Optimal Control of Microgrid Using Firefly Algorithm

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***Abstract*—Microgrid is a new idea for future energy distribution system that aids renewable energy integration. Itgenerally consists of many distributed generators that are usually interfaced to the grid through power inverters. In microgrid the power generation is mainly depends on renewable energy sources. The RES are unpredictable, so to maintain the system stability in uncertain environment is very difficult. When changes occur changes in microgrids, it should satisfy the demand with minimum tracking time and to stabilize the system. In order reduce the tracking time for achieving the system stability, robust PID control method is proposed. In that controller the firefly algrotihm is proposed. The new proposed is more robust and high performance control. The simulation has been done in MATLAB/Simulink with required formulation.Based on simulation result, operation optimization using firefly algorithm (FA) can minimize generation cost and life loss cost battery.**

Keywords—optimization of microgrid; DER-distribution energy resource; MG- maingrid;VSI-Multilevel inverter, FA-Firefliy Algorithm; RES-Renewable Energy Source.

I. INTRODUCTION

Electrical power grid, conventional power system has become increasingly vulnerable to manage with the reliability requirements and the diverse demand of power users. Moreover, distributed generation (DG) has advantages of pollution reduction, high-energy utilization rate, flexible installation location, and low-power transmission losses. DG units also present a higher degree of controllability and operability compared to the conventional generators [1], which will permitmicrogrids to play a major and serious role in maintaining the stability of electrical networks [3]. So, microgrids will gradually be a strong and effective support for the main power grid and potentially one of the future trends of power system [5].There are numerous research done in microgridand it shows the system operates on grid connected mode and stand alone mode. Reliability and frequency control are done on various methods[2].

In distribustion generator the microgrid the grid works as grid connected mode and islanded mode. In grid connected mode the system control is droop control. In islanded mode the converter is boundaries the micro sources which is answerable for power sharing and according to their power production and load demand[10]. Researches on control of grid forming units were performed initially in uninterruptible power supply systems with parallel operation . Power sharing control strategies of DG units based on communication include concentrated control.

This paper offers a distributed control scheme to regulate the power flows among multiple microgrids operating in islanded mode and grid connected mode. Each microgrid controller collectsinfo from adjacentmicrogrids and decreases dynamic interactions. Modal analysis and time-domain simulations are used to findserious issues that destroy the stability of microgrids under various operating conditions[12].due to the randomness in renewable power generation, the buffering effect of energy storage devices and the high mobility of PEVs. The bidirectional communication functionalities of the future smart grid offer an opportunity to address these challenges, by offering the communication links for microgrid status data collection. However, how to utilize stochastic modeling and optimization tools for efficient, reliable and economic planning, operation and control of microgrids remains an open issue.We investigate the key features of microgrids and provide a comprehensive literature review on the stochastic modeling and optimization tools for a microgrid. Future study directions are also identified[13].

II. DECENTRALIZED TOPOLOGY

A. Robust Optimization

The common grid is split into microgrids, and the power is generated from DGs. If the RES are more oscillated sources and seasonal one, so the battery storage and MG connection is more reliable operation of Microgrid. If the renewable energy is not present then the load gets the supply from the MG side or if the microgrid produces the more power then to supply to the MG. The MG is always operates at conventional sources. The microgrid operates based on decentralized controller algorithm flow. The controller is operates at firefly algorithm.

B.Firefly Algorithm

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The firefly algorithm is a mathematical algorithm, inspired by the flashing behavior of fireflies. The primary purpose for a firefly's flash is toi act as a signal system to attract other fireflies.This firefly algorithm formulated by Xin-she yang by assuming:

1.One firefly will be attracted to all other fireflies, because all fireflies are unisexual.

2. attractiveness is proportional to their brightness, and for any two fireflies, the less bright one will be attracted by the brighter one however, the brightness can decrease as their distance increases.

3.It will move randomly, if there are no fireflies brighter than a given firefly.

The brightness should be associated with the objective function.

The FA is processed on light intensity based, so the higher intensity fire flies are attractes and lower intensity fireflies are attracted. So the attractiveness is proportional to the light intensity or brightness of the fireflies. In function execution the fireflies is not bright than given fireflies then it moves randomly and the brighter flies is the objective function.

