Optimal Scheduling of Microgrid Using GAMS

Indurekha Shial and Rajat Kanti Samal

Abstract In a power supply system, a wide range of optimization problems exist where different processes are involved. Economic dispatch is an important optimization task in a power system. The information transparency and security of microgrid systems improve by microgrid economic dispatch. It also makes the power grid a very clear, safe, efficient, and reliable development path. Here this paper explains the solution to the economic dispatch problem for the different generating units including both conventional and non-conventional sources in a microgrid using the General Algebraic Modeling System (GAMS). The main purpose of this paper is to optimize the problem and minimize the total power generation cost. The scheduling problem is solved by using GAMS from which the total cost is found to be 119$ at 2.84 MW load.

Keywords GAMS · Microgrid · Renewable sources · Optimal scheduling

1 Introduction

In the power system for power generation, Distributed Generators (DG) are classified into two types dispatchable generators and non-dispatchable generators. Optimal Scheduling of dispatchable generators is a key to the operation of any microgrid economically. Microgrid is suitable and provides an optimal solution toward the electrification of small and isolated village areas in many developed countries. Recently, the concept of microgrid (MG) has been introduced in the distribution network. Microgrid is known as a small network of a synchronized power provider which is customer-controlled from a control center the small fraction of overall required demand and sometimes the overall load demand for a small distribution system during failure of main grid. A microgrid can joined with the main grid, in which they are connected to the main electrical grid or in an island mode, where they are disconnected from the main power grid and the minor scale generators (biomass,

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geothermal, wind, and solar) which are the only source of power generation. In this document, there is an idea to realize a simple network consisting of thermal generator, biomass, geo-thermal, wind, solar, and battery system in a microgrid, in spite of the fact that the upcoming focus is to unify the renewable generations and storage. Currently, it is focused in the case at which there is no generation from both renewable sources of generators and storages. There are many optimal scheduling problems which are presented and solved by methods: General Algebraic Modeling System (GAMS) and Genetic Algorithm (GA). The inputs to the microgrid central controller are scheduling and generator set point results. Here, the optimal cost might aid to justify as equipment in the installation of automation in the local load when multiple small size generators are used for supply; then it gives many advantages like increased reliability, improved operation efficiency, high availability, and maintainability [6]. Due to the use of multiple generators in a microgrid, complexity and cost increase, which gives difficulty in maintaining all generators at the same terminal voltage, phase angle, and frequency. In standalone microgrids when both voltage and frequency are regulated, then all DGs are suitably interfaced to the microgrid by means of either a traditional breaker or by use of a power electronics converter. In a microgrid, this does not consider the realization individually when the diesel generators are operated in isolated area. In the field of microgrid optimization, a large number of research topics focus on optimization. To be exact, appropriated power generation scheduling problems are usually non-convex, non-linear multi-objective optimization problems. For traditional optimization algorithms, it is very difficult. Most optimization algorithms include the particle swarm optimization (PSO), convex optimization, Genetic Algorithm (GA), and Ant Colony Optimization algorithm which have different optimization effects in different fields. Highly complex nonlinear problems can be optimized by using GAMS. In microgrids, an optimal scheduling of generation as a mixed-integer second order cone programming problem has been solved by GAMS software [4]. Here electric vehicles and demand response are modeled where by smoothing the load profile and reducing the cost of power purchases