VOLTAGE PROFILE AND LOSS REDUCTION ENHANCEMENT BY OPTIMAL PLACEMENT OF DG AND DSTATCOM IN DISTRIBUTION SYSTEM

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Abstract - *Focus on power generation by non-conventional methods are increased as the result of rapid depletion of fossil fuels and increasing green environment concerns. Technological research advancement made the distributed energy resources (DER) to use as microgrids formations and active distribution network. This paper proposes a scheme for loss reduction and bus voltage profile improvement in the active radial distribution network. DER are form of small renewable energy resources is Distribution generation such as solar PV, wind, biomass, is located optimally for power loss reduction in the network. DLF method load flow is utilized and LSF with voltage deviation is used in finding the optimal placement of DG. DSTATCOM is optimally placed in the network to maintain bus voltages profile within the limit by providing reactive power support to the network with DG. The methodology is tested on simulation of IEEE 69-bus radial distribution system on MATLAB.*

Key Words: Distribution Generation, Direct Load Flow, DSTATCOM, Loss Sensitivity Factors.

I. INTRODUCTION

Now a days, distribution system acquires huge rate of power losses, i.e., 13% in the power system which has been studied. Improvement of the operating condition and voltage stability of the radial distribution system are also considered together for the studied with much importance. Many research works were been done to reduce the power losses and improve the voltage stability of the distribution system [1].

Integration of DGs in the RDS has considerably increased which was one of the optimal way to improve the distribution system performances. The optimal placement of DG are must on integration and if required DSTATCOM a special FACTS devices designed for distribution system to solve out the power quality issues and problems in voltage stability.

Simultaneous allocation of DSTATCOM and DG in the RDS have more benefits such as reducing system power loss, voltage profile enhancement, power factor correction, load balancing, power quality improvement, on-peak operating costs reduction, shedding the overloading of distribution lines, system stability improvement, pollutant emission reduction, and increased overall energy efficiency. The feeder power flow is controlled by the regulated real and reactive power generation by the DG and DSTATCOM at optimal location in the RDS and it reduces the power import from the substation. Hence, the system total power loss has been decreased with good enhancement in voltage profile.

The term "Distributed" or "Dispersed" Generation (DG) is described as small electric power generation that is directly linked to the systems. DG components are induction generators, micro turbines, synchronous generators, reciprocating engines, fuel cells, combustion gas turbines, solar photovoltaic, wind turbines and other small power generation sources. Comparing with constructing high priced new power plants and distribution and transmission lines DGs installation have less investment. The features that attract toward the DGs are ecofriendly, power quality improvement and economic. Traditional generating methods is less reliable energy solutions than DGs.

Distribution STATic COMpensator (DSTATCOM) is a DFACTS device that enhances the distribution system efficiency and reliability by decreasing total lines losses with reactive power support and also increase voltage profile. In recent researches, this kind DFACTS are considered over existing shunt capacitor on the distribution system results in solving the defects on the capacitors and improves reactive power compensation. Advantages of DSTACOM over shunt capacitors are variable reactive power generation, load balancing, less resonance problems and in addition capacitor placement at right location and the cost involved in it due to constant reactive power generation is also eliminated.

This article is organized as follows. Section 2. explains about DSTATCOM 3. System description 4. Proposed methodology 5. Simulation and results 6. Conclusion of proposed work.

II. DSTATCOM

The DSTATCOM is a shunt connected voltage source converter used to compensate power quality problems such as unbalanced load, voltage sag and voltage unbalance in distribution system. DSTATCOM can inject both active and reactive power to the system for compensation of sensitive loads, and active power injection into the system must be provided by energy storage. Reactive power generated by the DSTATCOM is capable of continuously varied up to installed maximum MVAR rating. The DSTATCOM continuously checks the line voltage with respect to a reference ac signal, and therefore, it can provide the correct amount of leading or lagging reactive current compensation to reduce the amount of voltage fluctuations[2].

The major components of a DSTATCOM are shown in Fig. 1. It consists of a dc capacitor, one or more inverter modules, an ac filter, a transformer to match the inverter output to the line voltage. In this DSTATCOM purpose of voltage-source converter is to converts a dc voltage into a ac voltage that is synchronized with and connected to the ac line through a small tie reactor and capacitor (ac filter).

