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An Integration of Distributed Generation into A Weak Distribution Network

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***Abstract*— Distributed generation is the generation of electricity from many small energy sources, e.g., solar or wind, and is located closer to the user, or customer. A form of distributed generation is on-site generation where a customer owns its own generation and it is installed on its premises. The Distributed Generation power integration have some effect into the power system grids as power system issues: transmission congestion, optimal power flow, system stability, power quality, system economics and load dispatch. The integration of Distribution Generation into power system mainly in weak distribution is a challenge because of the voltage control, reactive power compensation, under voltage tripping and voltage collapse problem occur in the weak distribution network. The main objective of this paper is to investigate voltage sag when integration of DG in a weak distribution network. However, The mention method is tested on a standard IEEE 33-bus system and the results are obtained using MATLAB.**

Keywords*— distribution generation; voltage sag; distribution network; optimal power flow; power quality

I. INTRODUCTION

Utilities are continuously planning the expansion of their electrical networks in order to face the load growth and to properly supply their consumers. The traditional solution is the construction of new substations or the expansion of those already exists. However, these companies began to evaluate new manners of expanding their capacities when government started to simulate the addition of new power sources to the system. From that moment, Distributed Generation (DG) started to retake its importance. Distributed Generation can be defined as an electrical power source connected directly to the distribution network or on the consumer side of the meter. It may be understood in simple term as small-scale electricity market. There are a number of DG technologies available in the market today and few are still in research and development stage. Some currently available technologies are reciprocating engines, micro turbines, combustion gas turbines, fuel cells, photovoltaic and wind turbines. Each of these technologies has its own benefits and characteristics. Among all the DGs, diesel or gas reciprocating engines and gas turbines make up most of the capacity installed so far. Simultaneously, new DG technology such as micro turbine is being introduced and an older technology such as reciprocating engine is being introduced. Fuel cells are technology of the future. However, there are some phototype demonstration projects. The cost of photovoltaic systems are expected to fail continuously ever the next decade [1]. This all underlines the statement that the future of power generation is DG. the issue of distribution system planning considering the uncertainty in the penetration of distributed generation. They utilized the same approach described in [2] but replaced the uncertainty in the power generated by the uncertainty in the availability of DG units.At present the electric utility industry is undergoing significant changes with respect to its structure, operation and regulations. As a result of deregulation, the traditional vertically integrated structure of the electric utility industry has been split into individual generation, transmission and distribution entities [3]. Significant advances in the field of renewable energy and small power package such as microturbines, increasing attraction to " green house ", deregulation of the electric utility industry, saturation of existing networks and problems associated with building new large generation plants and transmission lines have resulted in the field of Distributed Generation (DG). Unit sizes vary from kilowatts to a few megawatts. In the future DG penetration is expected to rise to about 10% of total installed capacity in the next decade. The viability of distributed generators generally depends on economics, need efficiency of utilization of resources and benefits to the power delivery system, ultimately resulting in benefits to the customers.

II. EMPLOYING DG

A. Advantages of DG[4]

- Reduced line losses.
- Voltage profile improvement.
- Reduced emissions of pollutants.
- Increased overall energy efficiency.
- Enhanced system reliability and security.
- Improved power quality.
- Relieved T&D congestion.
- Reduced O&M costs of some DG technologies.
- Enhanced productivity.
- Reduced health care costs due to improved environment.
- Reduced fuel costs due to increased overall efficiency.
- Reduced reserve requirements and the associated costs.
- Lower operating costs due to peak shaving.
- Increased security for critical loads.

B. Disadvantages of DG[5]

- Reserve power flow as a result of connecting DG in the system causing malfunction of protection circuits as they are configured at present.
- Harmonics injection into the system by asynchronous

- DG sources which use inverters for interconnection.
- Stability issues.
- Increased fault currents depending on the location of DG units. A set of indices is proposed to quantify some of the technical benefits of DG. They are:
- Voltage profile improvement index.
- Line loss reduction index.
- Environmental impact index.
- DG benefit index.