from the main grid, the total operating cost reduced. Using differential evolution (DE) algorithm, a renewable energy source of microgrid is optimized and minimizez the cost [5]. Here DE algorithm is based on energy management system and also is compared with particle swarm optimization (PSO) algorithm. A multi-microgrid structure is integrated with power-to-X technologies optimized by robust decentralized optimization method [2]. A microgrid consisting of a fuel cell, photovoltaic(PV) cell, wind turbine, and storage system is used for optimal operation and supervision by using the stochastic optimization method [1]. The main purpose of this paper is to find out problem uncertainty. A novel stochastic framework based on the UT method is also used in some papers to model the uncertainty effects in the optimal solution of power generation in the renewable sources of energy of microgrids. In paper [7] according to power converter rule, the microgrid formed by the control techniques of the power converters is presented. Here we presented different droop control schemes for inductive, resistive, and generic lines. The hierarchical control structure on microgrids also presented for optimizing efficiency and performances, due to which here also the generation cost is reduced. In [8], a comparative analysis study of Quadratic Programming (QP) and GAMS approach is used to solve the ELD problem which is dynamic. In this power system, the transmission losses are considered. In [9], a multi-energy microgrids system, i.e. water energy microgrid is considered a combined scheduling model for the best dispatch of simulating, heating, power gas, and water sources. Here the problematic optimization model is accepted to reduce the total cost including working and emission costs and also reduced the volume of fresh water which is extracted from underground reservoirs. A multi-purpose optimal dispatching model is proposed by the paper [10] where the power generation is distributed in the microgrid. Here the grid-connected mode combines both the environmental benefits and operating cost. The paper [11] presents the solution of the economic load dispatch problems by using general algebraic modeling system (GAMS) and Quadratic Programming (QP). Both methods are proposed for optimizing the problem. In [12], both Genetic Algorithm (GA) and General Algebraic Modeling System (GAMS) are applied to reduce the cost of power generation and emission. It depends on high and volatile diesel prices. Here only diesel generators are used in this microgrid as dispatchable sources. The economics of the system depends on the cost/kwh of electricity supplied on that system. In [14], the microgrid consisting of wind and solar energy sources is considered for analyzing the dispatch rate of power. Due to the use of renewable energy sources, the microgrid reduces total generation cost of the system. To reduce the generation of cost, the most used method is optimal scheduling method. Different algorithms are used to solve the problem to find the best solutions. The operating cost of different endless energy sources like biomass, solar photovoltaic cells, wind power, and fuel cells are very less in comparison to conventional sources. In paper [15] for design and development of the microgrid system, renewable energy sources are used to analyze the cost. In [17], Artificial Fish Swarm Algorithm is used in a microgrid consisting of windmills, solar PV, and CHP. For a DC microgrid formed by wind, PV solar, battery, and load some energy management and control strategies are used to optimize the operation of that microgrid. In the linear programming model, a bi-level mixed-integer is used to present the optimal scheduling of the network where the system is distributed [19]. Microgrids and smart homes are considered in this network; more use of Distributed Energy Sources (DERs) in that network reduced the total operating cost and also increased social welfare and consumer comfort index due to the bi-level method. A centralized energy management system is designed for microgrids in stand-alone mode [21]. In paper [22] like GAMS software, a sufficient stochastic framework is also used to model the correlated uncertainties in the microgrid which includes the renewable energy sources. The main contribution of the paper is to find the result by optimizing the scheduling problem in microgrid using GAMS.