C. Algorithm Description

The pseudo code can be summarized as:

Begin

1) Objective function: f(x), X=(x1,x2,……,xd);
2) Generate an initial population of fireflies Xi (i=1,2,3,…….,n);
3) Formulate light intensity 1 so that it is associated with f(X)

   (for example, for maximization problems, I α f(X) or simply I = f(X);
4) Define absorption coefficient γ

   While(t<MaxGeneration)
   For i=1; n(all n fireflies)
   For j=1; n(n fireflies)
   If (I>I)
   Move firefly I toearrds j;
   End if
   Vary attractiveness with distance r via exp(-γr);
   Evaluate new soluutions and update light intensity;
   End for j;
   End for I;
   Rank fireflies and find the surrent best;
   End while
   Post-processing the results and visualization;
   End

The main update formula for any pair of two fireflies Xi and Xj is

$$X_i^{t+1} = X^t + \beta \exp[-\gamma r_{ij}^2](X_j^t - X_i^t$$

Where   is a parameter controlling the step size, while   is a vector drawn from a Gaussian or other distribution.

III. PROPOSED SYSTEM

A. Energy management control

The block diagram is consisting of pv array, wind turbine and battery storage devices and decentralized controller. It also connected variable loads. In figure the microgrid structure shown. The microgrids haves DC to AC bus. The sources of microgrids are connected in DC bus system and load is connected to boost converter for step up for small variation of irradiation and maintain the constant voltage as 600V. The PMSG output voltage AC. It also affects the wind variation so it is rectifying using rectifier and it maintain 600V DC. In battery storage system have the two controlled switch for energy storage and discharge. In storage switch is connected to MG. AC voltage is converted in to DC using rectifier circuit and it stored the SOC is less than 20%, once it comes in charging mode the SOC goes more than 70% it is stable in charging mode or the present of DG generation is more than load. If the SOC is above 70% and load is more than DG generation the battery is connected to discharge mode.

The conversion of DC to AC is made by the voltage source inverter using voltage source controller. The VSC controller is controls the inverter thyristors, based on the MG supply frequency.

The pulse generated from PWM and signal is gives VSI if The MG voltage when reaches to zero. So the grid synchronization is very easy and phase sequence is also alien. The load is variable character, it changes zero to maximum and it also three phase load.

The microgrids are connected to MG using three phase circuit breakers are operated decentralized controller. The battery operation is based on SOC battery level. The decentralized controller is operation is based on the figure flow chart. The controller focus is only to satisfy the load demand for internal source or DG generated power. If the DG not satisfy the demand then battery is connected to discharge mode and again the demand is high the MG is also connected.

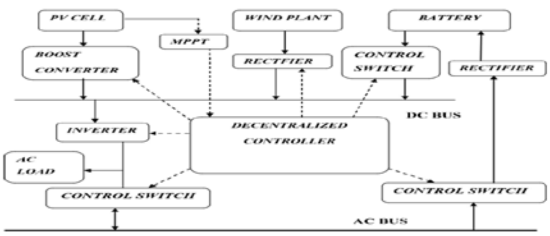

Figure 1.. Block diagram of proposed system

B. Mode of operation

The microgrid is having the self healing technology using decentralized controller. The controller gets all parameters of microgrid likes load power, irradiation, wind speed, battery SOC. The controller is designed FA and all parameters given as input, the algorithm is executed it operates the breakers then the microgrid operation is optimized. The microgrid basically operates in two modes

1. MG connected mode
2. Islanded mode

In MG connected mode, decentralized controller is first check the source availability of microgrid and it decides the operation. If the microgrid not satisfies the load demand and the battery SCO is less than 20%then it takes the power from MG and the load is negligible it supply to MG at same time SOC is more than 70%. The microgrid is operated in following two modes.

i. Supply to the MG
ii. Supply from the MG

In island mode the decentralized controller check the load; power generation of microgrid and SCO of battery. The SCO of battery is more than 20% and load demand is satisfy by microgrid power generation then the microgrid operates in islanded mode.

The aim of the microgrid is to satisfy the local demand without any disturbances and the generated power is tracks it faster. Based on the controller commend the switches are operated and the DG generated power is utilized and also send to MG. due to power send to MG the conventional power generation is minimized and source are saved. So the pollution also reduced.

The microgrid is connected in MG two ways. If generation of the microgrid power is exists load demand then it supply to MG at a same time the load demand is more than generation, then existed power is takes from MG if SOC is less than 20% the battery also charge and load also satisfy in MG.

