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Distributed Generation Planning and Analysis for Power Quality Improvement

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Abstract*: Distributed generation (DG) is an emerging concept in the power sector, which represents good alternatives for electricity supply instead of the traditional centralized power generation concept. Due to sharp increase in power demand, voltage instability & line overloading has become challenging problems for power engineers. Voltage collapse, unexpected line & generator outages & blackouts are the major problems associated with voltage instability. Reactive power unbalancing is the major cause of voltage instability. So that the problem of enhancing the voltage profile and decreasing power losses in electrical systems is a task that must be solved in an optimal way. This type of problem is in single phase & three phases. Therefore to improve & enhance the voltage profile & stability of the existing power system, FACTS devices and load flow analysis are the alternative solution. Traditional power flow analysis techniques such as the Newton-Raphson and The Gauss-Seidel methods are widely used in analyzing power transmission systems. However, they are inefficient and may diverge due to the different network characteristics of power distribution systems such as radial and high R/X ratio. Therefore, other techniques such as the voltage sweep algorithms are developed for power distribution systems. The sweep algorithm can deal with balanced networks which are radial or weakly meshed and contain distributed generators. Networks with different topologies are implemented to assess the convergence behavior of the sweeping algorithm and comparisons with established methods in the open-source sim power flow package (the Newton-Raphson and Gauss-Seidel methods) are made. This paper describes a forward backward sweep method based approach for load flow analysis in radial distribution system to improve voltage stability and to minimize the transmission line losses considering cost function for entire power system planning. The proposed approach will be tested on IEEE -33 bus system.

***Keywords*: Distributed generation, embedded generation, electricity, Forward-Backward Sweep Algorithm; Radial Distributed System**

1. Introduction

The liberation of the energy market and the new conditions in the energy field are leading towards the finding of more efficient ways of energy production and management. The introduction of new ideas capable of evolving in the new conditions might lead to more suitable solutions compared to any possible malfunctions the new market model can create. The electricity marketplace is undergoing a tremendous transformation as it moves towards a more competitive environment. The 'growing pains' of this transformation – price instability, an ageing infrastructure, changing regulatory environments – are causing both energy users and electric utilities to take another look at the benefits of distributed generation (DG). The combination of utility restructuring, technology evolutions, recent environmental policies provide the basis for DG to progress as an important energy option in the near future. Utility restructuring opens energy markets, allowing the customer to decide the energy provider, method of delivery, and attendant services. The market forces favor small, modular power technologies that can be installed rapidly in response to market signals.

A. Distributed generation

Generally, the term Distributed or Distributed Generation refers to any electric power production technology that is integrated within distribution systems, close to the point of use. Distributed generators are connected to the medium or low voltage grid. They are not centrally planned and they are typically smaller than 30 MW. A distributed electricity system is one in which small and micro generators are connected directly to factories, offices, and households and to lower voltage distribution networks. Electricity not demanded by the directly connected customers is fed into the active distribution network to meet demand elsewhere. Electricity storage systems may be utilized to store any excess generation. Large power stations and large-scale renewable, e.g. offshore wind remain connected to the high voltage transmission network providing national back up and ensure quality of supply. Again, storage may be utilized to accommodate the variable output of some forms of generation. Such a distributed electricity system both options require significant investments of time and money to increase capacity. Distributed generation complements central power by

- Providing in many cases a relatively low capital cost response to incremental increases in power demand,
- Avoiding T&D capacity upgrades by locating power where it is most needed, and
- Having the flexibility to put power back into the grid at user sites.

Significant technological advances through decades of intensive research have yielded major improvements in the economic, operational, and environmental performance of

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small, modular gas-fuelled power generation options.

2. Power quality

The definition of power quality given in the IEEE dictionary originates in IEEE Std. 1100 Power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment. Despite this definition the term power quality is clearly used in a more generic way. Within the industry, other definitions or interpretations of power quality have been used, reflecting dissimilar points of view. Thus, this definition might not be exclusive, pending development of a broader agreement. A point of view of an equipment designer or producer might be that power quality is a ideal sinusoidal wave, with no variations in the voltage, and no noise present on the grounding system. Ultimately, a point of view of an end-user is that power quality or "quality power" is basically the power that works for whatsoever equipment the end-user is applying. While each hypothetical point of view has a clear difference, it is clear that none is properly focused. An environment where the equipment designer or company clearly states the equipment wants, and the electrical utility engineer indicates the system delivery characteristics, and the end-user after that predicts and understands the equipment effective instability that will likely be encountered on a yearly basis is a better situation. This allows a cost validation to be performed by the end-user to either improve equipment operation by installing additional components or improve the electrical supply system through installation of additional, or alteration of existing components.

3. Implementation and results

The proposed method is implemented using MATLAB 2013b and tested for IEEE 33 bus system. Figure 1 shows the overall diagram of the IEEE 33 bus Test data system. In this system, bus 1 is considered as the slack bus, remaining buses are PQ buses. The buses are connected in loop thus it is considered as a power system that operates under 11 kV levels. The proposed method is tested for 200 KVA Base.

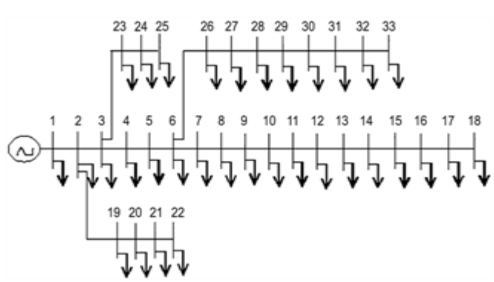

Fig. 1. Single line Diagram for IEEE 33-bus Distribution Network

The proposed method is implemented using MATLAB 2013b and tested for IEEE 33 bus system. Which is shown in Figure 1 The optimal number of DGs to be connected in the system identified is found to be 2 for 3039.533 W & 369.5 W each rating. Table 1 shows the optimal capacity of Distributed Generation. It is clear that, the total Active power loss at without DG is 0.531(PU) and the total active power loss after connecting the optimal number of DGs in the system is 0.139(PU) Thus there is a reduction by about 39.92 % of total power losses in the system.

