

A Resilient and Optimal Microgrid Scheduling Portfolio in Linear Programming Platform

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Abstract

In recent year, alarming rate of natural disasters around the world have demanded the need for operative solution in field of power generation, to control polluted energy sources which are major cause of global warming. Microgrid facilitates penetration of renewable energy sources into the existing distribution systems to reduce the overall carbon footprint of the globe by reducing the dependency on the main grid. Efficient but linear microgrid resource scheduling algorithms are gaining interest in present time due to its simplicity and fast computation. This research paper aims to serve the purposes by designing a mixed integer linear programming based microgrid scheduling problem while various types of scenario, minimize the electricity cost for the utilities also maintain the generation and load balance. The strategy is implemented on a small microgrid to prove its efficacy. In this paper mainly optimal scheduling of microgrid has been done in various scenario, and obtained there global minimum electricity cost to the help of mixed integer linear programming (MILP) algorithm. Microgrid is a small scale type of power grid, which provides the energy locally, its offers integration between distributed energy resources and the locally connected loads. Microgrid able to be operated with the main grid and in standalone mode also ability to transitions between these two modes, the mode of operation of microgrid is depends on the system operating condition. The reliability of power grid is improving more when it's integrated with the Microgrid and works together. Power exchange with the upper stream grid is done through the point of common coupling (PCC). Microgrid having renewable energy resources i.e. PV, Wind and non-renewable energy resources, DG, FC, and MC connected with the Battery storage type system and locally connected loads. So it is a very reliable scenario, main grid with the microgrid, it is more beneficial, economy and stable types of system.

Keywords: Optimal Microgrid Scheduling, Linear Programming

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1 Introduction

The microgrid is a combination of different types of energy sources, such as PV, Wind, Battery storage system, Diesel generator, Fuel cell etc. In all of this some resources are non- dispatchable energy sources and remaining has dispatchable energy sources. In this chapter we have done optimization the generating power from various resources of microgrid to meet the minimum generation cost as well as maintain the local demand also. The scheduling of microgrid is performed by the microgrid master controller (MGMC) in grid connected and islanded modes, based on reliability, security and economic considerations. As such a microgrid is used for the basically reliability point of view and when the main grid power may be disconnected, its provide the power user locally and fulfil the power requirement of demand side. We know very well the PV and the wind plant are

non-dispatchable type of power resources, because it depends on the environment constraints, but they provide the power in free of cost, there are no any generation cost required for the PV and Wind plants. Diesel generator is treating as a thermal generator in microgrid, so we can easily done the scheduling of this for the minimum generation cost. Main grid is connected to the microgrid to using the point of common coupling (PCC), so the microgrid is easily disconnected from the main grid in faulty condition. If any fault and disturbance occur in main grid, so easily interrupt the microgrid, and provide the energy for the local demanding loads and maintain the reliability. In this paper we have done the optimal scheduling in various scenarios and discuss the results also.