The microgrid power generation is more than the load and also the battery SOC is more than the 20% the microgrid is connected to the MG and the power flow is microgrid to MG.

The microgrid power generation is fully showdown or not satisfies the load demand at the same time the battery SOC is also less than the 20% the microgrid full load condition the power flow is takes from MG to Microgrid and battery is charged. It applicable both maximum load and minimum load but SOC is less than 20%.

The decentralized controller check the load, if the load is minimum level and SOC of battery condition the island mode is operated. It operates only the minimum load condition only. The battery charging and discharging is depends on SOC of battery.

The battery charging and discharging conditions are based on SOC of battery. The battery generally charge in MG only. In minimum load demand that time the microgrid tries to operate on islanded mode, so that time in discharge the energy. It is not enough to satisfy the demand that time microgrid connect to MG but the battery is operates in discharging condition.

The SOC of battery goes below the 20% that time it takes energy from the MG and it goes to charging mode. The SOC of battery goes up to 70% it is in charging mode only. Here the battery is laso act as source. The proper charging and discharging of the battery is very important. Then only the battery life will be increased.

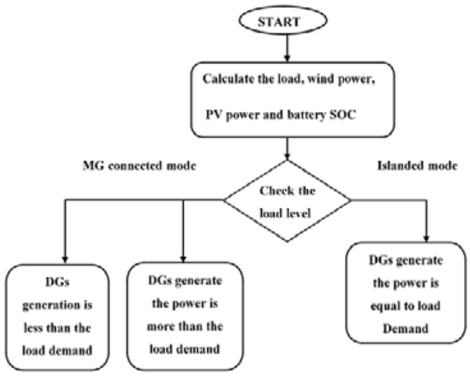

Fig 2. Flow diagram for microgrid operation

IV. SIMULATION CIRCUIT AND RESULT

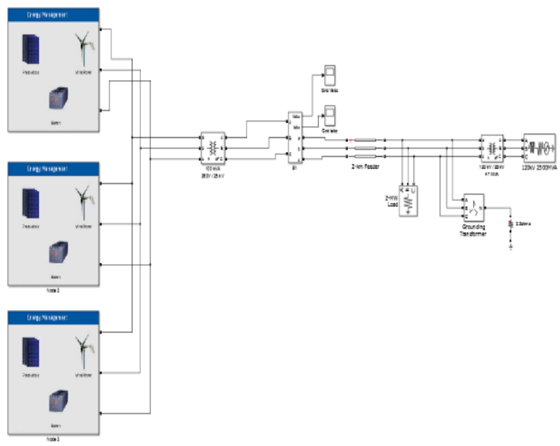

Fig 3. Overall simulation diagram

The simulation model was developed in Matlab/Simulink. Three mirogrid system model is shown in figure (c) the MG generator is 2500KW and it had the various type of loads and 2km feeders line. It also 120kV to 25kV and 25kV to 440kV transformers. The three microgrids are having same amount of PV cell, wind plant, battery and loads.

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The microgrid has 100kW PV cell , wind plant, 6.5Ah battery and 120kW linear load. The PV cell output boosted 600V by using boost converter. The wind generator it design at 30kw 440v, the AC output of PMSG is rectified in to DC. The microgrid operates in minimum load less than 10kW. It operate islanded mode, that time the DGs and battery storage is supplies the power.

