OPTIMAL ALLOCATION OF RENEWABLE DISTRIBUTED GENERATION WITH LARGE PENETRATION TO MITIGATE POWER QUALITY ISSUES

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ABSTRACT

The intervention of DG's in the electrical network has increased remarkably which has led to the requirement of optimally allocating them in the system. They should be allocated with an optimal size and appropriate locations such that they increase the system performance, reduce losses as well as to obtain better voltage profile. In this paper the nature inspired algorithm based intelligent technique called modified shuffled frog leap algorithm is used to obtain the optimal location of the renewable distributed generation. Here analysis is carried out on full load and heavy load and constant power load model is considered for the case of heavy load where drastic changes in the test system can be observed. Under this condition the optimal placement and selection of type of DGs with their penetration level is the important factor for consideration. The enhancement of power quality is achieved by nullifying the effect of the voltage sag at the affected busses by using the indices based on the variations in voltage. The entire analysis is carried out on standard IEEE 33bus test system.

Key words: Renewable Distributed Generation, Large Penetration, Optimal Location, Sag.

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1. INTRODUCTION

In the power system, it is required that the operator maintains the voltage within the limits for each customer bus. There are many standards which have been proposed for satisfactory voltage profiles in distribution systems. It is proposed that the voltage variations in the distribution system must stay in the range of -13% to 7%, which is generally maintained at 6% in the utilities. Introduction of the DGs in the networks enhances the voltage profile by changing the path of power flow.

With the enhancement of the technology, power quality issues have been under concern leading to the change in the nature of electric loads, due to their nonlinearity, they lead to disturbance in the voltage waveform. Power quality issues will increase the disturbance in the system. Any disturbance occurring will result in huge financial loss and consequent loss of productivity. Hence, some steps must be taken to mitigate these issues to obtain a good quality of power.

When the system voltage reduces to 10 to 90% of the RMS value of actual voltage for 0.5 second to 1 minute is called as the sag. This is caused mainly due to faults or overloading due to large motors. The voltage sag results in malfunctioning of protective devices which leads to an interruption in the processes and tripping.

2. PROBLEM FORMULATION

Power quality can be improved by optimally allocating the available distributed generation sources using the shuffled frog leap algorithm. The inclusion of DG in an appropriate way will give a better profile of the voltage and reduce the system losses, hence improving the system performance by reducing the power quality problems.

2.1. Power Quality assessment Indices

The system performance will be depending on the quality of the power supplied and in various cases it is specified by using System Average rms Frequency Index (SARFI) [3]., it presents the average number of RMS variations over the assessment period to the customer served, and it calculates the number of busses effected by voltage sag by crossing the lower limit of 0.9.p.u. If the limit is fixed to 90% irrespective of the duration it is represented as SARFI-90.

$$SARFI = \frac{\text{Total number of buses experiencing voltage sag (Nsag)}}{\text{Total number of customers served}}$$

And the improvement index of the same is represented as

$$SARFII = \frac{(SARFI_{\text{with DG}})}{SARFI_{\text{without DG}}}$$

Where,

SARFI = System Average rms Frequency Index

SARFII = System Average rms Frequency Improvement Index

SARFI_{withoutDG} = System Average rms Frequency Improvement Index without DG

SARFI_{with DG} System Average rms Frequency Improvement Index with DG

N_{sag} = Total number of buses experiencing voltage sag.

$$N_{sag} = \sum_{i=1}^{N_{bus}} \begin{cases} 1 & \text{if } 0.1 \text{ pu} < V_i < 0.9 \text{ p.u} \\ 0 & \text{otherwise} \end{cases} \quad (2.1)$$

Where, N_{sag} corresponds to busses which fall below the lower limit under the heavy loaded condition. N_{bus} corresponds to number of buses.

Hence, the following fitness functions are to be minimized to improve the quality of power.

$$F1 = \min(N_{sag}) \quad (2.2)$$

$$F2 = \min(SARFI) \quad (2.3)$$

2.2. Methodology

This section shows the results obtained after the execution of SFLA on IEEE 33 bus, For the network considered the following three cases are analyzed and for each case, three scenarios are considered.

Case-1: Allocation of only Solar DG units

Case-2: Allocation of only wind powered DG units

Case-3: Allocation of both solar and wind powered DG units

Scenario -1: With penetration level of 15%

Scenario -2: With penetration level of 30%

Scenario -3: With penetration level of 50%

Case -4: Allocation of only solar DG unit under heavy load condition

Case -5: Allocation of only wind powered DG unit under heavy load condition

Case -6: Allocation of both solar and wind powered DG unit under heavy load condition

Scenario -1: Integration of single DG unit

The allocation of DG is based on the population of shuffled frogs with its will decide the location of DG. With respect to the power requirement and the deviation in voltage, the bus with maximum voltage deviation is chosen as the best location with the corresponding size depending on power losses.

2.3. Modified Shuffled Frog-Leaping Algorithm

MSFL algorithm is a meta-heuristic method which finds the global optimal solution by performing a heuristic search. It is an evolution process in which information is exchanged globally carried by individual's memes and population. Thus it combines the benefits of the local search and global search. MSFLA mainly based on the behavior of groups of frogs searching for the location that has maximum amount of available food. The MSFLA involves a population of possible solutions defined by a set of virtual frogs. This set of virtual frogs is partitioned into subsets known as memeplexes. The memeplexes can be perceived as a set of parallel frog cultures attempting to reach same goal. Frog leaping improves an individual frog and enhances its performance towards the goal. Within each memeplex each frog holds different ideas and the idea of each frog can be used to infect the ideas of other frogs. The process of passing information between the frogs of memeplex is known as, 'local search' or 'memetic evolution step'. After a defined number of memetic evolution steps, the virtual frogs are shuffled and reorganized, so that the quality of memeplex is improved. Shuffling enhances

the memetic quality after infection and ensures the cultural evolution towards a particular interest. The process of evolution and shuffling are repeated until a required convergence is reached.

