Power Quality and Reliability improvement with Voltage Control for Radial Distribution Networks in Ghana

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Abstract

This work addresses the issue of power quality and reliability problems caused by voltage sag and swell with precise voltage control test system for medium-voltage radial distribution networks. The installation of distribution static synchronous compensator is analyzed and the steady state performance of both capacitor bank and DSTATCOM is determined and compared for various values of voltage sag and swell, loading level and system fault level. All simulations are performed and analyzed using PSCAD/EMTDC simulation software.Simulation results are presented to show theaccuracy and optimum performance of each device as a potential power quality and reliability improvement.

Keywords: Power quality, reliability, DSTATCOM, capacitor bank, PWM, PLL, voltage source converter, PI controller, voltage sag and swell.

1. Introduction

Voltage magnitude is one of the main factors that is affecting the quality and reliability of power supply in the Akuapim Ridge area in Ghana. The area was connected to the national grid for the past thirty-eight years and customers in the area cannot enjoy continuous power supply for even a week without power outage due to voltage sag, voltage swell or fault. This is because the existing network serving the area is a long 11KV radial distribution network leading to poor power quality and unreliable power supply to consumers. As a result of these problems, living standard and economic development in the area are deeply affected.

The most important power quality and reliability problems faced by many industries, utilities, and consumers are outages due to voltage sag and swell[1, 2].Millions of dollars are lost each year around the world due to these problems. The changes in voltage are generally caused due to the variation of load on the system [3]. For these reasons, analyses of a good distribution system are very important to ensure that the voltage variations at consumer's terminals are within permissible limits (i.e. ±10% of rated voltage).

In general, system reliability decreases as equipment loading increases. System reliability is reduced if less equipment capacity exists in the system. We propose power electronic converter systems as an attractive alternative, with their potential to provide both steady state and transient voltage compensation for a limited capital investment [4]. In this paper, DSTATCOM device is used with P I controller and

PWM to enhance power quality and reliability in medium-voltage radial distribution system.

2. Principles of DSTATCOM

The DSTATCOM is a solid-state dc to ac switching power converter that consists of a three-phase voltage-sourced inverter. A typical configuration of a voltage source converter based STATCOM is shown in Figure 1.

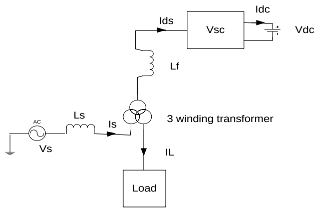

Figure 1: VSI based DSTATCOM

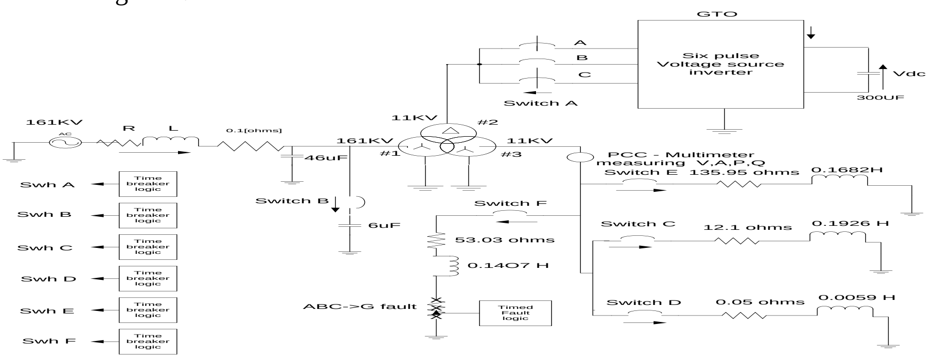

Figure 2: Test system for six-pulse distribution STATCOM for voltage control

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3. Simulation and Results Analyses

Figure 3 shows the test system implemented in PSCAD/EMTDC to carry out simulations for the DSTATCOM. The test system comprises of a 161/11KV, 100MVA, 50Hz transformer connected to a radial distribution networks, using the system voltages and frequency in Ghana. The 161KV transmission line represented by a thévenin equivalent is feeding into the primary side of a 3-winding transformer. A varying load is connected to the 11 kV secondary side of the transformer. A two-level DSTATCOM is connected to the 11kV tertiary winding to provide instantaneous voltage support at the load point. A 300 μF capacitor on the dc side provides the DSTATCOM energy storage capabilities. A 46 μF capacitor bank at the high voltage side is chosen as optimum value by simulation to aid minimum voltage regulation for the system. The six set of switches shown in Figure 2 were used for various loading scenarios under the simulations. A multimeter (shown in Fig. 2) is use to measure the rms voltage, active power and reactive power at the point of common connection. To show the effectiveness of this controller in providing continuous voltage regulation, simulations were carried out with no DSTATCOM, with DSTATCOM, with capacitor bank and with three-phase to ground fault in the system. A set of simulations were performed under several operating conditions.