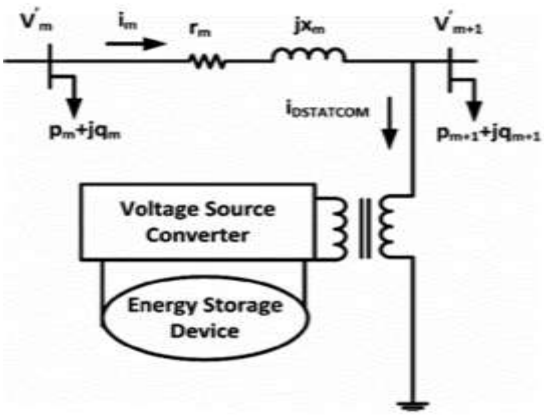

Figure.1. DSTATCOM Model

Basic operating principle of a DSATCOM is similar to that of synchronous machine. The synchronous machine will provide lagging current when under excited and leading current when over excited. DSTATCOM can generate and absorb reactive power similar to that of synchronous machine and it can also exchange real power if provided with an external device DC source. If the output voltage of voltage source converter is larger than the system voltage then the DSTATCOM will function as capacitor and generate reactive power (i.e. provide lagging current to the system).

Requirement of real power to the switches is provided by DC capacitors as the switching devices has its own losses. Hence there is a need for real power exchange with an AC system to make the capacitor voltage constant in case of direct voltage control. In case of very low voltage in the distribution system or in case of faults voltages are regulated by external DC source provided along with DSTATCOMT here is also a real power exchange with the AC system if DSTATCOM is provided with an external DC source to regulate the voltage.

III. SYSTEM DESCRIPTION

The power system comprises Generation, transmission and distribution. Distribution system is responsible for providing power to the end consumers. The classification of distribution lines based on their configurations are three types: doubly fed, ring and radial distribution system. Radial distribution system is one of the most widely used configurations because of its rugged and economical nature. Disadvantages of Radial distribution network suffered from high losses happened because of voltage sag and issue on stability limitation.

In India about 13% of the total power production is spent as distribution losses. These losses can be minimized by optimal location of DG and DSTATCOM at weak bus in the distribution network. Generally, distribution system has high R/X ratio, due to which the conventional load flow models such as Gauss–Seidel, Newton–Raphson and Fast-Decoupled methods cannot be applied for load flow on distribution system. Hence, in this paper, Direct Load Flow (DLF) analysis is the load flow analysis formulated for distribution system is carried out.

A 12.6 kV, 100 MVA of base MVA IEEE 69 bus radial distribution system show in figure 2 is considered as test system. Bus 1 is taken as the references and has 7 lateral branches from bus 3, 4, 8, 9, 11, and 12. The total real power and reactive power load is 3.802590 MW and 2.69460 kVAr. These loads are not evenly spread over the system instead loads are scattered where some buses has no loads.

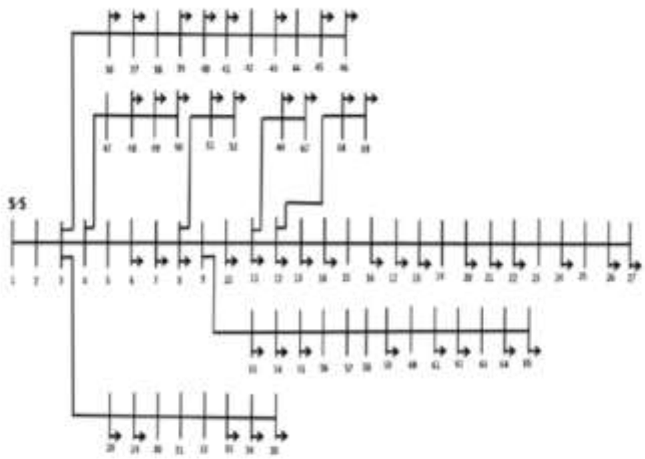

Figure.2. Line diagram of IEEE-69 Radial Distribution system

IV. PROPOSED METHODOLOGY

This section explains the methodology proposed for selecting the optimum location of DG and DSTATCOM and their respective sizes[1].

- Optimal location of DG :

Loss Sensitivity Factor (LSF) is being utilized for finding the best location for DG placement in the given distribution network. For a optimization process it is necessary to reduce search space for faster calculation this is achieved by using LSF in the problem. Real and reactive power loss for lth line between 'm' and 'm + 1' buses can be written as

$$P_{line,loss}(m+1) = \frac{\left(p_{eq}^2(m+1)+q_{eq}^2(m1)\right)*r_l}{(v^2(m+1))}$$

$$q_{line,loss}(m+1) = \frac{\left(p_{eq}^2(m+1)+q_{eq}^2(m1)\right)*x_l}{(v^2(m+1))}$$

Where,

peq (m + 1): total real power supplied ahead of the node m + 1,

qeq (m + 1): total reactive power supplied ahead of the node m + 1,

peq (m + 1) and qeq (m + 1) are evaluated with the help of BIBC as shown in below equations

$$p_{eq}(m+1) = BIBC * P_{RLPM}$$

Where,

p_{RLPM} : real power matrix of the total power system,

q_{REPM} : reactive power matrix of the total power system.