2 Problem Formulation

2.1 Formulation for Microgrid System

A microgrid is a very small system where the electric power incorporates generation, transmission, and distribution. It can attain the power equilibrium and allocation of optimal energy over a given field or as an effective source of power or in the network where the load is distributed. A microgrid is a self-contained grid where it uses thermal generators, battery system, and renewable energy sources for power generation. A microgrid can work independently. A microgrid may be grid connected or islanded mode. In the grid connected mode, the microgrid is connected to the distributed system where it exchanges power with a utility grid. In the islanded mode, the microgrid itself is generally small and sufficient to arrange the demand of all loads; it is required to catagorize loads based on their significance and ensure continuous supply to important loads. The main benefit of a microgrid is that it can operate in standalone mode or the main grid disconnection mode. Microgrid has reduced in cost due to the use of renewable energy sources. The structure of the microgrid test system considered is shown in Fig. 1. For a thermal generator, the overall fuel minimization cost function considering valve point loading of the generating unit is given as

$$\texttt{Minimize}\ \ F_i = \sum_{i=1}^{10} a_i + b_i P_i + c_i P_i^2 + |d_i sin\left(e_i(P_i^{min} - P_i)\right)^2| \tag{1}$$

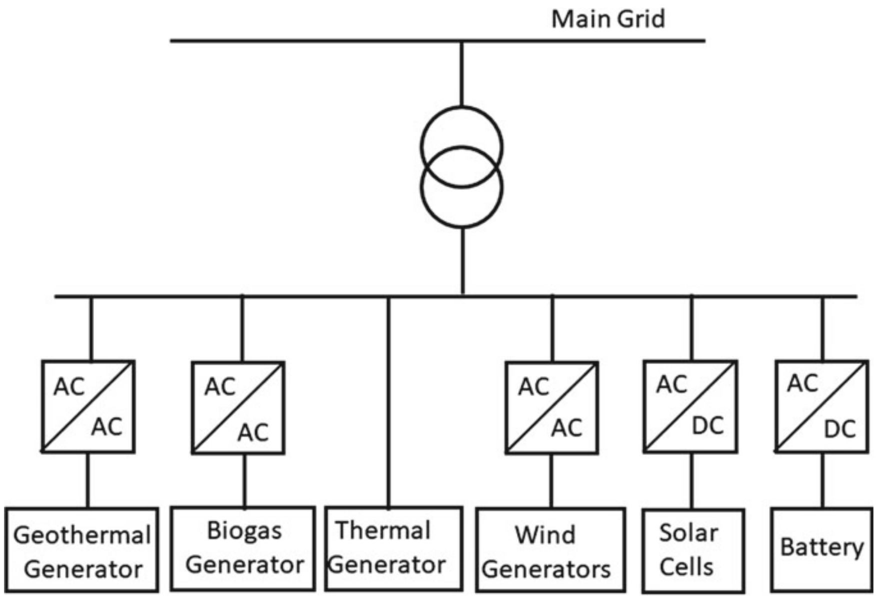

Fig. 1 Microgrid structure

Here, F in (\$/h) is the cost function. The real power output of the ith generator is denoted by P_i while a_i, b_i, and c_i are the cost curve coefficient. Biomass energy is a highly available energy that reduces waste and is of very low cost, but it requires a very large area to operate and store. Approximately 86 percent of modern bio energy is used for heating applications, 9 percent for transport, and rest 5 percent is used for electricity. For biomass generator, the cost function is given as

$$\texttt{Minimize}\ \ F_i = d_i P_i + e_i P_i \tag{2}$$

Geothermal energy is an exceptionally constant source of energy, with practically no emission, high efficiency, and high investment cost than other renewable sources. It is a natural heat derived from the interior of the earth which is used to generate electric power supply. The study and exploration of GE started in India in 1970. Currently, in 26 countries geothermal electricity generation is used and in 70 countries geothermal heating is used. For geothermal generators, the cost function of the microgrid is given as

$$\texttt{Minimize}\ \ F_i = \left(\frac{h}{u} + k_i\right) P_i \tag{3}$$

Wind energy is a reliable and infinite renewable energy source. The wind is a consequence of solar energy that is around 2% of the energy of the sun reaching the earth is converted into wind energy. The wind energy installed capacity was 41.93 GW, but recently its generation capacity in India has increased. Like other RE sources, a linear cost function used for the wind power is expressed as

$$\texttt{Minimize}\ \ F_i = w_i P_i \tag{4}$$

Solar energy can be used for diverse purposes like electricity (photovoltaic cells) or heat (solar thermal). Photovoltaic (PV) cell is one of the most popular renewable energies. Recently, India stands in the fourth position across the globe in solar PV deployment. The installed capacity of solar power has reached around 61.97 GW. A linear cost function that is used for solar PV power is expressed as

$$\texttt{Minimize}\ \ F_i = v_i P_i \tag{5}$$

For battery systems, the linear cost function is the same as solar PV power. In an electric grid, the battery energy storage system is the fastest responding source. The electric battery is provided to power electrical devices like electrical car and smart phones.

Among all the generators, the thermal generator has a non-linear cost function which makes the whole scheduling problem non-linear in nature. So while choosing the solver for the problem, we have to describe the model as non-linear.

2.2 *General Algebraic Modeling System (GAMS) Section to Solution Methodology*

GAMS is a high-level powerful mathematical optimization model. It is used for modeling the different types of complex, linear, non-linear, mixed-integer type problems and mixed complementary problems also. Specially GAMs handles large complex problems. It requires more revision to get an accurate model by using other software. Using the same GAMs model file, the models can be developed, documented, and solved simultaneously. GAMs can handle different optimization problems (linear and non-linear) simultaneously. To represent new ideas, GAMs language offers sufficient flexibility. The model statement first collects the equations and makes a group, then levels them to solve. The model is shown in Fig. 2.

Modeling languages of GAMS have a syntax that is generally sets, variables, equations, model statements, and output. The data is very important for modeling. After collecting data as per the procedure of GAMS, it declares the variables and then declares the equations. To code the basic structure of a mathematical model, there is a solution procedure of GAMS. Different components of GAMS are sets, data, variables, equations, model, and output explained below.

GAMS Formulation follows the basic format as given below

- Sets: Declaration, Assignment of members;
- Data (Parameters, tables, Scalars): Declaration, Assignment of values;
- Variables: Declaration, Assignment of types, Assignment of bounds and/or initial values (optional);
- Equations: Declaration, Definition;
- Model and Solve Statements;
- Display Statements (optional).