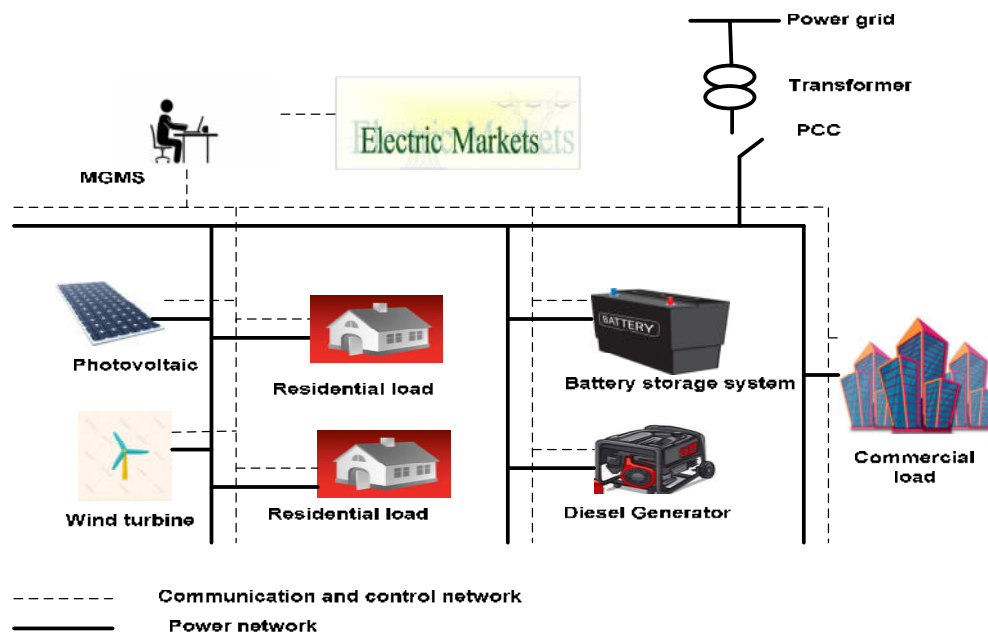


Fig no 1 Architecture of Microgrid

Literature Review

The optimal power flow solution for distribution networks with DG, considering the uncertainty based on different objectives and method reporting in the literature. The main objective of this paper is to minimize the operation cost of the microgrid using available generation resources, energy storage system, loads and the main grid power, subject to prevailing operational constraints [1]. This paper presents the results of numerical case study, Battery optimal sizing, its impact and reliability. As a function of its cost of installation and amount of data centre demand is determined [2]. In this study two control strategies involving continuous and on/off operation of the diesel generator in the PV-Wind- Diesel-Battery hybrid systems are optimized using the mixed integer linear programming [3]. The objective is to minimise the total operation cost, including generation cost, and spinning reserve cost of load resources as well as purchasing cost of energy from main grid [4]. The main aim of this paper is to minimize the economic cost of a microgrid by jointly scheduling various devices, e.g. appliances, batteries, thermal generators, and wind turbine [5]. Optimal power flow in microgrid using mixed integer linear programming [6] the trust – region sequential quadratic programming method is proposed for the optimal power flow in distribution line with the integration of DG, the objective is to minimize line losses,

voltage deviation and maximize the DG active power [7]. Minimization losses and loss payment using MINLP algorithm considering the uncertainty in energy market [8]. MINLP- based optimization has been done to obtain the minimization of fuel cost of DG sources as well as minimization the line loss, in this paper presents mixed integer nonlinear approach for determining optimal location and number of distributed generators in hybrid electricity market, for optimal location of distributed generation, in this paper the interfacing of MATLAB and GAMS are shown also [9]. Optimized the linear power- flow equation using mixed – integer quadratic programming (MIQP) [10]. MINLP algorithm is used for Stochastic bidding strategy of microgrid in a joint day ahead market and manages the uncertainty of renewable DG [12]. To use the direct method minimize the fuel cost of DG during the grid connected operation, and to achieve the minimum cost of goal in various cases with many constraints i.e. reverse for variation in load, reverse for variation in the power outputs of non- dispatchable DGs, flow limits between two adjacent areas, and reverse for the stable islanded operations [13]. In this paper proposed a comprehensive BES sizing model for microgrid applications which takes these critical factors into account when solving the microgrid expansion problem and accordingly returns the optimal BES size, technology, number, and maximum depth of discharge. The microgrid expansion problem is formulated using mixed integer linear programming [14]. Optimal Integration of distributed energy storage devices in smart grids [15]. Probabilistic load flow for uncertain parameters using Point Estimate Method, in this paper the uncertain parameter of bus injections and line parameters can be estimated and measured. This paper shows how to estimate the corresponding uncertainty in load flow solution [16]. Optimization the energy storage system, minimization the battery operating cost, maintain the uncertainty in electrical price using Conditional Value- at- Risk method [17]. Probabilistic model of determine the optimal transmission line expansion using mixed integer linear programming also maintain the uncertainty in demand power, wind power generation and energy price using point estimate method, here the bender decomposition approach and the point estimation method are used to solve the developed mixed – integer optimization problem and track the uncertainty respectively [18]. Reconfiguration of distribution network for the loss minimization with using the mixed – Integer Convex algorithm.[20]. Reconductoring in radial distribution network using Mixed –Integer Linear Programming [21]. Reconfiguration of distribution network at presence of Distributed generation using Harmony Search algorithm.[22] Fast reconfiguration of distribution system using mixed- integer nonlinear problem [23]. Heuristic optimization approach for reconfiguration of distribution network [24]. Sizing of energy storage for microgrids[25]. Stochastic energy scheduling in microgrid with intermittent renewable energy resources [26].