The most important motivations for the studies on the integration of distributed resources to the grid is the exploitation of the renewable resources such as; hydro, wind, solar, geothermal, biomass and ocean energy, which are naturally scattered around the country and also are smaller in size. Accordingly, these resources can only be tapped through integration to the distribution system by means of distributed generation. Although there is no consensus on the exact definition of distributed generation (DG), there are some significant attempts to define the concept. Meanwhile DG, which generally consists of various types of renewable resources, can best be defined as electric power generation within distribution networks or on the customer side of the system. DG affects the flow of power and voltage conditions on the system equipment. These impacts may manifest themselves either positively or negatively depending on the distribution system operating conditions and the DG characteristics. Positive impacts are generally called 'system support benefits', and include voltage support, power loss reduction, transmission and distribution capacity release, improved utility system reliability and power quality. On account of achieving above benefits, the DG must be reliable, dispatchable, of the proper size and at the proper locations. The worst placement in some situations can reduce system benefits so the placement should be optimal in order for maximum benefit of DG implemented to the system. For that reason, the use of an optimization method capable of indicating the best solution for a given system can be very useful for the system planning when dealing with the increase of DG penetration that is happening nowadays. Recently, the meta-heuristic optimization methods are being successfully applied to combinatorial optimization problems in power systems; in addition to, the optimization techniques have been applied to optimal DG placement such as genetic algorithm, tabu search algorithm and simulated annealing. The project attempts to implement Simulated Annealing in DG allocation where the power loss in an existing network is minimized.

III. ALLOCATION OF DG

The distribution systems are usually regulated through tap changing at substation transformers and by the use of voltage regulators and capacitors on the feeders. This form of voltage regulation assumes power flows circulating from the substation to the loads. DG introduces meshed power flows that may interfere with the traditional used regulation practices. Since the control of voltage regulation is usually based on radial power flows, the inappropriate DG allocation can cause low or over-voltages in the network. On the other hand, the installation of DG can have positive impacts on the distribution system by enabling reactive compensation for a voltage control, reducing the losses, contributing for frequency regulation and acting as spinning reserve in main system fault cases

DG growth has some effect in the planning and operation for existing power system network. The voltage regulation and reactive power compensation is held when the DG is integrated into the power system. Such integration affects several power system related issues as

- Optimum Power Flow
- Transmission Congestion
- Power Quality
- System Stability
- System Economics and Load Dispatch
- $P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}[\alpha_{ij}(P_iP_j + Q_iQ_j) + \beta_{ij}(Q_iP_j - P_iQ_j)$ 1
- $\alpha_{ij} = \frac{r_{ij}}{V_iV_j}\cos(\delta_i - \delta_j)$
- $\beta_{ij} = \frac{r_{ij}}{V_iV_j}\sin(\delta_i - \delta_j)$
- $z_{ij} = r_{ij} + jx_{ij}$ is the ijth element of $[Z_{bus}] = [Y_{bus}]^{-1}$
- $P_i = P_{gi} - P_{di}$ & $Q_i = Q_{gi} - Q_{di}$
- P_{gi} & Q_{gi} are injection powers of generators to the bus.
- P_{di} & Q_{di} are the loads.
- P_i & Q_i is the active and reactive power of the buses

C. Proposed algorith

The purpose of this paper is to find the best location and size of a DG unit in order to decrease the power losses of the system when we speak about the best location and size, it means that the most optimum location and the best size of a DG unit in a distribution system to minimize the losses, in other hand in a system, there may be some optimum locations and sizes for a DG unit but one of them is the best location and size between them. The proposed algorithm of this paper gives the most optimum and size of a DG unit in a distribution system because of analyzing the entire sizes and locations for a DG unit.

D. ComputationalProcedure

a) Run the base case load flow.
b) Consider the active power limits of a DG unit.
c) Change active power from the minimum value to the maximum value with small steps.

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d) In each step of the real power, change the reactive power from zero to eighty percent of the real power on that step and then calculate the losses from the Eq(1)
e) Store the reactive power that gives the minimum loss for the related active power
f) Choose the real power with its reactive power that gives the minimum loss for that bus.
g) Repeat these steps for all of the buses and find the best size (active and reactive power) of the DG unit for each bus.
h) Compare the losses of each state find the minimum loss in the distribution system.
i) Store the bus that gives the minimum loss with its DG sizes.
j) Run the base case load flow with DG.

Voltage magnitude (PU) in all the buses should be between 0.95 to 1.05 pu

IV. Results & Discussion

The proposed method is tested on a case study. The system has 33 bus and 32 branches. It is a radial system with the total load of 3.72 MW and 2.3 MVAr. Fig.1 shows the test system [6].

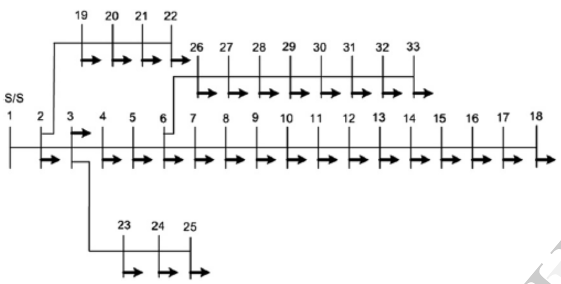

Fig.1.Single line diagram of a 33 bus distribution

The integration of DG in weak distribution with the help of the dynamic power compensation and then analyses the results in to two different techniques as

- Analysis of the results without integration
- Analysis of the test system with DG integration

The results describe the behavior of the weak distribution into DG that is connected with the load side, and shows the effect of the DG connected to the load.

