



Optimal Energy Management and Battery Sizing Method in Microgrid

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KEYWORDS	ABSTRACT
Microgrid (MG), Energy Management, Battery Energy Storage (BES), Renewable Energy	Now electricity became the basic commodity to mankind. Demand for high quality and reliable electrical power supply is growing day by day. Due to increase in electrification for daily life purpose, surge in sensitive/critical load and since fossil fuels are exhausting there is an urgent requirement for increasing green energy production from renewable energy sources. Another important factor which contributes for revolutionary development in microgrid (MG) is the behind recent blackouts and lack of power supply to critical loads at the time of blackout. But in implementing MG there are few challenges and problems to be addressed. One of the important challenges is energy management in MG. Optimal allocation of generation to sources including economic load dispatch with unit commitment involving continuously varying generation is a challenge. Owing to the intermittency in power generation, allocating generation to each source within limits makes the problem a multi objective optimization. To maintain the stability, power and frequency balance using battery energy-storage systems (BES) is necessary in microgrid. While including BES in MG, sizing of BEs is also an important parameter since deficient capacity makes the system unstable whereas excess capacity increases the operating cost. This paper includes optimal energy management with battery sizing in microgrid.

INTRODUCTION

India is a developing country and the primary measure used for distinguishing developed countries from developing countries is gross domestic product (GDP)

per capita and population in India is growing day by day but energy needs of Individual is not fulfilling up to standards. Quality power to each and every one will make India a developed country. But to provide that we

need enough power generation since fossil fuels are exhausting it can't be achieved with conventional power generators an alternative is to look for distributed generation with renewable sources. Another main reason for looking forward for microgrid is failure to provide emergency power supply to critical loads in case of blackouts/grid failures. The reasons behind blackouts/grid failures are minor CB failures in tie lines which resulted in entire grid collapse but it is very much important to have backup power supply in those cases which urges for the development of micro grid. But there are few challenges in developing micro grid some of them have been studied as literature review.

Microgrid is one of the best solutions to present energy crisis in India. It is basically system comprising of distributed generators with renewable power generation, Energy storage system and controllable loads, which can work in both modes like grid connected mode and isolated mode in case of faults. Various advantages to end customer utilities can be provided by micro grid. Some of the advantages like improvement in energy efficiency of grid, minimizing of overall energy consumption and providing better quality power supply to customers and increasing reliability of power supply have been included. Since multiple energy sources which have different dynamic properties and versatile electrical characteristics are interconnected they will have impact on safety, efficiency, control and stability of microgrid. Various technical issues with operation of microgrid are interconnection of multiple sources and the islanding mode.

Interconnection of microgrid with main grid is quite difficult and this difficulty in interconnection is affected by different types of power generation number of power generating sources. More number of distributed generators in microgrid system will cause several technical problems in working of the main grid such as dynamic behavior of the system, voltage surges and sinks at point of common coupling, protection equipment malfunctions, increase in short circuit levels and power quality problems.

Low Capacity Hydro power plants, wind generators, diesel-turbines, PV cells etc are the different types of energy resources in MG. To electrify many areas in rural places where it is not cost effective to access grid electricity due to non availability of transmission lines and technical requirements, MG is the only choice for

providing electrical energy. The MG should be designed in a cost effective manner while installation, commissioning, operation and maintenances of MG. The MG helps in minimizing the cost by less network congestion & line losses and line costs and thereby increasing energy efficiency.

Now a days the main challenge is to implement renewable energy sources into existing system. MG provides greater flexibility, reliable electrical energy as MG can operate in grid connected as well as islanded mode. MG sources and components can be physically close or can be distributed geographically. To meet the continuously growing demand for electricity, for better energy utilization, for increasing efficiency and reliability, new innovative power generation technologies including RES have been developed. The MG concept is based on the assumption that more number of micro generators are connected to system to decrease the urge of transmission and HV distribution system. However the MG can be incorporated with the distribution system but it may be a threat to the safe and reliable working of the main grid due to the gross loss in line flow, voltage and quality power.