Components of microgrid

The main contents of microgrid are renewable and non-renewable type of energy resources, with the energy storage system and connected loads. The brief introduction of PV, Wind, diesel generator and battery storage system are given in this Chapter as seen:

(a) Diesel Generator

In modern power system the diesel generator is used mostly, it is the combine model of electric generator and diesel engine. The design of diesel engine is very properly and high efficient, to be operated in power system. Diesel generator has been used to similar of thermal power plant in microgrid, its having a convex type of cost characteristics. The main fuel of diesel generator is diesel, it is dispatchable type of power generating unit having

minimum start up and shut down time. If the diesel generator is run with the high load factor, the fuel consumption should be less so that the benefit for the economy as well as the life of diesel generator also improved. DGs also shows quadratic input-output characteristic, as expressed below,

$$F_g(P_{g,t}) = C_{diesel} (aP_{g,t}^2 + bP_{g,t} + c)Rs./hr, \forall_{g,t} \quad 1$$

Where, C_{diesel} is the cost of diesel in Rs./lit. a, b and c are the characteristic coefficients of DGs. The above quadratic cost function is linearized as follows,

$$F_g(P_{g,t}) = F_g(P_{g,min}) + C_{diesel} [\sum_{m \in M} S_{m,g,t} P_{m,g,t}] \quad 2$$

Where, M is the total number of linearized segments and S is the slope of the linear segment. Therefore, the operation cost of the g^{th} DG at time t is given by,

$$C_{g,t} = u_{g,t}F_g(P_{g,t}) + SU_{g,t} + SD_{g,t} \quad 3$$

Where, $SU_{g,t}$ and $SD_{g,t}$ are the start up and shut down cost of the DG. These can be expressed as follows,

$$SU_{g,t} = C_g^{SU} \max(u_{g,t} - u_{g,t-1}, 0) \quad 4$$

$$SD_{g,t} = C_g^{SD} \max(u_{g,t-1} - u_{g,t}, 0) \quad 5$$

Now it can be observed from equations (1)-(3), that the expression regarding operation cost of DG is non-linear in nature due to presence of multiplication of binary variable and continuous variable in the first term of (3), and utilization of “max” function for determining the start-up/shut-down costs. The above non-linearities can be omitted by assigning auxiliary variables as shown below-

Let, the auxiliary variables are defined as,

$$y_{m,g,t} = u_{g,t}(P_{m,g,t}) \quad 6$$

$$Z_{g,t} = u_{g,t} - u_{g,t-1} \quad 7$$

$$V_{g,t} = u_{g,t-1} - u_{g,t} \quad 8$$

Therefore, the operation cost of the DG is given by,

$$C_{g,t} = u_{g,t}F_g(P_{g,min}) + C_{diesel} [\sum_{m \in M} S_{m,g,t} Y_{m,g,t}] + C_g^{SU} Z_{g,t} + C_g^{SD} V_{g,t} \quad 9$$

The following constraints (6) to (8) are added to balance the optimization process.

$$P_{m,g,t} - Q(1 - u_{g,t}) \leq y_{m,g,t} \leq P_{m,g,t} + Q(1 - u_{g,t}), \quad \forall_{m,g,t} \quad 10$$

$$-Qu_{g,t} \leq Y_{m,g,t} \leq Qu_{g,t}, \quad \forall_{m,g,t} \quad 11$$

$$Z_{g,t} \geq 0 \text{ and } V_{g,t} \geq 0$$

12

Where, Q is large positive number. Equation (10) says that if $u_{g,t}$ is equal to zero then the constraint (6) will be relaxed. On the other hand, if $u_{g,t} = 1$, then (6) shows that $y_{m,g,t} = P_{m,g,t}$. Therefore, the fuel cost non-linearity has been linearized appropriately. Again, positive values of $z_{g,t}$ and $v_{g,t}$ ensure that start-up and shut-down cost only present if $u_{g,t} \geq u_{g,t-1}$ and $u_{g,t-1} \geq u_{g,t}$ respectively. Hence, non-linearity associated with “max” function no longer exists.

Apart from the previous constraints, diesel generators also have operational constraints regarding the generation limit, minimum up/down time as formulated below,

$$P_g^{min} \leq P_{g,t} \leq P_g^{max} \quad 13$$

$$X_{g,t}^{ON} \geq T_g^{ON} \quad 14$$

$$X_{g,t}^{OFF} \geq T_g^{OFF} \quad 15$$

$$P_{g,t} - P_{g,t-1} \leq RU_g \text{ and } P_{g,t-1} - P_{g,t} \leq RD_g, \forall m,g,t \quad 16$$

Equation (13) says that DG generation is bounded by its minimum and maximum capacity limits. Expression (14)-(15) defines the minimum up/down time constraints. Ramp up/down capability of the DG unit is shown in equation (16).

(b) PV System

The PV cell works on the principle of PV effect, in PV system the cells are made by the gallium arsenide, silicon or cadmium sulphide. When the solar radiation strikes on the PV cell, an electric current is flow, through the connected circuit and the power has been generated. The main purpose of photovoltaic panels is to generate power from the sunlight. The generated solar power depends on mainly two variable quantities- ambient temperature and amount of solar irradiation absorbed by the panel. For PV system, the authors assume that the panel is always tuned to track the maximum power point. Therefore, the maximum solar generation at time t is given by [25],

$$P_t^{PV} = \eta_{PV} A I_t (1 - 0.005(T_t^{amb} - 25)) \quad 17$$

Where, η_{pv} , A , I_t and T_t^{amb} are efficiency of solar panel (%), array area (m^2), solar irradiation (kW/m^2) and ambient temperature ($^{\circ}C$) respectively.