The Loss Sensitivity Factor can be calculated using equation (5) and (6)

$$\frac{\partial p_{line,loss}}{\partial p_{eq}} = \frac{2 * p_{eq}(m+1) * r_l}{\left(v^2(m+1)\right)}$$

$$\frac{\partial q_{line,loss}}{\partial p_{eq}} = \frac{2 * q_{eq}(m+1) * r_l}{\left(v^2(m+1)\right)}$$

Optimal location of DG is determined to as bus having highest LSF for both real and reactive power. The objective function for optimal location of DG is as follows:

$$max(F1) = w_1 * P_{lsf} + w_2 * Q_{lsf} - w_3 * \left[\sum_{m=1}^{nb}\{(v_m - v_{min})^2 + (v_m - v_{m+1})^2\}\right]$$

Where,

W_1, W_2 and W_3: weighting factor

- Optimal location of DSTATCOM:

Optimal location of DSTATCOM for reduction of power losses on the entire network and voltage profile improvement the every bus in the network. For the placement of DSTATCOM every operational and constraints of the system are considered and verified. Also depends on the acceptable range of voltage deviation and on entire system power losses. Hence, the objective f unction (F2) can be formulated as$min(F2) = \left(\frac{p'_{loss}}{p_{loss}}\right) * (0.01) + \left[\sum_{m=1}^{nb}\{(v_m - v_{min})^2 + (v_m - v_{m+1})^2\}\right]$ Where,

p'loss: Net real power loss of the network after the installation of DSTATCOM,

ploss: Net real power loss of the network before the installation of DSTATCOM,

vmin: Minimum allowable limit of voltage,

vmax: Maximum allowable limit of voltage,

nb: total number of buses in the system.

- Optimal size of DSTATCOM and DG:

The optimal size of DG and DSTATCOM is must to be calculated for betterment of system. Size of DG can be found by considering power loss reduction and investment cost of DG based on which objective (F3) is formed. Size of DSTATCOM is determined as number of buses violating limits and injected reactive power is not greater than reactive power demand of the particular bus.

The size of the DSTATCOM can be calculated using equation below:

$$jq_{DSTATCOM} = v'_{m+1} i^*_{DSTATCOM}$$

The size of DG is taken as the value of PDG for which the function F3 expressed in equation below gives the maximum value.

$$max\{F3\} = C_E * P_{PLR} * 8760 - C_{DG} * P_{DG} * \gamma$$

Where,

CE: Cost of the energy (INR/kW h),

PPLR: Power loss reduction after the installation of DG,

CDG: Capital cost of the DG (per kW),

PDG: Total capacity of the DG (kW),

ϒ: Annual rate of depreciation & interest charges

V. SIMULATION RESULTS AND DISCUSSION

To validated the proposed work, IEEE-69 bus radial distribution system performances were examined with base case loading in absences of DG and DSTATCOM, presences of DG only and presences of both DG and DSTATCOM.

- Without DG and DSTATCOM

Under base case loading, bus 56 with 0.9312 p.u is identified as weaker bus after load flow, out of 69 buses 9 buses(56,57,58,59,60,61,62,63,64) has voltage violation and real and reactive power loss as 0.218774 MW and0.9944 kVAr.

Hence, both power loss reduction and voltage profile improvement is must for maintaining system reliability.

- With DG alone

As there is the necessity for improving power loss reduction DG is installed. For better results DG must place on the system at suitable location and size which is found using analytical equations in section IV. The cost of energy was 6 Rs/unit, cost of initial investment is 1.3 core per MW, ϒ is 0.30 and total capacity is 3 MW. The optimal location for taken test system is found to be bus 61 of size 0.9 MW. The percentage of real and reactive power loss reduction is 50.9% and 47.8% respectively but still there are 6 buses that violate voltage limit.