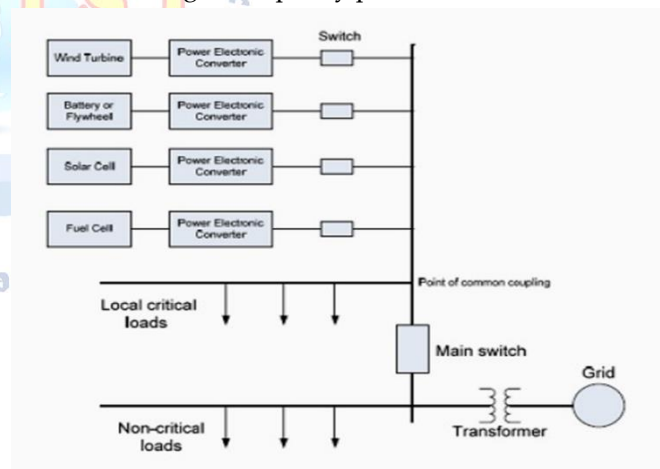


Fig1 Schematic diagram of Micro grid

The conventional energy generation and distribution is replacing with renewable generators which incorporated in Micro Grid. And by using smart grid technologies, integrated controlling strategies in distributed power generation can be obtained. Fig-1 shows a normally working microgrid in a grid-connected mode along with a substation transformer via Point of common coupling (PCC). Point of common coupling is the point in the electric network where a MG is connected to main grid. The power electronic converters play an important role

by connecting DG systems in shunt with the grid or other conventional sources, and to continue to operate in stand-alone mode, when crucial loads are not fed from other sources. The system can isolate from the main grid in case of abnormal conditions like faults, voltage surges, and voltage collapses, and when the quality of power from the grid reduces below certain IEEE standards.

With continuously growing demand for Electrical energy, To reduce the emission of Green house gases (GHG) contributing for global warming, For the improvement of energy efficiency and to provide quality power to every consumer have become biggest challenges in the power sector. One of the best solutions to these problems is implementation of microgrid with distributed energy sources such as PV cell, wind turbine, and fuel cells etc. The microgrid can work in self-sufficient/isolated mode called standalone microgrid with local sources or grid-connected microgrid along with conventional main utility grid. After implementing microgrid irrespective of its structure, it is observed that reduction in the greenhouse gases such as CO₂ and energy costs has been reduced.

However, due to the fluctuations in energy production and intermittency of output power from distributed-energy sources such as wind power plants (WTs) and photo voltaic (PV) units, the participation of storage devices has become mandatory to maintain stability as well as to meet load demand at each hour in the microgrid. These Battery energy storage systems can supply charged power to the microgrid/main grid during a power deficiency and can store the extra amount of power from the renewable sources during light load demand condition. As quoted above, the energy storage systems are necessary (charging/discharging) in microgrid to maintain the power balance during fluctuations. Nevertheless, Greater battery capacity would maximize the operating cost whereas smaller battery capacity results in deficient power that may lead to instability in micro grid which may cause its failure or increases the cost of purchased energy from utility main grid. Therefore, determining the optimum capacity or size for battery energy storage systems is greatly important for reducing microgrid energy management and optimizing operation costs.

Microgrid is interconnection of different renewable energy sources in the best possible connection and switching for supplying to local loads with the capability

to operate either in isolated or grid-connected mode. It can be termed as a subsystem which can be controllable for generating power from the distribution Energy sources (DER) which are generally renewable in nature. Microgrid was first developed by the Consortium for Electric Reliability Technology Solutions (CERTS). In recent times they have improved the flexibility of the power systems greatly by increasing the reliability of the power supply. Microgrid, even though we are discussing about it lately, it is an old concept in many parts of the world. If we can notice the recent developments of the power systems, they have been isolated mostly. The world's first common power station was a steam powered electrical energy generating station started by Thomas Alva Edison in London in the early years and later at Manhattan in 1882. He proposed the generation of electrical power generation locally by using DC generators, since there were no devices available for conversion of voltage to the desired magnitudes for transmission etc conventional grids came into existence. Microgrid shares most of similarities with these early stations and systems as they too are dedicated to generate locally and to feed local loads. Hence we can conclude that the initial isolation techniques are now re visited as microgrid which has the extra unique capability of interconnecting with grid as and when needed.