(c) Wind energy system

The power generation in wind energy system is depends upon the velocity of air flow. The wind systems are first to converts the kinetic energy of wind into the mechanical energy than convert into the electrical energy. The generated wind power equation are shown below[6],

$$P_{wt} = \frac{1}{2} \times \rho_a \times A_{wt} \times C_{p,wt} \times \eta_{wt} \times \int_{t_0}^t (V_a^3(t))dt \quad 18$$

where ρ_a = is the air of water ($1225\text{kg}/\text{m}^3$)

$C_{p,w}$ = is the coefficient of the wind turbine performance

η_{wt} = combine efficiency of the generator and wind turbine

A_{wt} = Swept area of wind turbine in m^2

V_a = Velocity of wind in m/s

(d) Battery storage system

Battery storages are installed to manage the variability and vulnerability of the solar power generation. Battery units are modelled as variable load and variable energy supplier depending on the operation mode of the battery. The dynamics of battery storage system is determined by the SOC (State of charge). The operating constraints are summarized below,

$$SOC_{b,t} = SOC_{b,t}^{ini}, t = 1 \quad 19$$

$$SOC_{b,t} = SOC_{(t+1)} - SOC_{(t)} + \left(t_s * \left(\frac{\eta_{bat}}{E_{norm}} \right) * P_{bat,t} \right) \Delta t, t > 1 \quad 20$$

$$SOC_{b,t(min)} \leq SOC_{b,t} \leq SOC_{b,t(max)}, \forall t, b \quad 21$$

$$P_{bat,t(min)} \leq P_{bat,t} \leq P_{bat,t(max)}, \forall t, b \quad 22$$

$SOC_{(t)}$ – State of charge

η_{bat} – Efficiency of battery

E_{norm} – Rated power of battery in kwh

P_{bat} – optimizing power of battery at a given time

Equation (19)-(20) determines the energy stored inside the battery at each time interval t . Equation (21) to (22) ensure that stored energy, charging and discharging power should be within limit.

2.2 Scheduling of microgrid

The optimal scheduling of all microgrid resources is the most challenging but unavoidable task, The obstacles faced by the microgrid operators to design an efficient scheduling algorithm are as Microgrid components and power network exhibit non-linear behaviors and therefore, most of the existing scheduling algorithms are of non-linear type, which has higher computation time and also cannot guarantee about the global optimal solution. Moreover, presence of binary variables in the formulation makes the non-linear method much more complex in nature. So all this problem having in the non-linear system, in this work the optimal scheduling of microgrid had been done to use of linear formulation, because of it global minimum optimal solution, if the scheduling of microgrid has been done with the help of linear formulation, its gives most feasible solution, and minimum cost

of electricity, in case of microgrid the scheduling is a big task due to its non-renewable and renewable type of energy sources, but in case of MILP we have done the optimal scheduling of microgrid, with low computation and feasible solution also, it is a efficient method for the scheduling of microgrid.

2.3 Scheduling algorithm

Microgrid scheduling problems are mainly formulated in mixed integer linear programming platform for its easy execution. MILP also guarantees global optimal solution to the scheduling process. In MILP, the concerned objective is either minimized or maximized while satisfying the constraints. The objective function and the constraints are composed of continuous, integer and binary variables. Presence of any non-linearity in the objective functions and constraints should be linearized first before moving towards the final solution process.

In this work, MILP algorithm has been used for the optimal scheduling of microgrid in various scenarios. The MILP known as mixed integer linear programming, it is a type of optimization method, in this work Mixed integer linear program (MILP) are used for the optimization of generating power and minimization of overall cost of generating power. In the MILP formulation considered the objective function those are minimize or maximize, equality and inequality constraints as well as lower and upper bound of variables. The objective function is the combination of mixed variables such as continuous, integer and binary, they are also called the decision variables, and solved with the subjects to various constraints. The MILP have different types of optimization algorithm, but in this work the branch and bound type of method is used for the optimization. In this method the upper and lower bound of the variables are set before the optimization, than with the help of equality and inequality constraints, the main objective will be found. It is a simple formulation type of method so that used in this work. The generalized MILP model is of the form-

Min $f(x)$ subject to. x are integer

$$Ax \leq b \quad (\text{used for inequality constraints}) \quad 23$$

$$Aeqx = beq \quad (\text{used for the equality constraints}) \quad 24$$

$$lb \leq x \leq ub \quad (\text{this is used for bound fixation}) \quad 25$$

MILP basically used for its feasible solution, revised formulation and also is a global optimization algorithm technique. In this work taken the linear equation for the scheduling, because if the non-linear equations are used so that never reach the global optimal point as well as computation time is so long in case of non-linear optimization algorithm. Here we have used logical variables also, in case of non-linear it is typical to solve.