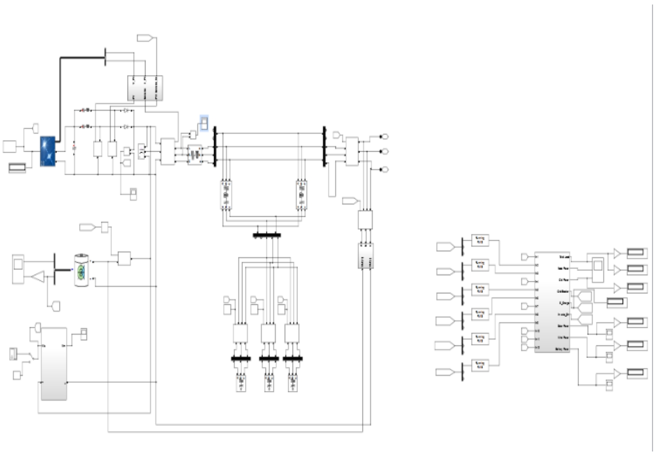


Fig 4. Single microgrid diagram

The microgrid consist of DGs like PV cell, wind turbine, battery for storing the storage of power, load. Power electronics devices and control switches. The Microgrid self-healing process is controlled using decentralized controller. Figure (d) shows simulation model of Microgrid. The controller having algorithm for Microgrid. Robust optimization for self-healing and optimum usage of DG power generation. The output of PV 80KW, wind plant 24KW and 100Ah battery. In testing purpose 120KW load is connected, the SCO of battery is varying. The operation is controlled by decentralized controller to operate the controlled switches.

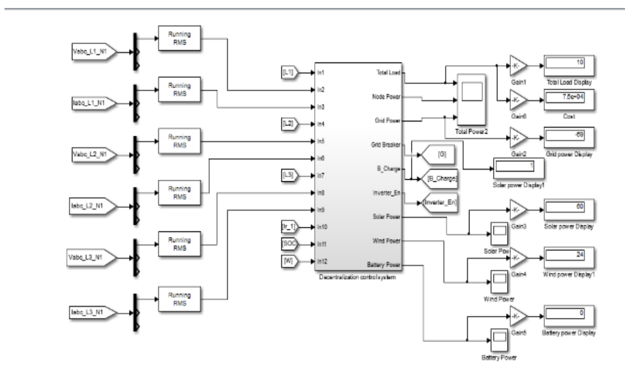


Fig 5. Decentralized controller

The decentralized controller is operates the maximum load demand and the source power which compensate the load. The mode of operation is decided the controlling of switches. In each microgrid having the three controlled switches. The main switch is connected in three phase line, the control signal of the breaker is varied in controller connection.

The controller inputs are load voltage, load current, irradiation in sun, wind speed and battery SCO. By the various parameters the various mode of operation and the system stabilization time also discussed. The MG is connected 2500MW conventional generator, the main generator is operated the microgrid reflections. The below figure shows the voltage and current waveform.

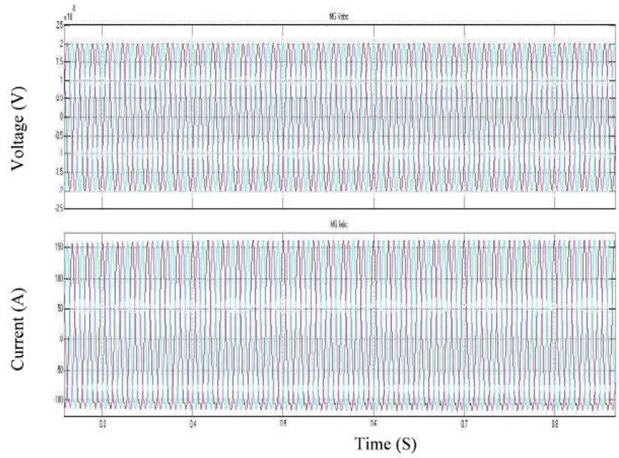


Figure 6. current and voltage waveform

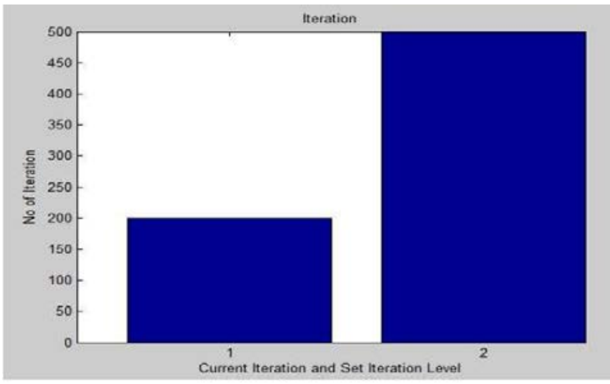


Figure 7. Number of iteration

The complete iteration process required for running FA is shown in figure. it evident that total iteration required to attain system stability is 200. In some cases the system is operated in uncertain environment and the microgrid goes to unstable state.