2. ELITISM GENETIC ALGORITHM

Genetic algorithm (GA) which is proposed by Holland in 1975 and is inspired by the biological selection and the evaluation of humans. And it is one of the basic and most popular evolutionary-based optimization algorithms. The planning programs that finally achieve the convergence criterion are translated into a bundle of chromosomes by encoding and control the search direction by the merits of fitness function. It has been successfully applied to numerous problems both at the level of structural and parametric optimization. Steps of GA are listed as follows:

GA performs the following steps

- 1.Initialization
- 2.reproduction
- 3.cross over
- 4.mutation
- 5.repeat steps

Elitism

Elitism is a method which copies the best chromosomes to the new off-spring population before crossover and mutation.

Objective:

- When creating a new population by crossover and mutation the best chromosome might be lost.
- Forces GA to retain some number of best individuals at each generation.
- Has been found that elitism significantly improves performance.

Summary of GA

Step 1: Generate an initial population randomly which satisfies all constraints.

Step 2: Calculate the fitness which is defined to reflect the practical problem for each individual.

Step 3: Stop the calculation and output the optimal solution, if the termination rule is met, or follow the next step.

Step 4. Selection, which is to generate a new population based on the probability which is determined by the fitness of each individual.

Step 5: Make crossover and mutation on individual of population.

Step 6: if the number of iterations is achieved, stop the iteration and output the result; otherwise return to Step 2.

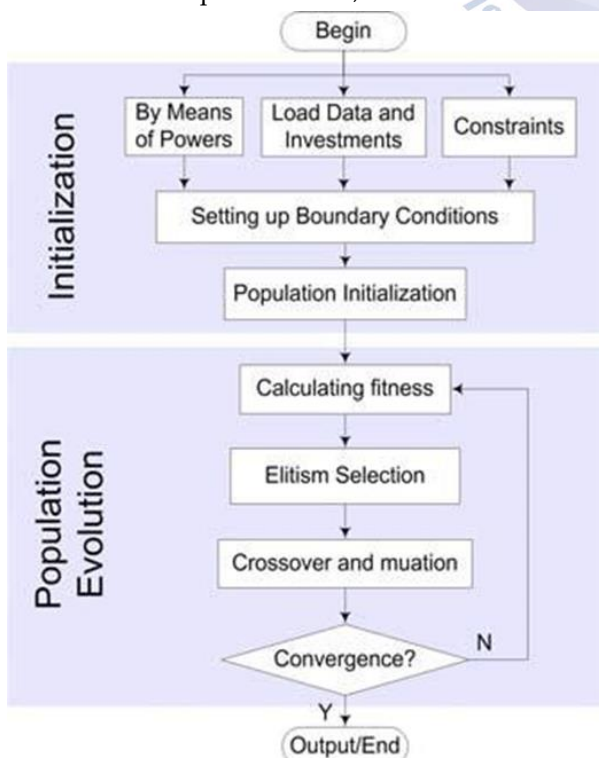


Fig. 2 Flowchart of Elitism Genetic Algorithm

Recommendations:

- 1) Crossover rate(pc)-80-90%
- 2) Mutation rate(pm)-0.5-1.
- 3) Population size -30-60.

Very big population size usually doesn't improve performance of GA. Good population size is about 30-60. However, sometimes sizes 50-100 are reported as best population size depends on encoding, size of encoding string. Encoding depends on the problem to be solved. Elitism=0.2.