In the mixed integer linear programming we can handle the all types of variables and constraints easily, so that in this work MILP optimization had been done.

2.4 Objectives of the work

The main objective of this work is optimal scheduling of microgrid in various scenarios, also the analysis the role of distributed generator of microgrid in various situations arises in power system. Such as standalone operation of microgrid and contribution of microgrid when it is connected to the main grid.

Here we also see that, if the main grid disconnected by the microgrid due to some reason, so how to microgrid provide the supply to the locally connected load, its having self healing properties as well as reliability also improved and the availability is power should be maintained.

2.5 System Model

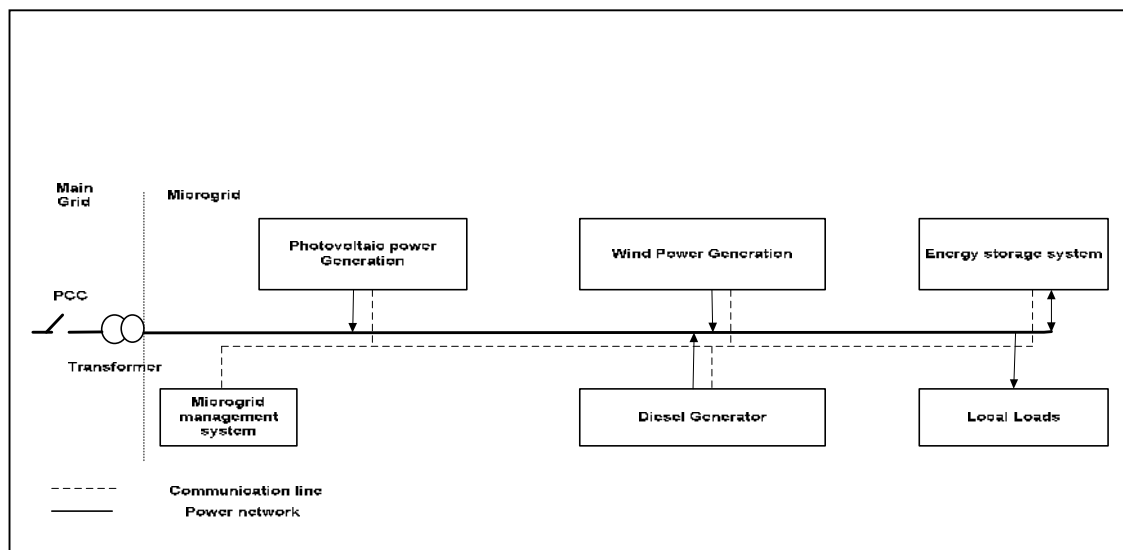


Fig 2 System architecture of microgrid

In the system model, there are a microgrid contain with resources of power generation such as PV, Wind, Diesel Generator and ESS (Energy storage system). Here microgrid is connected to the main grid by PCC(Point of common coupling), if the microgrid is connected to the main grid, it's called the grid connected mode of operation, if the microgrid operated as disconnected from the main grid this is called standalone mode or islanded mode. If the main grid becomes faulted due to any reason, microgrid provide the power to locally connected load also maintain the reliability of electrical supply system.

3 PROBLEM FORMULATION

3.1 Objective function

The objective of the proposed microgrid scheduling process is to minimize the total electricity cost. Therefore, the objective function is given by

$$\text{Min}C_T = C_{grid,t} + C_{MG,t} (1 \leq t \leq N) \quad 26$$

The first term of the equation (26) represents the cost of power taken from main grid and the second term defines the microgrid operation cost, microgrid operation cost includes the operation cost of the dispatchable diesel generators and the grid cost includes the cost of power transfer from the upper grid. This is expressed as follows,

$$C_{MG} = \sum_{t \in T} \sum_{g \in DG} (F_g(P_{g,t}) \cdot u_{g,t} + SU_{g,t} + SD_{g,t}) \quad 27$$

$$C_{grid} = \sum_{t \in T} \rho_t^{grid} P_t^{grid} \quad 28$$

The first term in (27) signifies the fuel cost, than start up and shut down cost of the diesel generator. The cost of power transfer from the upper grid is represented in (28), This can be positive or negative. The negative cost, which signifies a power injection back to the main grid, appears as an earning to the microgrid.

