A REVIEW ON VOLTAGE BALANCING TECHNIQUES IN DISTRIBUTION NETWORK WITH THE IMPACT OF DISTRIBUTED GENERATION

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Abstract: **In present scenario, there is a rapid depletion of conventional energy sources that has led to the development of power generation using renewable energy sources. These renewable energy sources are distributed generators (DGs) feeding power in to the distribution network. However, increased penetration of these DGs in the existing power system has relaxed the burden of power generation by conventional energy sources but at the same time has placed challenges for the power system. Distribution networks are often designed for a different purpose than transmission networks. The main difference is that distribution systems are usually not designed for the connection of power generation devices, e.g. the connection of distributed generation leads to a change in the fault-current, and hence a re-design of local fault protection system might be required. Furthermore, distribution networks have usually a radial or loop design, and not a meshed design like transmission networks. Therefore, the power flow in distribution networks usually is mostly one-directional. This paper discusses a comprehensive review and comparison of various distributed generation schemes used by utilities for mitigation of voltage dips in power networks.**

IndexTerms: DistributedGenerators,DistributionNetwork,Voltagedip

I. INTRODUCTION

DG is defined as electric power generation within distribution networks or on the customer side of the network. [1] Network and connection issues of distributed generation are also presented in the paper. High voltage lines, e.g. transmission lines or urban distribution lines have a low resistance compared to low voltage lines in distribution networks. In transmission lines or urban distribution networks, the effect of line or cable resistance (R) on voltage drop is small, since its specific magnitude is generally much less than the reactance (X). Hence, the reactance is the most important parameter in regards to voltage drop and line losses. In rural distribution systems, however, the resistance in the distribution lines is often larger than, or at least similar to, the inductance. Hence, the distribution line resistance causes a significant proportion of the voltage drop along the distribution lines as well as of the line losses. The connection of distributed generation can therefore have a significant influence on the local voltage level. The voltage rise in the distribution network is the main limitation of increasing the penetration of DG. The effects of DG on the voltage in the distribution network are explained by Fig. 1, where the DG is located where the generator "G" is placed. In this case nominal power is injected from the DG while the load power demand is at its lowest excess generation in the Low Voltage (LV) grid which may lead to a reverse power flow and voltage rise. The opposite scenario is also undesirable when the load demand is at its highest and the DG is at its lowest creating an under voltage. [4]

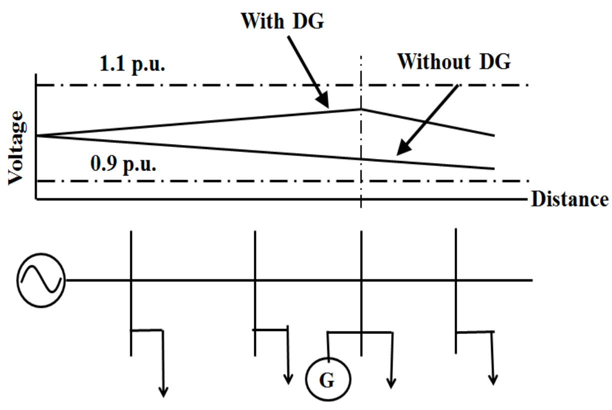

Fig. 1. Effect of DG on the voltage profile of the distribution network

The increasing presence of single-phase distributed generators and unbalanced loads in the electric power system has led to unbalance of the three phase voltages, resulting in increased losses and heating. Increased concern over depletion of fossil fuels has led to the development in technology for renewable energy sources like photovoltaic, wind energy, etc. Voltage fluctuations in the power system mainly result from impedance of transmission lines, loading types and uneven distribution of single-phase loads. The issue becomes more severe in the distribution network due to reverse power flow contributed by distributed generations (DGs) at point of common coupling (PCC) in either three- or single-phase connection. [5]

II. DISTRIBUTED GENERATION AND ISSUES

Ideally, the generated voltages in three-phase power systems are symmetrical. However, the resulting voltages at the point of common coupling (PCC) can be unbalanced for several reasons. The nature of the unbalance includes unequal voltage magnitudes at the fundamental system frequency (under- and over-voltage), fundamental phase angle deviation and unequal levels of harmonic distortion between the phases. Unbalance can result in adverse effects on equipment and on the distribution system. An unbalanced distribution system will be subjected to more losses and heating effects. Voltage unbalance can also have negative effects on equipment such as induction motors, power electronic converters and adjustable speed drives. Avoiding these negative effects requires maintaining a balanced voltage at the PCC. [7] Voltage control is one of the key tasks of distribution system operator, which is required to stay within the permissible limits during all loading conditions in an optimal way. This task is fulfilled using passive methods via on-load tap changer (OLTC) transformers, step voltage regulators, and shunt capacitors in passive distribution networks. In the last years the integration of distributed generators (DGs) in the distribution network has significantly increased. [9] With this increase in the injection of energy from decentralized generators the grid faces new challenges. Energy surplus coming from renewable energy sources may produce a reverse power flow in the network altering the way conventional power systems operate. Due to this the presence of overvoltage and voltage unbalances will be more commonly seen in the grid. [8] Thus utilization of classical compensation methods in active distribution system with different type of DGs is not sufficient alone. Hence, new and advance techniques for voltage control in a distributed generation scenario are need of the day.