3. PARTICLE SWARM OPTIMIZATION

First paper developed by James Kennedy and Russell Eberhart 1995. PSO simulates the behavior of bird flocking in social system, collective behavior of simple individuals interacting with their environments and each other. PSO inspired from nature, social behavior and dynamic moments with communications of insects, birds and social experiences. In PSO, each single solution is a bird in search space we call it particle. All of the particles have fitness values which are evaluated by fitness function to be optimized and have velocities which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles.

PSO search scheme

- 1) It uses of a number of agents i.e., particles that constitute a swarm moving around in the search space, looking for best solution.
- 2) Each particle is treated as a point in a N-dimensional space which adjust its flying according to its own flying experience as well as flying experience of other particles.
- 3) Each particle keeps track
 - i) The best solution achieved so far by that particle is (P_{best}).
 - ii) The best solution obtained so far by any particle in a neighbourhood of that particle (or) best position of swarm is (G_{best}).
- 4) The basic concept of PSO lies in accelerating each particle towards its P_{best} and G_{best} locations, with a random weighted acceleration at each time.
- 5) Each individual in a population will gradually towards the better areas of proper space. Hence, the overall population moves towards better areas of problem space.
- 6) The direction of movement is a function of its current position and its current velocity and location of

individual best success and location of entire swarm (or) neighbourhood best success.

7) A swarm consists of N-particles in a D-dimensional search space. Each particle holds a position (which is a candidate solution to the problem) and velocity which means the flying direction and step of the particle.

8) Each particle successfully adjusts its position towards the global optimum based on two factors.

i) The best position visited by itself (*Pbest*).

$$P_i = (P_{i1}, P_{i2}, \dots, P_{in})$$

ii) The best position visited by whole swarm (*Gbest*).

$$P_g = (P_{g1}, P_{g2}, \dots, P_{gn})$$

9) Particle update rule

$$v_i(t+1) = wv_i(t) + c_1 \times \text{rand} \times [P_{best} - x_i(t)] + c_2 \times \text{rand} \times [G_{best} - x_i(t)] - 1$$

$$x_i(t+1) = x_i(t) + v_i(t+1) - 2$$

In the above equation-1, 1st part($wv_i(t)$) indicates inertia which balances diversification and makes the swarm to explore over search space where as the other two parts combines personal and social intensification i.e., exploitation.

x = particle position.

v = particle velocity (path direction).

c_1 = weight of local information (importance of personal best value).

c_2 = weight of global information (importance of swarm best value).

Pbest = best position of particle.

Gbest = best position of swarm.

Rand – random variable between [0,1].

Population size: The size of population is set on the basis of dimensionality and difficulty of problem. Generally the population size is 30-60.

Similarities of GA and PSO:

- ⊗ Both algorithms will start with a group of randomly generated population.
- ⊗ Both have the fitness values to evaluate the goodness of the population.
- ⊗ Both updates the population and search for optimization with random or stochastic techniques.
- ⊗ Both the methods reach near global optimum.

Dissimilarities of GA and PSO:

- ⊗ Unlike GA PSO has no evaluation operations such as crossover, mutation, elitism etc.
- ⊗ In PSO the potential solution called particles fly through the problem space.
- ⊗ Particles update themselves with internal parameters

Advantages of PSO:

- ⊗ PSO is easy to implement since there are few parameters to adjust compared to GA, all the particles tend to converge to best solution quickly even in the basic version of PSO.
- ⊗ Simple implementation
- ⊗ Derivative free
- ⊗ Insensitive to scaling of design variables.
- ⊗ Very efficient near global search algorithm
- ⊗ Simple and efficient algorithm.