4.2 Constraints

The different types of equality and inequality constraints are used in the optimal scheduling of microgrid in various scenarios. Here mainly two types of equality constraints are use they are given below

(a) Power balance equation

Power balance equation is a equality type of constraint. At any time interval, the sum of the supplied powers from PV, WT, diesel generator, ESS and main grid must be equal to the connected load in microgrid. This can be expressed as

$$P_t^{PV} + P_t^{WT} + P_t^{DG} + P_t^{bat} + P_t^{grid} = P_t^{load} \quad 29$$

P_t^{DG} – Supplied power from diesel generator at a given time

P_t^{bat} - Supplied power from ESS

P_t^{PV} - Supplied power from PV

P_t^{WT} - Supplied power from Wind

P_t^{grid} – Supplied power from main grid

P_t^{load} - Connected load of microgrid

This is the power balance equation used as a equality constraints, other constraints are given in Chapter 2, that is the equation (21), it is useful for the battery power, and it is provide the information of positive and negative power from battery, this is known as charging and discharging power.

(b) Variables limits

The energy resources are modelled as variable power sources controllable in the range of their minimum and maximum rated value. For the different load profile of 24 hours they supplied the different amount of power depends upon its rating. Therefore, the variable limits are the output limits of these different power sources as well as of the battery storage system at any time. The upper and lower bound defining the various components of microgrid.

$$P_{t(min)}^{DG} \leq P_t^{DG} \leq P_{t(max)}^{DG} \quad 30$$

$$P_{t(min)}^{bat} \leq P_t^{bat} \leq P_{t(max)}^{bat} \quad 31$$

$$0 \leq P_t^{PV} \leq P_{t(max)}^{PV} \quad 32$$

$$0 \leq P_t^{WT} \leq P_{t(max)}^{WT} \quad 33$$

$$SOC_{t(min)}^{bat} \leq SOC_t^{bat} \leq SOC_{t(max)}^{bat} \quad 34$$

$$P_{t(min)}^{grid} \leq P_t^{grid} \leq P_{t(max)}^{grid}$$

35

The above proposed scheduling of microgrid, required all the variables limits given in equation (30) – (35). That is shown the upper and lower limits of various components of microgrid, this is necessary for the optimal scheduling of microgrid.

4.3 Algorithm:-

Step1:- Take the input data of the microgrid grid parameters, such as loads, rating of battery

Step2:- Generate the unknown variables and logical variables.

Step3:- Set the lower and upper bound of generated variables.

Step4:- Write the power balance, energy storage balance equations.

Step5:- Get the equality and inequality constraints to used of this equations.

Step6:- Call the function for optimization using mixed integer linear programming.

Step7:- Print the results and plot it.

4.4 System Data:-

The proposed optimal scheduling algorithm is performed on the data of a small microgrid taken from [6]. The data is given by the 24 hours of time duration. The specification of variables and the system data is tabulated in the following-

Table 1 Specification of Variables

S.NO	Power resources	Technical specifications
1	Diesel Generator	Rated Power = $0.12_{(min)} \leq P_{dg(t)} \leq 5_{kw(max)}$ Start up cost = 6 Rs. Start up time = 2 hr Shut down time = 1 hr
2	ESS	Rated Power = $-5.6_{(min)} \leq P_{bat(t)} \leq 5.6_{kwh(max)}$ $SOC_{(min)} = 40\%$ $SOC_{(max)} = 95\%$ Efficiency of battery = 95%

4.5 Simulation Result

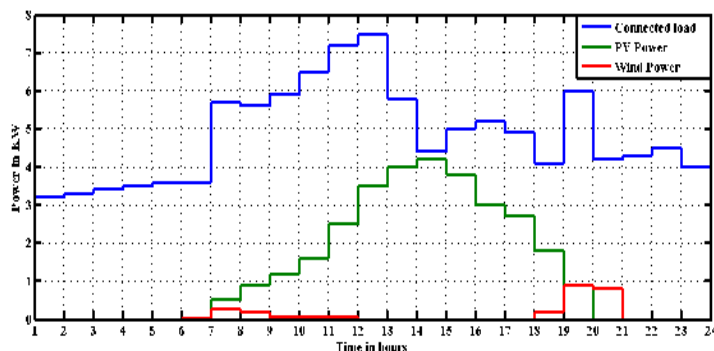


Fig 3 Forecasted data of connected load, PV power and Wind Power[6]

In the figure (3) shown the forecasted data of connected load, generating power from the PV and wind power plant. Due to the analysis and simulation purpose, taken the forecasted value of the above forecasted data, than the calculation should be easy. Here we have seen that the load pattern for the 24 hours of duration. The load power has been change in each sampling time interval because its depends on the consuming power by the consumers, and the power cost of each interval is also different, its depends on the base load or peak load.

