimization of the hybrid system.
Here, the objective function becomes

$$F=f\ (x,u,d)$$

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Vol. 5, Issue 5, May 2016

Where, 'x' is a state variable, i.e. output power of the renewable sources that are considered. 'u' is the control variable, that is excitation current in generator etc, d is the disturbance factor, like wind speed, Solar irradiations, Load demand etc.
Thus the cost function (either capital cost or operating cost) is a non-linear equation, contains state variable, control variable and disturbance variable with equality and inequality constrain, such as maximum and minimum power generation, charging time of battery, constant voltage irrespective of variable load demand, constant frequency, etc. The system can be solved by multi-objective optimization algorithm in multiple probabilistic scenarios.

For example

$F = \sum_{i=1}^{G} C_i * P_i * \Delta T$

Where C_i is the cost of generating power from the ith DG in Rupees per kilowatthour. P_i is the amount of load optimally allotted to the ith DG in kilowatts. ΔT is the duration of the commitment interval in hours and the constraints are

$$\sum_{i=1}^{G} P_i = \text{Lspecified}$$

$$0 \le P_i \le \text{Pispeciifed}$$

L specified is the aggregated demand of the micro-grid in kilowatts. P is specified is the specified power availability from i^{th} DG in kilowatts H.S.V.S Kumar worked on energy management in MG using demand response and distributed storage by Multi-agent approach. He suggested an agent based architecture to embed demand response into micro-grid. In agent based architecture there are

1. Local and generation agents,
2. Micro-grid intelligent agent,
3. Demand response agent,
4. Global intelligent agent.

Market simulation is done for power related commodities in demand interval of different time and it is assumed that the demand and supply remains constant. He has also formed a storage agent, which represents the storage system in the MG [24]. Augusto C. Rueda suggested distributed generators as reactive power provider. He proposed settlement procedure for reactive power market for DGs in distribution system. The generation uncertainty is reduced by running a multi-objective algorithm [25]. He tried to minimize payment of the distribution system operator to DGs for reactive power. In earlier paper, market simulation is done on active power (supply) is considered for calculation. Also voltage profile index is not considered.

VI. RISK MANAGEMENT: EXPECTED ENERGY NOT SERVED

Optimal scheduling for power production, charging/discharging and energy storage in the energy storage devices is done in such a way that, profits are maximised. However, it would not address the possibility of deviation of wind power from the forecast or the irradiation of PV and so on. With forecast uncertainties as high as 40%, it would be very important to assess possible risks in the schedule. A. Dukpa1 I. Duggal2 B. Venkatesh2 L. Chang1 have worked on this and presented a strategy to manage the risk if expected energy is not served. Risk in the participation strategy is quantified by computing expected energy not served (EENS). The multi-objective mixed integer linear programming formulation is transformed into a fuzzy optimisation. The optimal participation strategy has two objectives: a) maximise profits from sale of energy into the market and (b) Minimise risks due to uncertainty by minimising EENS. With best forecast constraints and Energy deficit forecast constraints.[26]

VII. CONCLUSION

From the serve I came to this conclusion that there is future scope in load automation by integrating demand response and demand side management get efficient use of energy or reliability of the non-dispatchable energy sources. Hence the and Challenges And Approach are

1 .Design:
- To make the system predictable (non deterministic approach) and affordable
- Novel storage design and its integration with the system

2. Monitor:
- To know the system that manages the system.
- System performance monitoring
- Renewable energy demand forecasting

3. Manage:
- Optimization of the integrated system
- Network system optimization
- Demand response management

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