2.4. Solution Methodology

The sequential steps are as follows [7]:

1. Begin
2. Generate random population of P solutions (Frogs)
3. for each individual P: calculate fitness
4. Sort the population P in descending order of their fitness
5. Divide P into m memplexes;
6. for each memplex: Determine the best and worst frogs
7. Improve the worst frog position.
8. Repeat for a specific number of iterations, End
9. Combine the evolved memplexes
10. Sort the population P in descending order of their fitness
11. Check if termination = true
12. End

3. RESULTS AND DISCUSSIONS

This method is applied to the standard IEEE 33 bus system operated at 12.66kV level of voltage and consists of 33 busses, 32 branches, with 3715kW and 2300kVar of power respectively as shown in Figure.3.1. The base case load flow is obtained where the power losses without the connection of the DG's are 202.68kW and 143.22kVAr respectively.

Figure 3.1 Single diagram of IEEE 33 bus test system

Table 3.1 Case 1,2,3 for scenario 3 with 15% penetration with three DGs

3	Solar DG	Wind DG	Both Solar and Wind
1: Optimal location	Bus 17	Bus 29	Bus 33
2 : Optimal size in MW	Bus 07	Bus 07	Bus 06
	Bus31	Bus31	Bus31,
3: Base case power losses	202.68	202.68	202.68
4: Power losses with DG in	152.7	164.77	123.62
5: Power loss reduction in	49.83	37.82	78.97
6: power loss reduction in	24.6	18.67	30.98
7: Minimum voltage without DG in p.u.	Bus 18	Bus 18	Bus 18
	0.91309	0.91309	0.91309
8: Minimum voltage with DG in p.u.	Bus 14	Bus 18	Bus 18
	0.96517	0.93978	0.95705

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Table 3.2. Case 1,2,3 for scenario 2 with 30% penetration with two DGs

Particulars	Solar DG	Wind DG	Both Solar and Wind
1: Optimal location	Bus 32	Bus 2,	Bus 6, Bus33,
3: Base case power losses in kW	202.68	202.68	202.68
4: Power losses with DG in kW	128.15	142.23	103.7
5: Power loss reduction in kW	74.53	60.37	98.86
6: power loss reduction in %	36.88%	29.80	48.81
7: Minimum voltage without DG in p.u.	Bus 18	Bus 18	Bus 18
	0.91309	0.91309	0.91309
8: Minimum voltage with DG in p.u.	Bus 30	Bus 18	Bus 18
	0.96872	0.96308	0.9249

Table 3.3 Case 1,2,3 for scenario 1 with 50% Penetration with single DG

Particulars	Solar DG	Wind DG	Both Solar and Wind
1: Optimal location	Bus 7	Bus 31	Bus 32, bus 15
2: Base case power losses in kW	202.68	202.68	202.68
3: Power losses with DG in kW	108.08	121.61	61.23
4: Power loss reduction in kW	94.6	81.07	141.45
5: power loss reduction in %	46.67	40.01	69.7
6: Minimum voltage without DG in p.u.	Bus 18	Bus 18	Bus 18
	0.91309	0.91309	0.91309
7: Minimum voltage with DG in p.u.	Bus 18	Bus 18	Bus 18
	0.94526	0.92515	0.9398

Table 3.4 Case 4,5,6 for scenario 1 with 100% penetration single DG

Heavy load	Solar DG	Wind DG	Both Solar and Wind
1: Optimal location	Bus 29	Bus 30	Bus 31, bus6
2: Base case power losses in kW	559.66	559.66	559.66
3: Power losses with DG in kW	322.16	381.28	206.69
4: Power loss reduction in kW	237.5	178.38	352.97
5: power loss reduction in %	42.43	31.87%	63.06%
6: Minimum voltage without DG in p.u.	Bus 18	Bus 18	Bus 18
	0.85493	0.85493	0.85493
7: Minimum voltage without DG in p.u	Bus 18	Bus 18	Bus 18
	0.8853	0.87733	0.90211
Sag exposed area % before DG	53.33	53.33	53.53
Nsag, Before DG placement	16	16	16
Sag exposed area % after DG	15.15	18.18	3.03
Nsag, After DG placement	5	6	1
SARFI, Before DG placement	0.0051233	0.0051233	0.0051233
SARFI, after DG placement	0.001601	0.001701	0.0011
SARFII	0.68750	0.80286	0.78529

Table 3.1,3.2 and 3.3 shows the different penetration levels at 15%, 30% and 50% respectively, of solar, wind and hybrid solar with wind distributed generators. The losses are reduced the maximum value with hybrid combination for the same penetration level. The losses with solar distributed generation are obtained to be less compared to wind distributed generators. Table3.4 shows the results obtained by integrating Renewable DGs at optimal buses with 100 percent penetration levels using MSFLA under the heavy load condition. The renewable distributed generators are able to manage the heavy load on the system as obtained in Table3.4 with single DG integration and with hybrid power generation.

4. CONCLUSION

In this paper, the allocation of DG with optimal size and location is done using a nature-inspired algorithm called modified shuffled frog leap algorithm. This is a newly developed intelligent technique which gives better results. Here, optimal placement of DG is done based on the moment of frogs in search of food. The analysis is carried out on the IEEE 33bus test system for different scenarios by considering the renewable distributed generators. It is evident that the percentage losses in the system are reduced and minimum voltage at the bus is increased with the hybrid generation of both solar and wind. During heavy load, the DG will compensate the entire additional load by nullifying voltage sag at the affected nodes.

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