In above fig.(3) We have seen that the forecasted PV power, in the morning and evening time period the PV power generation is approximate to zero, and in the mid day time the generating power from the PV are maximum, because the generating power is depends on the solar radiation. We have also seen the forecasted wind power generation, in which time periods velocity of wind flow is maximum the generation will be high and when the velocity of wind flow is minimum the wind power generation will be low, this all data is refer from [6]

4.5.1:- Optimal scheduling in Isolated Mode

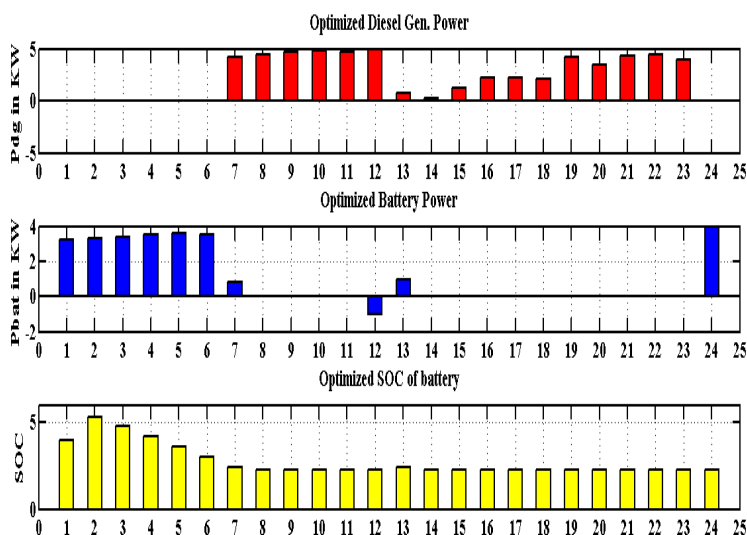


Figure 4 Simulation result of case -1

In this figure no. 4 we have seen that the result of optimization of microgrid using mixed integer linear programming without main grid, in this simulation the main fun is only the minimize the diesel generator cost and the grid cost are taken to zero value. Here the power from the diesel generator is optimized; the time period of working hour of diesel generator has more because it is a islanded microgrid, and whole demand power gives provide by locally. Battery also provides the charging and discharging power at appropriate timing on the basis of its state of charge. We have seen also that, when the battery gives the power and take the power from microgrid, the soc will be also change, so this is the optimal scheduling of microgrid in islanded mode.