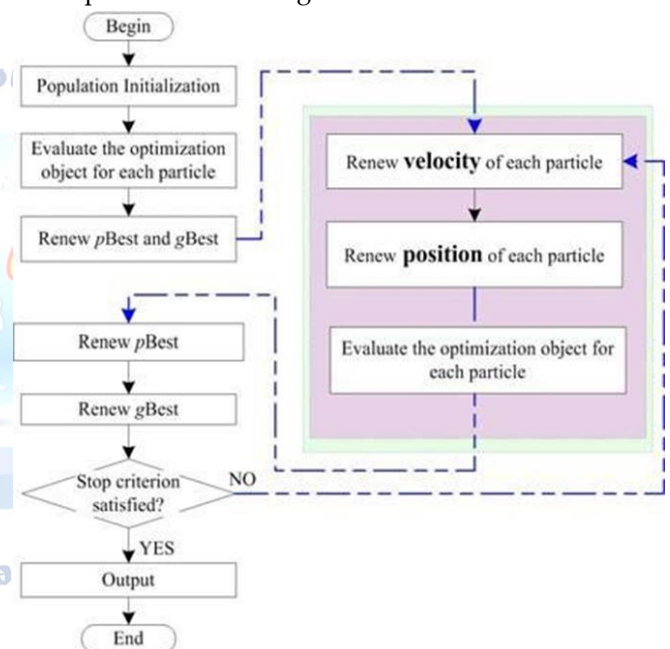


Fig. 3 Flowchart of PSO algorithm

Algorithm for solving the optimization problem using EGA

1. Read input data
 - ⊗ Cost coefficients of DGs
 - ⊗ Maximum generation limits on DGs
 - ⊗ BES constraints.
 - ⊗ Grid constraints.
 - ⊗ Other parameters required for optimization problem
2. Randomly initialize 3- dimensional population of population size(N) for I number of generators for 24 hours with time stamping within limits.
3. Compute objective function value
4. Check for constraints violation

5. Check for maximum number of iterations if no go to step 6 else stop.
6. Perform genetic operators
 - ⊗ Selection/reproduction
 - ⊗ Crossover
 - ⊗ Mutation
 - ⊗ Elitism
7. Combine initial population and updated population/new offsprings and sort them according to objective function.
8. Pick 'N' best solution for next generation.
9. Perform from step 3.

Algorithm for solving the optimization problem using PSO

1. Read input data
 - ⊗ Cost coefficients of DGs
 - ⊗ Maximum generation limits on DGs
 - ⊗ BES constraints.
 - ⊗ Grid constraints.
 - ⊗ Other parameters required for optimization problem
2. Randomly initialize 3- dimensional particles of population size(N) for I number of generators for 24 hours with time stamping within limits.
3. Randomly assign velocities to each particle(initially it is assumed all the particles are of zero velocity).
4. Compute objective function value
5. Check for constraints violation
6. Check for maximum number of iterations if no go to step 6 else stop.
7. Update particles and their velocities using
8. Combine initial population and updated population/new offsprings and sort them according to objective function.
9. Pick 'N' best solution for next generation.
10. Perform from step 3.

4. CASE STUDY WITH RESULTS

Table 1 limits on generators in microgrid and load demand

S.NO	PWT1 (KW)	PWT2 (KW)	PMT1 (KW)	PPV1 (KW)	PPV2 (KW)	LOAD (KW)
1.	660	658	429	0	0	1471
2.	699	707	442	0	0	1325
3.	740	698	220	0	0	1263
4.	723	699	39	0	0	1229
5.	666	576	21	0	0	1321
6.	558	675	167	0	15	1509

7.	669	674	351	10	71	1663
8.	666	693	532	67	90	1657
9.	719	732	497	98	116	1643
10.	711	746	504	122	140	1643
11.	711	686	507	139	155	1652
12.	716	661	366	145	163	1666
13.	706	638	372	145	163	1639
14.	678	561	195	133	155	1642
15.	697	650	74	120	133	1640
16.	709	652	23	94	107	1676
17.	693	657	138	61	86	1920
18.	707	660	381	17	46	2214
19.	721	659	617	0	1	2382
20.	644	668	652	0	0	2327
21.	674	664	706	0	0	2174
22.	677	661	744	0	0	1903
23.	688	642	696	0	0	1666
24.	694	674	711	0	0	1665

Table 2. cost coefficients of the respective DGs

PLANT	B (RS/KWH)
WIND PLANT1	17.83
WIND PLANT2	17.54
MICRO TURBINE	17.23
SOLAR PV1	29.30
SOLAR PV2	29.58
CHP(grid)	75.73

The following table 1 indicates the maximum generation limit on each generator in the taken microgrid test system where as all the units are in kilowatt.