There are various issues with Distributed Generation like Anti-Islanding protection, Auto reconnection after a trip, Short circuit capacity AC and DC Isolation, Installation safety requirements, Voltage regulation, Harmonics Flicker, unbalance Over-voltage from direct/indirect lightning Transient overvoltage in grid, DC injection and power factor etc. Conventionally, voltage fluctuations in the power system mainly result from impedance of transmission lines, loading types, and uneven distribution of single-phase loads. [6] This issue becomes more severe in the distribution network due to reverse power flow contributed by distributed generations (DGs) at point of common coupling (PCC).

Voltage regulation at PCC can be achieved by either effectively controlling the converter used for interfacing DGs with the grid or by using voltage source converter based custom power devices like distribution static compensator (DSTATCOM) [2] [3]. Various techniques like Monte Carlo, I-BAVR, Fuzzy, positive & negative sequence control, etc. are used for the effective control of the converter interfacing DGs with the grid, in order to mitigate voltage unbalance issues. Controlling DG by connecting a three phase inverter rather than three single phase inverter for interconnection with the grid also helps in voltage balancing.

III. REVIEWS ON VARIOUS METHODOLOGIES

(a)Inverter topology

This method can be implemented with different control strategies, the effect of connecting DG units by means of a three-phase connection instead of -phase connection on voltage unbalance. When connecting DG units to the grid, it is recommended that the DG is connected by means of a three-phase inverter which is controlled using a three-phase damping control strategy. The inverter will inject power in the grid and will help improve voltage unbalance. [2]

(b)Monte Carlo method

This method is carried to investigate and predict the network voltage imbalance for the uncertainties arising due to rooftop PV power ratings and locations. Based on the numerical results, a generalized characteristic of voltage imbalance of LV residential networks due to rooftop PV installation can be utilized. [3]

(c)Fuzzy Method

Control strategy is implemented by means of two alternative methods. In order to determine how a change of the reactive power affects the voltage, a network sensitivity analysis is performed; the second one is based on the designing of a fuzzy controller. The fuzzy method is more advantageous in comparison with the sensitivity method. (i) it provides a gentle action control with a lower reactive power consumption during control operations as the reactive power profile follows better the voltage variations; (ii) the tuning of the fuzzy controller is independent from the knowledge of network parameters and its topology. [4]

(d)Identification-based adaptive voltage regulation (I-BAVR)

This method Introduces a novel voltage control approach for VSC interfaced DG units known as Identification-based adaptive voltage regulation (I-BAVR), uses real-time identification of the Thevenin equivalent circuit of the system, giving the X/R ratio to identify the active and reactive power dispatch of the DG unit. Pseudo-reactive is effective in determining the right amounts of active and reactive power keeping the PCC voltage level at acceptable levels. The penetration level of the DG unit is not fixed but constantly changes with operating conditions of the network. [5]

(e)Advanced scheme for managing DER in LV networks

The approach developed for voltage control includes an advanced scheme for managing DER in LV networks that may constitute an important tool for the DSO, since it uses various distributed resources that may be available in order to ensure that voltage profiles are kept within admissible limits. A methodology that can help the DSO in controlling the voltage profiles in LV networks while maximizing the integration of renewable microgeneration. [6]

(f)Control strategy for voltage unbalance

Presents a novel power control strategy for voltage unbalance and harmonic compensation in an islanded micro grid consisting of the power-electronics-interfaced DG units. The results demonstrate the effectiveness of the proposed control structure in the unbalance and harmonic compensation of the CLB (Critical Load Bus) voltage and proper power sharing of reactive, unbalanced and harmonic powers among the DG units. [7]

(g)On-load tap-changing transformer control

This method addresses the problem of voltage rise mitigation in distribution networks with distributed generation. A distributed automatic control approach is proposed to alleviate the voltage rise caused by active power injection. This method addresses the problem of voltage rise mitigation in distribution networks with distributed generation. A distributed automatic control approach is proposed to alleviate the voltage rise caused by active power injection. The reactive control relationship with on-load tap-changing transformer control has been illustrated and increased stress in tap changing has been verified when compared to CPF approach. [9]

(h)PMS (Power Management System)-

PMS (Power Management System) in conjunction with suitable voltage control equipment that provides an efficient and robust method for the control of voltage levels and management of reactive power flows has been demonstrated through case study. Generators and tap-changing transformers can be used to control the level of voltage throughout a network. The transformers in the network also influence the direction and magnitude of the reactive component of power that flows to the loads. The reactive control relationship with on-load tap-changing transformer control can be illustrated and increased stress in tap changing has been verified when compared to CPF approach.