4.5.2 Case 2;- Optimal scheduling in Grid- connected mode

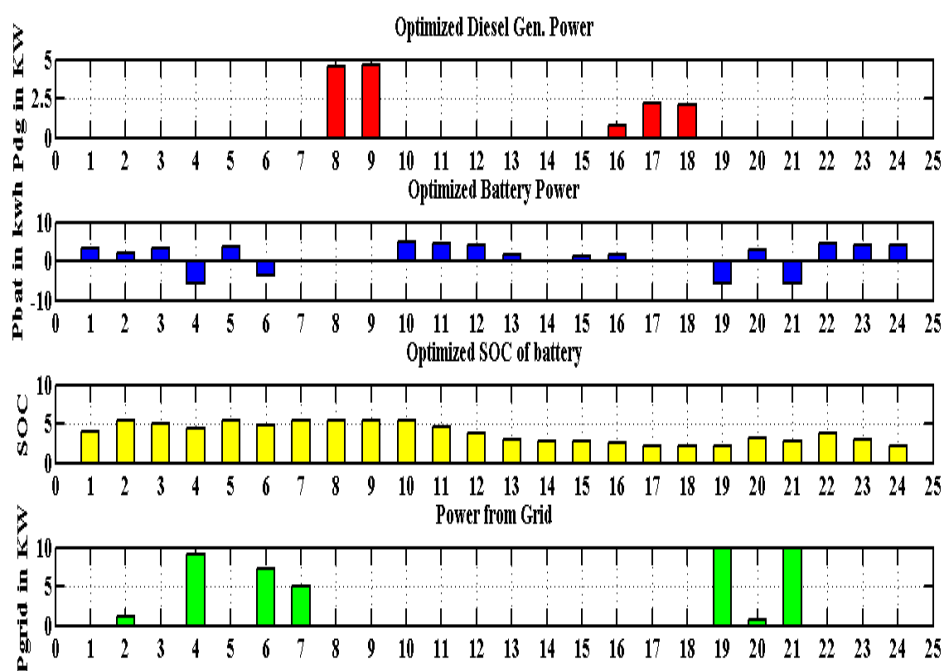


Fig 5 Simulation results of case- 2

Fig 5 are shown the simulation result of grid connected microgrid, in above result we can understand that the demanding power is depends on the diesel generator power, battery power as well as the main grid power, means the locally load are shear by the main grid and the microgrid. This is the best configuration as reliability, availability power point of view. Here also see that the power from energy storage system as well as the optimized data of state of charge of battery storage system. Here the PV and the wind are provides the power to the consumers after that remaining demand fulfil by the diesel generator and main grid depends on its limits of generation and the cost of energy, here main object function is the cost of energy, on the basis of there cost the MILP algorithm obtained its optimized generating power, in fig 5 both are provide the electricity diesel

generator and the main grid, this is the more economy scenario, and consumers gets supply more economy and more efficiently.

4.5.3 Optimal scheduling in (T- τ) time of intrusion: _

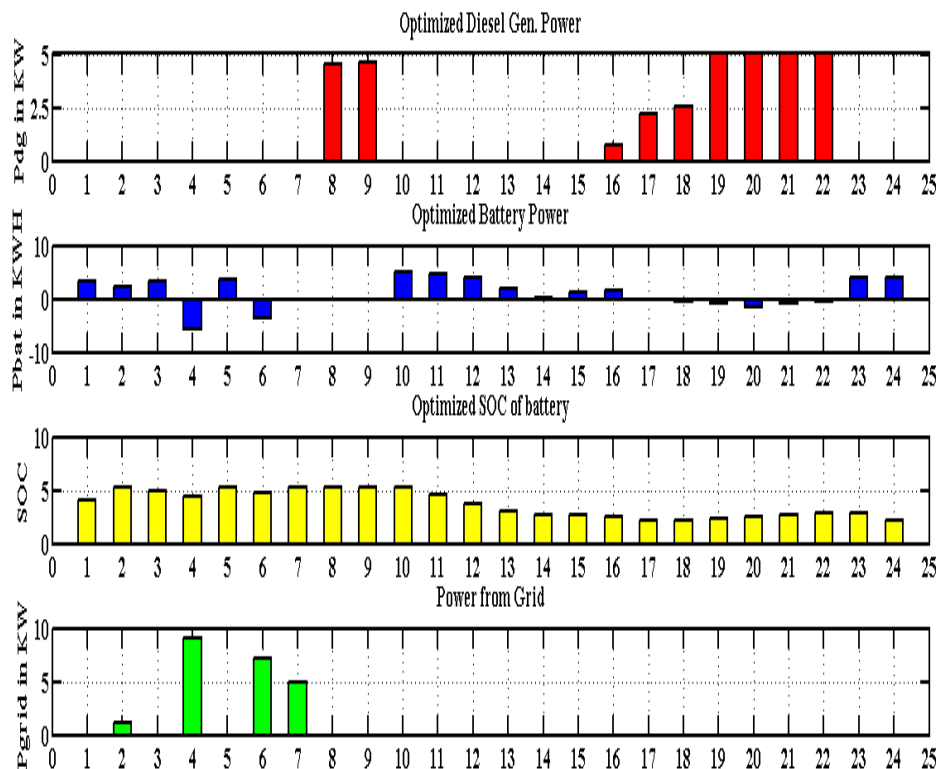


Figure 6 Simulation result of case -3

The above simulation result shown the optimization result of grid connected microgrid, when the main grid supply is interrupt for the four hours in the evening from 7 o'clock to 10 P.M., So in that duration the whole demand power supplied by the microgrid only, so in this simulation result has provide the information how to microgrid maintain the balance between demand and generation power when the main grid becomes interrupted due to some reason. In fig (6), observed that, in the time duration of interruption, the diesel generator are fulfil the requirement of consumers, and maintain the availability of electricity supply, this is a very useful scenario, because this is shown the advantage of microgrid connected main grid, when due to some reason either fault or maintenance purpose if the power supply from main grid is cut out, than the microgrid play important role of power balance, and provides continuous supply to the consumers that is seen in the upper figure also between the duration of 4 hours in evening .

4.6 Comparisons between all three cases

Table 2 Comparisons of simulation Result in all three cases

S.No	Parameters	Case1	Case 2	Case 3
1	Cost	512.46 Rs.	483.64 Rs.	493.79 Rs.
2	Economic	Less economic	More economic	Intermediate
3	Reliability	More	Less	Intermediate
4	Fuel consumption	More	less	Intermediate
5	Emission	More	Less	Intermediate
6	On time of DG Generator	More	Less	Intermediate

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