E. Before DG insertion

The system is run without any renewable resource (DG) is used in the first stage. The purpose of the running the coding is to find the voltage and determine that the system is weak. The result of the system is shown in fig 2 as below.

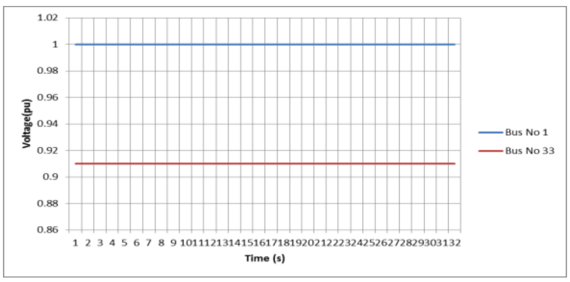

Fig 2: Voltages at Bus No. 1 and 33

The voltage of bus no. 1 and 33 show in the figure. The value of bus voltage 1 is approxmate 1 pu, and after distribution the voltage at bus no. 33 is 0.91 pu. This result shows the system is weak because the voltage of the system is not in the limit means not above the 0.95 pu.

F. After DG insertion

The proposed method is now tested on a case study with integration of renewable source (DG). It is a radial system with the integration of DG the total load of 3.72 MW and 2.3 MVAr. Fig.3 shows the test system with DG installed into it.

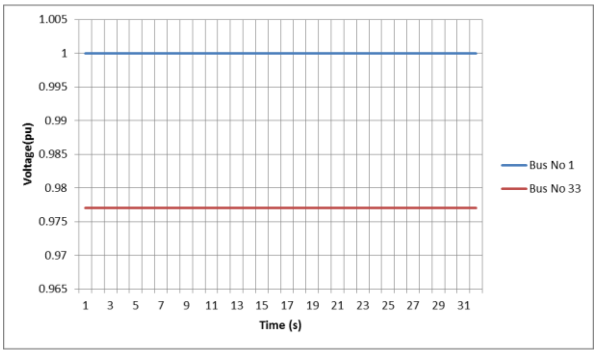

Fig 4: Voltages at Bus No. 1 and 33

The voltage of bus no. 1 and 33 show in the figure. The value of bus voltage 1 is approximate 1 pu, and after distribution the voltage at bus no. 33 is 0.977 pu. This result shows the system voltage of the system is above the 0.95 pu.

G. Figures and Tables

Table 1 shows the voltage in pu before and after the distribution generation insertion which shows the voltage in pu before DG insertion is below 0.95 pu which is a weak distribution network and after DG insertion of 3MW and 1.8MVAR is above 0.95 pu

TABLE I. Voltages at Bus

Bus no.	Before DG	After DG
1	1	1
2	0.997	0.999
3	0.983	0.998
4	0.975	1
5	0.968	1.002
6	0.95	1.008
7	0.946	1.004
8	0.932	0.992
9	0.926	0.986
10	0.92	0.98
11	0.919	0.979
12	0.918	0.978
13	0.912	0.972
14	0.909	0.97

15	0.908	0.969
16	0.906	0.967
17	0.904	0.965
18	0.904	0.965
19	0.996	0.999
20	0.993	0.995
21	0.992	0.995
22	0.992	0.994
23	0.979	0.994
24	0.973	0.988
25	0.97	0.985
26	0.948	1.006
27	0.945	1.003
28	0.934	0.993
29	0.925	0.985
30	0.922	0.982
31	0.918	0.978
32	0.917	0.977
33	0.916	0.977

The result has discussed in the different mode and describe one by one, in the weak distribution, the different voltage and power at various points. In the first case the voltage at bus no. 1 and 33 is differ and not within the acceptable limit because the total load is approximate the generation and the losses is occur in the network. The voltage at bus 1 is about 1 pu and after distribution line the voltage is 0.90 pu if any disturbance occur then the system may be shut down.

When DG used to compensate the real and reactive power and the DG is integrated with the distribution network and all power generate from the DG is occupies in the weak distribution network. When the DG is applied then the voltage of the bus no.33 is also improved very fast, and the power supplied into the network that why the distribution network, improved and the DG is integrated in the system

V. CONCLUSION

Employing DG in a distribution system results in several benefits. One of the important one is the line loss reduction. This paper proposes an analytical algorithm to find the optimum location and size of a DG unit. The obtained location and size is the most optimum location and size in all of the possible optimum solutions because of analyzing all of the locations and sizes for each bus. Results for the test system can show the applicability of the method. In practice the choice of the best site and size may not be always possible due to many constraints, for example because of not being a DG unit with each sizes in the market.

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