(i) A sequence network analysis-based methodology

A sequence network analysis-based methodology, in which separate single-line diagrams are developed for each of the positive-, negative- and zero-sequence systems using the method of symmetrical components. The methodology simplifies the analysis of unbalanced conditions in a polyphase system and provides the straightforward visualization of the propagation of sequence voltages using single-line diagrams.

(j)Voltage source inverters

This method uses voltage source inverters with distributed generation to control the voltage in a distribution network. The method for voltage control can be used to mitigate voltage-control problems associated with embedded generation. The method can be applied to any load or generator with reactive-power control capabilities, like solar panels, micro turbines, but also synchronous-machine-based distributed generation and load with an active front end.

(k)Variable forgetting factor recursive least square (VFFRLS)-based control algorithm

A variable forgetting factor recursive least square (VFFRLS)-based control algorithm is discussed for effective operation of DSTATCOM to estimate weighted values of active and reactive power components of load current. It has been found that the proposed VFFRLS-based control algorithm offers fast convergence and robustness with system parameters. The DSTATCOM with the proposed control algorithm has been found to work well under different loading conditions in PFC and voltage regulation modes.

(l)Methods of sequential convex programming (SCP)

This method demonstrates how reactive power injection from distributed generators can be used to mitigate the voltage/VAR control problem of a distribution network. a suboptimal approach is proposed based on methods of sequential convex programming (SCP). The proposed approach provides a near optimal solution with much lower computation complexity (runtime) relative to a global solver based on branch and bound method. This method focuses on reactive power minimization, the effect of voltage/VAR on system losses is not considered while optimizing the control problem.

IV.PROBLEM DEFINITION AND OBJECTIVES OF RESEARCH WORK

The increasing presence of single-phase distributed generators and unbalanced loads in the electric power system has led to unbalance of the three phase voltages, resulting in increased losses and heating. Increased concern over depletion of fossil fuels has led to the development in technology for renewable energy sources like photovoltaic, wind energy, etc. Voltage fluctuations in the power system mainly result from impedance of transmission lines, loading types and uneven distribution of single-phase loads. The issue becomes more severe in the distribution network due to reverse power flow contributed by distributed generations (DGs) at point of common coupling (PCC) in either three- or single-phase connection.

Voltage regulation in the power system could be realized by using an on-load tap changer (OLTC) or a static VAR compensator (SVC) at substations, and a step voltage regulator or a switched capacitor on feeders. With the help of these devices, the voltage profile could be improved on a real-time base. With the advancement of semiconductor technologies, voltage-source converter based solutions, such as static synchronous compensator (STATCOM), unified power flow controller (UPFC), distributed STATCOM (D-STATCOM), and active power filter (APF), have been realized practically. Where, STATCOM and UPFC provide the solution for system control at transmission level, D-STATCOM and APF are used at distribution level. The distribution system integrated with distribution static compensator (DSTATCOM), shown in Fig. 2 is effectively examined to control harmonics, to meet the reactive power demand of load as well as for voltage regulation under balanced and unbalanced loads. The Objectives of Research work are to develop Control technique for inverter interfacing the DGs with the grid for effective voltage regulation and also to develop Control technique for custom power device DSTATCOM for effective voltage regulation under power system scenario with DGs.

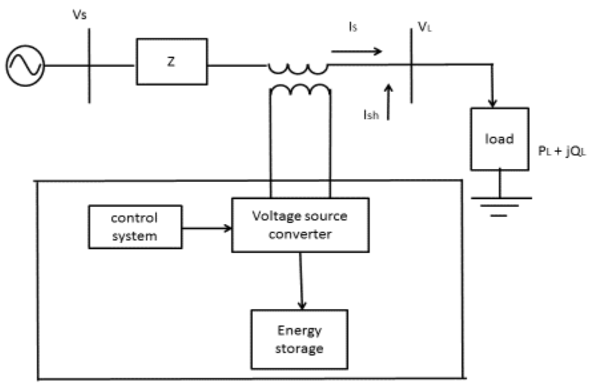

Fig 2. DSTATCOM Schematic Diagram

V. Conclusion and Future Work

Various control techniques like least mean square, least mean eight, learning vector quantization, artificial neural network, etc., are reported for improving the performance of DSTATCOM. However, these conventional techniques face challenges like involvement of more number of sensors and multipliers, sluggish response of the controller, less competent under various balanced, unbalanced and distorted or any possible choice of supply and loading condition. Hence development of effective control technique which enables the DSTATCOM to provide a versatile solution in any supply or load condition is need of the day. Control technique for inverter interfacing the DGs with the grid for effective voltage regulation can be developed. Control technique for custom power device DSTATCOM for effective voltage regulation under power system scenario with DGs can be developed. The proposed research work is focused on development of novel strategies for control of inverters of DGs which will effectively regulate voltage at distribution level. The proposed research work will lead to development of control technique for DSTATCOM which will enable its effective operation for distributed generation scenario.

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