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Impact of DG and D-STATCOM placement on improving the reactive loading capability of mesh distribution system

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Abstract

In this paper, Distribution Generation (DG) and Distribution STATic COMpensator (D-STATCOM) are optimally placed in mesh distribution systems using sensitivity approaches. The objective of this paper is to improve the reactive loading capability of the network with maintaining voltage profile in an acceptable limit. Optimal locations of DG and D-STATCOM are determined using Voltage Stability Index and Combined Power Loss Sensitivity approaches respectively. The size of DG and D-STATCOM are determined by variational algorithm subjected to minimization of total power loss. In order to quantitatively analyze the impact of DG and D-STATCOM on voltage stability margin, Q-V curves are drawn using continuation power flow method. In this study the impact of simultaneous placement of DG and D-STATCOM is investigated separately for large industrial motor load as well as industrial load. Also, load growth scenario is considered for better planning of the system. The results are obtained on standard IEEE-33 and 69-bus mesh distribution systems to check the feasibility of proposed methodology.

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Keywords: DG; D-STATCOM; Mesh Distribution system; Optimum location; Optimum size; Voltage Stability Index

1. Main text

Most of the power system loads such as motors, fans, pumps etc, are reactive in nature, which demand reactive power. Since, these loads draw lagging currents the burden of reactive power increases in the distribution system. The reactive power demand increases more in the presence of unbalanced loads. More reactive power demand

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increases feeder losses and also it reduces the capability of active power flow in the distribution system, whereas unbalancing also affects the operation of transformers and generators [1]. As the reactive loading of distribution system increases, voltage profile of the network becomes poor. Voltage collapse is the catastrophic result of a sequence of events leading to a low-voltage profile suddenly in a major part of the power system [2]. Voltage profile of distribution system can be maintained within an acceptable limit by providing reactive power from external compensating devices like capacitor banks, voltage regulators or custom power devices such as static synchronous series compensators (SSSC), D-STATCOM and unified power quality conditioner (UPQC). Among all compensating devices, D-STATCOM has several features, like low power losses, compact size and low cost [3]. Voltage stability is the ability of power system to maintain steady acceptable voltage at all buses in the system at normal operating conditions and after being subjected to a disturbance. A voltage stability indicator is proposed for analysis of voltage stability of distribution system in [4]. DG provides several advantages, such as, economical, environmental and technical and plays a vital role in improving the voltage profile of distribution network [5]. A Q-V curve is used as a technique of voltage stability measurement as in [6, 7]. Voltage stability improvement by placement of wind and solar based DG in distribution system is explained in [8]. Voltage profile of distributed wind generation can be improved with D-STATCOM as in [9].

From the literature survey, it is found that authors have proposed separate placement of DG as well as D-STATCOM in radial distribution system for voltage stability analysis. But, voltage stability analysis for finding critical loading condition with simultaneous placement of DG and D-STATCOM in mesh distribution system (MDS) is hardly available. In this paper, optimal placement of DG and D-STATCOM in MDS is presented using sensitivity approaches for voltage stability analysis to find out the critical loading condition with voltage dependent load models including load growth.

2. Voltage Stability Analysis

Voltage stability is the ability of power system to maintain steady acceptable voltage at all buses in the system at normal operating conditions and after being subjected to a disturbance. Voltage collapse is the catastrophic result of a sequence of events leading to a low-voltage profile suddenly in a major part of the power system. A power system network becomes unstable when voltages uncontrollably decrease due to outage of equipments (generators, lines, bus bars, any major compensating devices etc.), increment of load etc. Main factor causing voltage instability is the inability of the power system to meet the demands for reactive power in the heavily stressed system to keep desired voltages. The mathematical equation of voltage stability analysis is derived in [10]. In this study, Impact of voltage dependent load models and load growth are also considered on the voltage stability analysis. Continuation load flow method is applied to determine critical voltage stability limits in the presence of DG and D-STATCOM.

3. Load Model

Load model will affect voltage instability, reactive power imbalance, power system planning, and availability of shunt devices. Common static load models for active and reactive power are expressed in a polynomial or an exponential form. The characteristic of the exponential load models can be given as:

$$P = P_o \left(\frac{V}{V_o} \right)^{n_p} \quad (1)$$

$$Q = Q_o \left(\frac{V}{V_o} \right)^{n_q} \quad (2)$$

where, n_p and n_q stand for load exponents, P_o and Q_o stand for the values of the active and reactive powers at the nominal voltages. V and V_o stand for load bus voltage and load nominal voltage, respectively. The load exponents for different components are given in [11]. The load growth equation [12] can be given as:

$$Load_i = Load \times (1 + \mathrm{r})^{\mathrm{m}} \quad (3)$$

where, r =annual growth rate, m=plan period in years. In this paper, r=7% and m=5