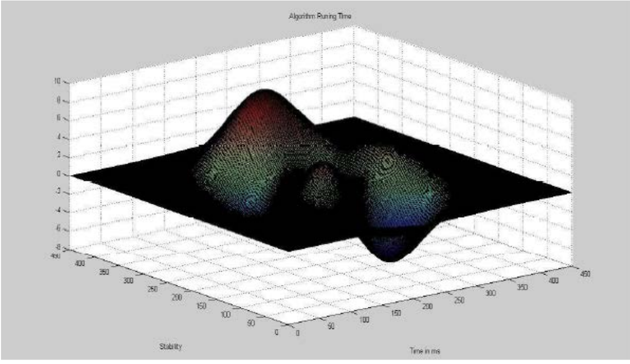
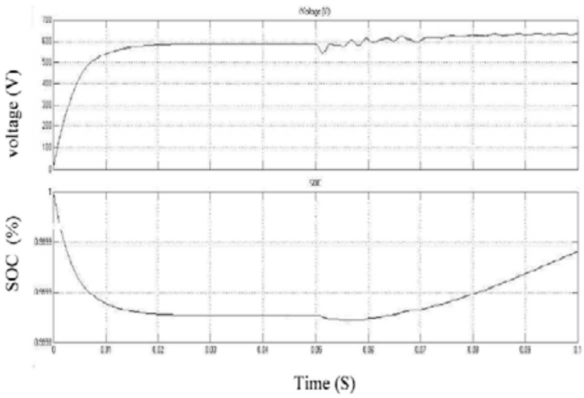


Figure 8. computation for FA

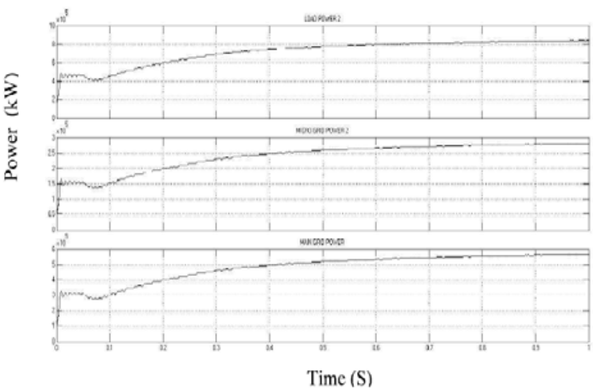
Figure 9. power flow in microgrid1

In this microgrid works as a islanded mode, it haves minimum load. The figure shows the comparison of load power, microgrid1 power and MG power. The microgrid1 is operated in minimum load this load is satisfied by the DGs so it operated islanded mode. Figure shows the battery discharging, because of the load maximum when compared to PV cell, wind power generation, so the battery is discharge up to 20% at same time the DGs are produces the power. The DGs fails or increases the load the conntrollers check the parameters then the mode of operation are



changed.

Figure 10. Battery discharging



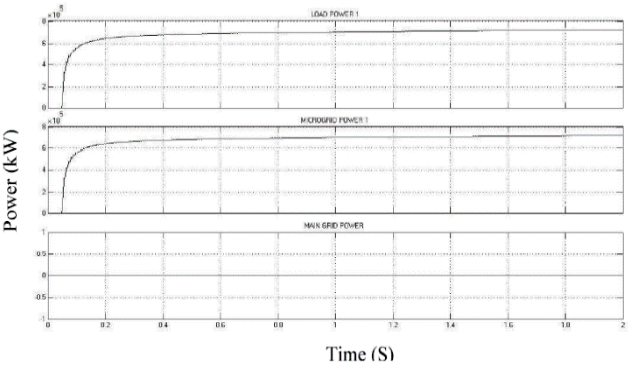


Figure 11. power flow in microgrid2

In microgrid2 the load ismaximum and DGs are also working condition then load is shared both MG and DGs. The Figure shows the load sharing. The total demand of load is shared by DGs and MG.

The load of microgrid2 maximum so load sharing is compensated by DGs and MG, at the same tiemm the battery SOC is more than 70%, so the battery also no charge. The controller opens the rectifier switch and battery charging switch, because the load compensated by DGs and MG. The SOC is also more than 70%. The miscrogrid3 shows the full load condition, but the DGs are on off condition or not unbelievable, so the microgrid3 is connected in MG.