Table 1
The optimal capacity of DGs

S. No.	DG
1	3039.533
2	369.5

Table 2
Voltage Comparison after and before DG Condition

Bus	Without DG Bus voltage (PU)	With DG bus Voltage (PU)
1	0.9960	0.9988
2	0.9769	0.9944
3	0.9785	0.9952
4	0.9667	0.9966
5	0.9566	1.0005
6	0.9315	0.9957
7	0.9268	0.9771
8	0.9082	0.9592
9	0.8995	0.9571
10	0.8915	0.9487
11	0.8903	0.9455
12	0.8883	0.9436
13	0.8798	0.9417
14	0.8767	0.9389
15	0.8748	0.9381
16	0.8729	0.9981
17	0.8702	0.9933
18	0.8693	0.9924
19	0.9953	0.9915
20	0.9905	0.9684
21	0.9896	0.9604
22	0.9888	0.9890
23	0.9721	0.9896
24	0.9632	0.9807
25	0.9587	0.9763
26	0.9289	0.9979
27	0.9254	0.9944
28	0.9099	0.9788
29	0.8987	0.9676
30	0.8939	0.9627
31	0.8881	0.9570
32	0.8869	0.9557
33	0.8865	0.9554

The Table 2 shows the per unit bus voltage profiles after installing DGs in the system network.

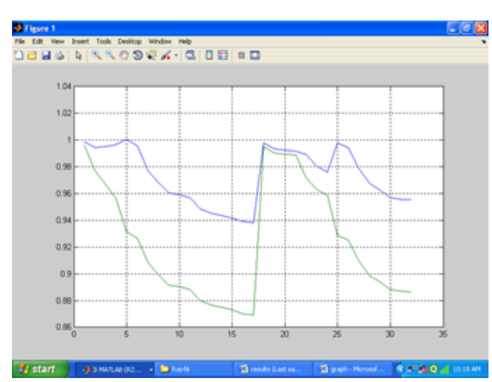

Fig. 2. Bus voltage before and after installing DGs in the system network

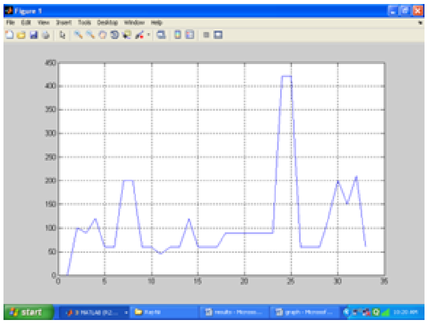

Fig. 3. Active Power flow after DG Placement

The effects of the significant parameters have been shown. From the result it is clear that there is optimal enhancement in the system parameters. The voltage profile is improved and power loss is minimized.

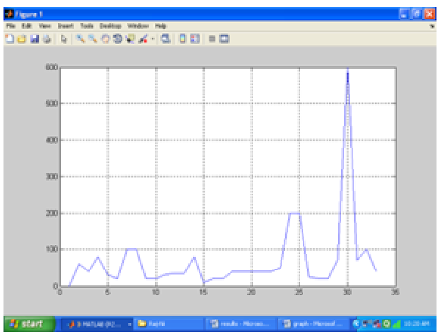

Fig. 4. Reactive Power flow after DG Placement

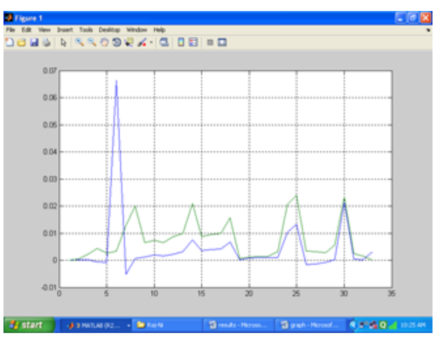

Fig. 5. Single line Diagram for IEEE 33-bus Distribution Network

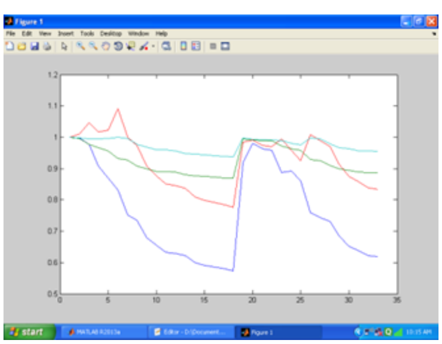

Fig. 6. Voltage Profile with DG & Without DG for all Cases

The voltage profile is improved and power loss is minimized. The proposed method uses many possible significant parameters into account to be optimized. The optimal number of DGs to be connected in the system was identified as 2 and the power loss was reduced. Hence, the system performance is improved.

4. Conclusion

In this paper, optimal placing of DG using forward sweep algorithm was tested for an IEEE 33 bus test system. The effects of the significant parameters have been shown. From the result it is clear that there is optimal enhancement in the system parameters. The proposed method is implemented using MATLAB 2013b and tested for IEEE 33 bus system. Which is shown in Figure The optimal number of DGs to be connected in the system identified is found to be 2 for 3039.533 W & 369.5 W each rating. Table shows the optimal capacity of Distributed Generation. It is clear that, the total Active power loss at without DG is 0.531(PU) and the total active power loss after connecting the optimal number of DGs in the system is 0.139(PU) Thus there is a reduction by about 39.92 % of total power losses in the system.

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