PW1- Wind power plant 1. PW2- Wind power plant 2.
 PMT1- Micro turbine 1.
 PPV1- Photo voltaic cell 1(solar plant). PPV2- Photo voltaic cell 2(Solar plant).
 LOAD – maximum predicted load demand in the given system.

The above table 2 indicates cost coefficient (B in RS/KWH) of each generator in the taken microgrid test system where as all the units are in Rs/kilowatt.

Other parameters required for optimization algorithm
 For Genetic algorithm

Population size-50 T=24

Probability of Mutation (pm)=0.01(trail and error)

Probability of cross over (pc)=0.4(trail and error)

Maximum number of iterations=5000.

Maximum step size in battery capacity=100 kw. Levels in battery capacity=50,500.

For Particle swarm optimization algorithm

Population size=50. T=24.

Constant for controlling global search($C1$)=2. Constant for controlling local search($C2$)=2.

Minimum inertia=0.1. Maximum inertia=0.9. Initial velocity=0.

Initial particles=randomly generated power generation.

Maximum number of iterations=5000

Maximum step size in battery capacity=100 kw Levels in battery capacity=50,5.

Table 3 optimal power allocation using GA without ESS

S.NO	PWT1 (KW)	PWT2 (KW)	PMT1 (KW)	PPV1 (KW)	PPV2 (KW)
1.	611.77	143.53	410.4127	0	0
2.	134.55	630.00	195.153	0	0
3.	105.03	221.01	55.7	0	0
4.	554.07	481.1354	8.422	0	0
5.	205.578	295.7061	9.8835	0	0
6.	385.1130	500.0911	56.4497	0	0
7.	184.6490	90.2551	180.6541	0	12.2102
8.	441.7893	13.0780	288.4951	5.9456	2.2102
9.	614.3077	193.4055	394.9695	59.0248	78.2238
10.	403.6027	47.3392	327.5364	77.7128	61.2423
11.	45.6368	384.8424	277.5233	113.4299	82.8508
12.	283.5418	337.9346	279.1757	20.9455	55.3684
13.	216.5486	42.7854	160.3093	54.0999	123.9992
14.	607.0541	59.7439	14.5621	143.0915	142.2756
15.	161.9870	371.0392	13.3674	122.7729	12.3662
16.	372.5449	234.5489	16.9654	92.2996	39.6912
17.	515.8496	21.4229	42.2178	15.7372	67.3892
18.	557.2127	420.1244	87.9239	11.1141	30.9814
19.	482.9711	308.2326	533.2405	10.2055	23.6550
20.	40.5629	411.2462	441.4257	0	0.2993
21.	322.9227	255.3173	590.2843	0	0
22.	25.8765	403.1793	402.6511	0	0
23.	67.3227	404.9119	531.6197	0	0
24.	7.6061	334.5585	427.3853	0	0

Table 3 gives optimal power sharing on each generator in the taken microgrid test system where after running the optimization algorithm(GA) without including BES for maximum number of iteration. Each cell in tabular column indicates power generation of the respective DG for that particular time stamping in kilowatts.

Table 4 gives optimal power sharing on each generator in the taken microgrid test system where after running the optimization algorithm(GA) after including BES for maximum number of iterations. Each cell in tabular

column indicates power generation of the respective DG for that particular time stamping in kilowatts.