- With DG and DSTATCOM

DSTATCOM is added in the system to improve the voltage profile of entire system by offering reactive power support. Since, there are few buses which violate the voltage limit it is mandatory to install DSTATCOM at suitable place and size using the mathematical formulation provided in the section IV. The optimal location and size is found to be bus 61 and size of 600kVAr in the test system results percentage of real and reactive power loss reduction is 71.6% and 69.8% and every bus voltage lie within the limit.

Figure 3 and 4 give the comparison of real and reactive power loss reduction in all cases.

Figure 5 gives information about real and reactive power loss sensitivity factor of entire system.

Figure 6 gives the voltage profile improvement at every bus in all cases.

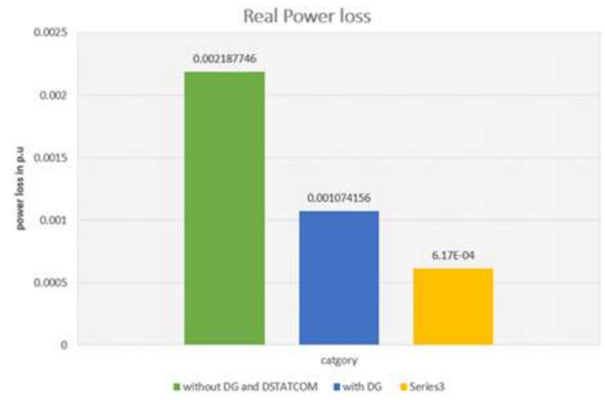

Figure.3. Real power loss

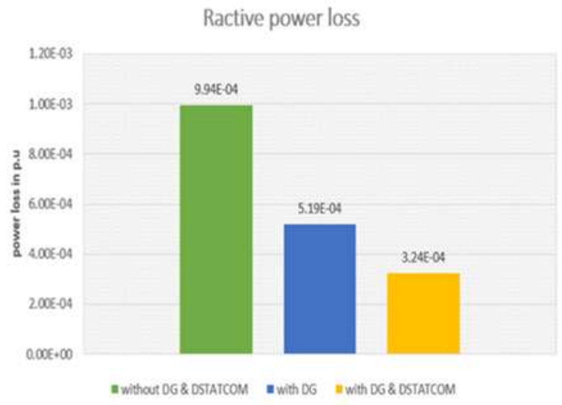

Figure.4. Reactive power loss

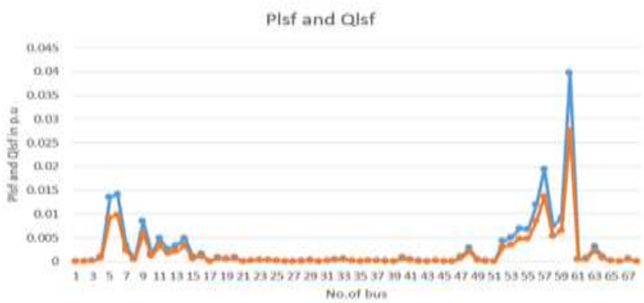

Figure.5. Plsf and Qlsf

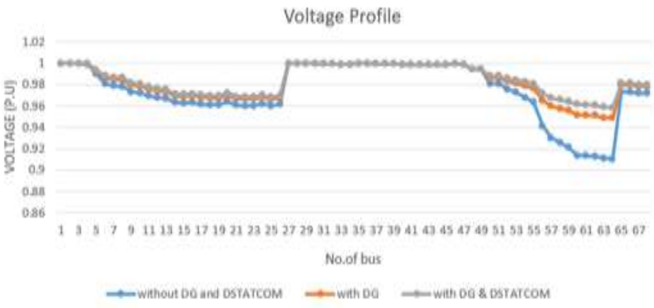

Figure.6. Voltage profile

VI. CONCLUSION

Microgrids and active distribution networks are major research topics nowadays, because it provides self-sufficiency to existing networks and also provides a confines construction of new grid to the far areas where electricity availability is marginal or negligible. There is a necessary to reduce losses in the active distribution network as very small energy is supplied to these grids and reduction in supply resulted due to any kind of losses. In this paper, DG and DSTATCOM are optimally located for real and reactive power loss reduction and voltage profile improvement. From the simulation result concluded that allocating both DG and DSTATCOM at same bus resulted in minimum losses and minimum capacity requirement of DG and DSTATCOM is much better. It is also observed that use of DSTATCOM only results in good voltage profile enhancement with less loss reduction and in the case of only DG placement, high losses reduction with poor voltage profile enhancement. Hence, on the basis of obtained result for both improvement in the entire network voltage profile and minimization of the total real and reactive power losses can be obtained by placing both DSTATCOM and DG at the same bus.

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