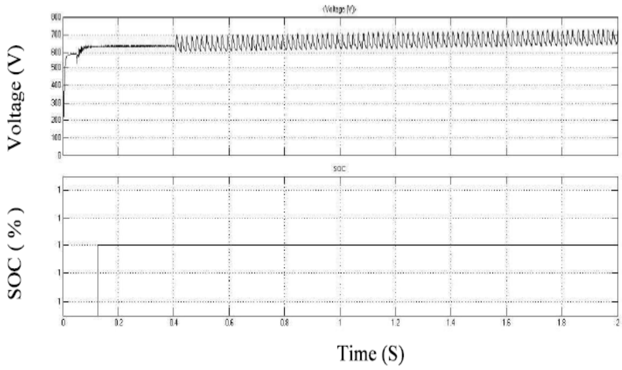


Figure 12. for battery discharging

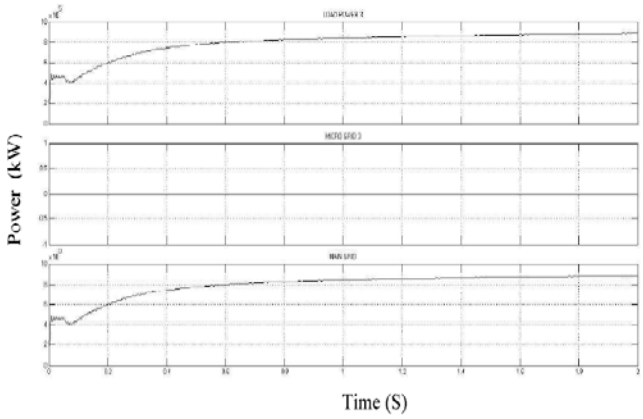


Figure 13. power flow in microgrid3

The DGs are not produces any power and the battery SOC is also loss than 20%, so the microgrid3 load and battery are connected in MG. the controller connects charging switch and main switch. The rectifier operates so the DC power is stored in battery charging condition.

The microgridtechnique is mainly lkused for self-healing and maximized the usage of generated power in DGs. The controller controls the connection of Gs, MG and battery operations. The signal for all operation is based on load current, load voltage, irradiation of sun, wind speed, and battery SOC.

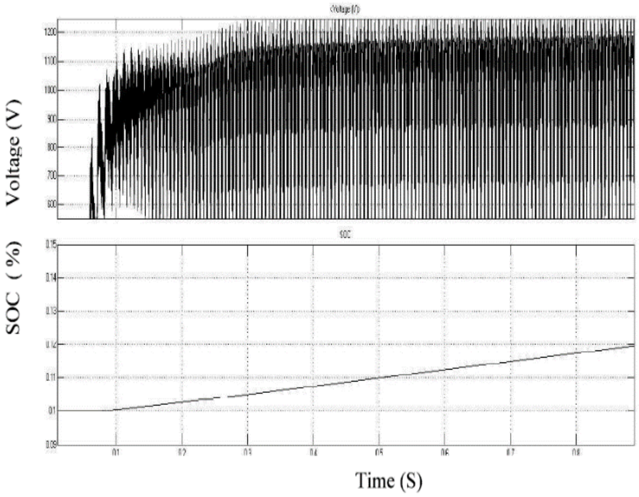


Figure 14. Battery discharging

V. Conclusion

AMicrogrid are bidirectional power flow system. In this project small scale range of RES and loads are used for simulation. In microgrid the RES are the main source for power generation and battery is supporting source. Before the simulation running time, the parameters like sun irradiation, wind speed and battery SOC are fixed but are different in all microgrids. During simulation running time load values are possible to change manually. If any changes in the microgrids, the demand is compensate by DG or MG or combined both.

The microgrids are connected with MG. The source of microgrids are 100KW of PV cell, 30KW of PMSG wind plant and 6.5Ah battery. The load range of each microgrid is 120KW linear load. The decentralized controller is used for self-healing process, because the parameters are dynamically or manually changed. The operation is based on load voltage, current, sun irradiation, wind speed, battery SCO and then the controller decides the operation of microgrid is islanded mode or MG connected mode. If the load demand is equal to DG power generation the microgrid is operate in islanded mode. Otherwise the load demand is exceeds the generation or lower than the generation the microgrid are operated in MG connected mode.

During the changes in microgrids, to satisfy the demand with minimum tracking time and to stabilize the system, proper algorithm is needed to control the switches and operate the converter and inverter. The computation time is different for various algorithms. In this robust optimization contour plot, number of iteration are shown. In robust optimization the number of iteration is 4 and computation time is 40 to 50 ms.

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