Table 4. optimal power allocation using GA with BES

S.N O	PWT1 (KW)	PWT2 (KW)	PMT1 (KW)	PPV1 (KW)	PPV2 (KW)	PSS (KW)
1.	497.3183	533.7468	108.6458	0	0	83.2587
2.	337.8865	218.4671	202.3133	0	0	8.3259
3.	522.9014	333.7869	178.7970	0	0	-24.3018
4.	154.7457	696.8659	6.7325	0	0	-9.2372
5.	40.1899	261.5388	1.7934	0	0	-31.2678
6.	338.3705	278.4089	150.5447	0	10.237	-79.118
7.	158.3610	543.3220	109.3978	0	39.6367	42.3838
8.	309.9948	391.5629	500.3155	5.8422	18.5640	20.2870
9.	181.9069	549.5259	386.4566	23.7270	88.5650	-11.7047
10.	314.5912	643.5072	439.1137	90.2060	34.9005	-51.0742
11.	2.5913	561.4280	136.3949	104.2741	92.8335	-26.8045
12.	143.0666	225.6154	168.3431	133.7390	106.9091	-67.1514
13.	548.1429	601.8621	116.6310	66.3335	4.9030	-10.7083
14.	0.8031	439.1605	56.8440	33.3456	2.4945	-50.1661
15.	488.8662	262.0657	25.3437	93.5139	51.1039	75.8786
16.	58.2252	225.9073	21.1938	75.1311	103.2611	50.9555
17.	647.8439	137.4981	32.7866	76.1108	58.4613	81.5819
18.	441.6659	137.4744	342.4013	23.3063	22.3591	27.7409
19.	88.2252	209.1889	80.0959	2.4645	0.8207	20.2477
20.	362.5883	102.7671	205.7689	0	0	-16.4911
21.	556.3767	584.7616	415.708	0	0	-28.2793
22.	308.0470	348.5119	687.6345	0	0	-22.2525
23.	78.3983	286.232	406.9846	0	0	-36.1321
24.	45.633	198.56	183.1638	0	0	-49.5441

Table 5 optimal power allocation of each DG using PSO without BES

S.NO	PWT1 (KW)	PWT2 (KW)	PMT1 (KW)	PPV1 (KW)	PPV2 (KW)
1.	654.3221	249.0739	429.000	0	0
2.	103.4343	101.8158	149.3132	0	0
3.	238.7510	231.8317	220.000	0	0
4.	1.2241	91.7904	39.00	0	0
5.	7.7987	270.5829	21.000	0	0
6.	225.4959	195.7297	167	0	0
7.	70.3009	343.9515	346.0160	0	15

8.	616.9987	145.8786	147.1884	5.0494	71
9.	702.6464	86.3629	497	19.0731	90
10.	711.000	264.2529	258.5286	97.3323	38.7031
11.	637.0543	254.8291	63.4804	105.8630	48.9326
12.	346.9304	126.1958	71.1637	58.0337	155
13.	22.6439	722.1439	57.8798	6.2977	101.87
14.	86.3019	158.3155	57.8798	0.4090	160.8474
15.	222.5075	82.3552	195.0	13.6455	4.2153
16.	1.2945	14.0314	30.4607	81.7092	91.7486
17.	601.6785	771.7080	23	53.3404	28.2347
18.	364.8104	172.2756	111.884	46.2619	86

Table 6 optimal power allocation using PSO with ESS

S.NO	PWT1 (KW)	PWT2 (KW)	PMT1 (KW)	PPV1 (KW)	PPV2 (KW)	PESS (KW)
1.	497.3183	533.7468	108.6848	0	0	83.2587
2.	337.8865	218.4671	202.3133	0	0	8.3259
3.	522.9014	333.7869	178.7970	0	0	-24.3018
4.	154.7457	696.8659	6.7325	0	0	-9.2372
5.	40.1899	261.5388	1.7934	0	0	-31.2678
6.	338.3705	484.3857	150.5447	0	0	-79.1188
7.	597.8860	278.4089	109.3978	0	10.2232	42.3838
8.	158.3610	543.3220	500.3155	5.8422	39.6367	20.2870
9.	309.9948	652.2940	386.4566	23.7270	18.5640	-11.7047
10.	181.9069	391.5629	439.1137	902060	34.9005	-51.0742
11.	314.5912	549.5259	136.3949	104.2741	92.8335	-26.8045
12.	2.5913	646.5072	168.3431	133.7390	106.9061	-67.1514
13.	143.0666	561.4280	116.6310	66.3335	4.9030	-10.7083
14.	548.1429	225.6154	56.8440	33.3456	2.4945	-50.1661
15.	0.8031	601.5621	25.4347	93.5139	51.1039	75.8789
16.	488.8661	439.1605	21.1938	75.131	103.2611	50.955
17.	58.4176	262.0657	32.7866	76.1108	58.4613	81.5819
18.	647.8439	225.9073	342.4013	23.3063	22.3591	27.7409
19.	441.6659	137.4744	80.0959	0	0.8207	20.2477
20.	85.2252	137.4981	205.7689	0	0	-16.4911
21.	363.5883	209.1889	415.7089	0	0	-28.2793
22.	556.2767	102.2744	667.6345	0	0	-22.2323