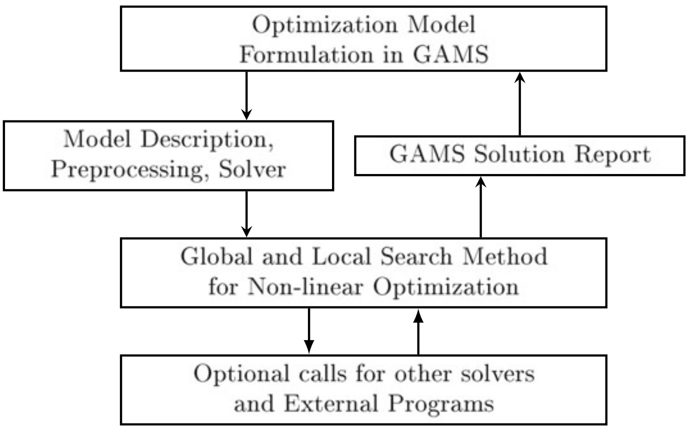

Fig. 2 Solution methodology

3 Results and Discussion

A microgrid test system is considered which contains various generators. Here Table 1 shows the system parameters [23]. After solving the scheduling problem in GAMS, the obtained results are shown in Table 2. The individual generation of each generator for different demands is given in Table 3.

So from the above results by applying GAMS to a six generators microgrid scheduling including thermal generator, biomass generator, geothermal generator, wind generator, solar cell and battery system; the total cost is found to be 119.855

Table 1 System parameters of microgrid

Type of generator	Values of parameter	Type of cost function	Rated capacity in MW
Thermal	a = 10	Non-linear	1.0
	b = 200		
	c = 100		
	t = 33		
	v = 0.0714		
Biogas	d = 180.39	Linear	0.8
	e = 0.56		
Geothermal	u = 58.6	Linear	0.9
	h = 332		
	k = 28.3		
Wind	w = 3.25	Linear	0.8
Solar	v = 3.5	Linear	0.8
Battery	v = 3.45	Linear	0.9

Table 2 Results of microgrid

Load in MW	Cost in $
2.834	119.855
4.834	416.147

Table 3 Individual generation of microgrid

Generator no	Load = 2.834 MW	Load = 4.834 MW
G1	0	0.634
G2	0	0.800
G3	0.334	0.900
G4	0.800	0.800
G5	0.800	0.800
G6	0.900	0.900

$ at 2.834 MW load and 416.147 $ at 4.834 MW load, respectively. Here CPLEX solver is used to solve the scheduling problem. It is observed that for thermal generator and biomass generator at the first case of load demand the microgrid system is not operated, but when the load demand increases then the system starts operating. So it has been found that the microgrid has minimum cost and emission also due to the presence of more number of renewable energy sources. Here, the cost function of the thermal generator is taken as non-linear type at 1.0 MW rated capacity where the cost function of other generation sources that is biogas, geothermal, wind, solar cells, battery system for rated capacity of 0.8 MW, 0.9 MW, 0.8 MW, 0.8 MW, 0.9 MW, respectively. In this microgrid individually, the generations are 0 MW, 0 MW, 0.334 MW, 0.800 MW, 0.800 MW, and 0.900 MW at minimum load 2.834 MW of thermal generator, biomass generator, geothermal generator, wind generator, solar cells, and battery system, respectively. Similarly for those above sources at maximum load 4.834 MW the individual generations are 0.634 MW, 0.800 MW, 0.900 MW, 0.800 MW, 0.800 MW, and 0.900 MW, respectively.

4 Conclusion and Future Scope

In this work, a microgrid system having different generating sources like thermal generator, biomass generator, geothermal generator, wind generator, solar cells, and battery system is optimized for economic scheduling of meeting load demand by implementing the GAMS software. Results of this microgrid system are shown in the above tables. From this above work, it is clear that total cost and emission can be reduced using renewable energy sources in a microgrid system on existing grid. It is also clear that to reduce emission and the increasing environment degradation, the use of clean energy is the only way. Renewable energy source is the clean source which can reduce the overall stress on existing grid. In this six generators microgrid system more reduction in cost and emission can be achieved by using mini hydropower plants in place of thermal turbine generation unit, but it requires more efficient storage capacity battery, also more optimized cost reduction and improvement in energy efficiency can be achieved by including additional electric vehicle in the above microgrid system.

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