23.	308.6470	584.7616	406.9846	0	0	-36.1321
24.	78.383	348.5119	183.1638	0	0	-49.5441

Table 5 gives optimal power sharing on each generator in the taken microgrid test system where after running the optimization algorithm(PSO) without including BES for maximum number of iteration. Each cell in tabular column indicates power generation of the respective DG for that particular time stamping in kilowatts.

Table 6 gives optimal power sharing on each generator in the taken microgrid test system where after running the optimization algorithm(PSO) after including BES for maximum number of iterations. Each cell in tabular column indicates power generation of the respective DG for that particular time stamping in kilowatts.

The following table 7 gives the comparison of objective function value (which includes minimization operating cost of microgrid like DGs maintenance cost , sizing of battery etc..) in different case studies (with BES and without BES) and with different optimization algorithms(EGA and PSO)

F- objective function value in RS EGA- elitism genetic algorithm PSO-particle swarm optimization

Where as in table first column indicates serial number and next two columns for case study a i.e., without BES and last two columns indicates with BES

Table 7 comparison of objective function(F)value with GA & PSO with and without ESS

S.NO	F(EGA) (RS)	F(PSO) (RS)	F(EGA) (RS)	F(PSO) (RS)
1.	6005	5159	5855	8669
2.	7321	5267	5500	7079
3.	3560	2437	8079	4279
4.	2322	4115	2999	00320
5.	2732	1643	2192	2789
6.	4277	3906	5144	4843
7.	3737	7143	7069	6025
8.	5390	6379	7499	7957
9.	3213	11695	10729	7388

10.	10913	10688	7125	4983
11.	15405	11476	11450	1148
12.	9788	15971	8785	10221
13.	11754	4648	5351	10337
14.	13346	8084	8229	5623
15.	9857	7192	12462	10990
16.	10338	6602	5582	2869
17.	6291	8081	5165	10480
18.	6016	1952	7586	2418
19.	6897	8651	8782	8095
20.	5836	5913	5823	5328
21.	4872	5316	9133	8614
22.	5190	6635	2845	1563
23.	7377	7639	6401	6932
24.	3216	7630	9162	8452

5. CONCLUSION AND FUTURE WORK

- Optimal scheduling of DGs problem been solved using Genetic algorithm along with particle swarm optimisation algorithm and test results been included in report.
- Knowledge about modeling and different costs involved in operation of microgrid has been acquired.
- When copared the results obtained with two algorithm PSO appears to be effiecient than GA but in some cases premature convergence is observed.
- It is observed that participation of BES is mandatory as in some cases DGs in microgrid alone cannot staisfy the peak demand, eventhough it incurs higher objective function values.
- Before starting with the project, it is assumed that microgrid test system is provided with an efficient v/f controller such that variation in power will not effect voltage, frequency and stability.
- Results obtained involves optimal scheduling of 6 dgs for a day as pv cell will not contribute during night time and contributes maximum during day time.
- Future scope of work will be encountering the other challenges in microgrid so that implementation of

microgrid will be possible and economical. As we have discussed implementation of microgrid is becoming more and more crucial day by day.

- Other challenges in microgrid invovles protection issues, autonomous operation and voltage and frequency control. Many reasearches is being done in these areas also.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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