For the simulation period 800–1000 ms, before DSTATCOM, the load is increased by closing Switch C and D. The voltage drops by almost 16% with respect to the reference value, after the simulation time 1000ms, keep the switch C and D open, the load voltage is close to the reference value, i.e., 1 pu. Result is shown in Figure 3a.

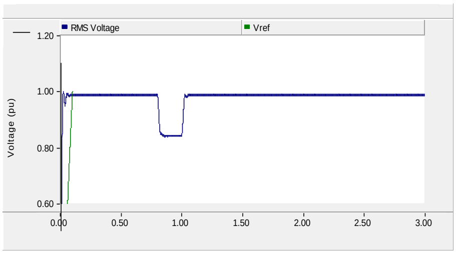

Fig. 3a: RMS voltage before DSTATCOM

For the simulation period 1200–1500 ms, before DSTATCOM, Switch B is closed which connected additional capacitor to the high voltage side of the network. The rms voltage increases by 7% with respect to the reference voltage as shown in Figure 3b.

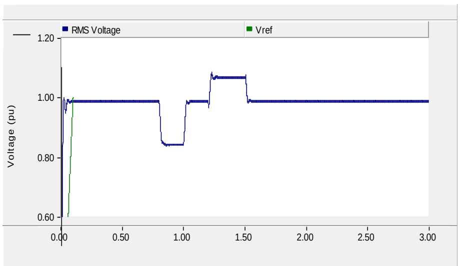

Fig.3b: RMS voltage before DSTATCOM

For the simulation period 2000 – 2850ms, a three-phase to ground fault is applied. The rms voltage decreases by only 3% as shown in Figure 3c.

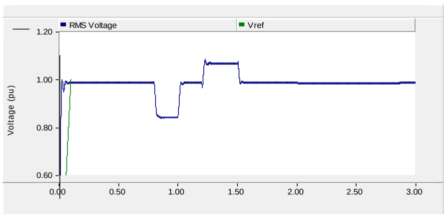

Fig.3c: 3-phase fault before DSTATCOM

After the DSTATCOM connected to the system, the rms voltage is close to the reference value as shown in Figure 3d.

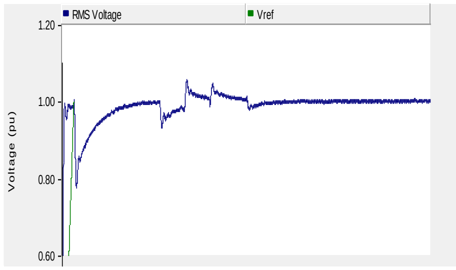

Fig. 3d: RMS voltage after DSTATCOM

Here, it can be seen that, the radial distribution system is heavily loaded but, with the DSTATCOM connected to the system, the voltage variations are still less than ± 10% of Voltage. When*switch E*, *switch F* load and the 46 μF capacitor are connected with no DSTATCOM and the 6 μF capacitor, the rms voltage is almost close to 1pu as shown in Figure 3e, and these satisfied the IEEE recommendations and guidelines on voltage variations for power quality.

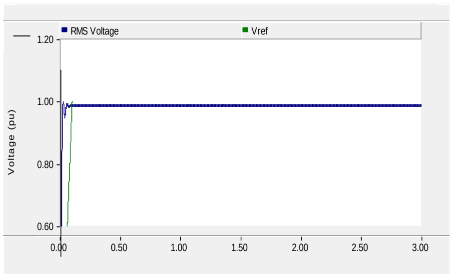

Fig.3e: RMS voltage with only 46 μF capacitor connected before DSTATCOM.

With all switches closed at simulation period 10 – 3000ms, and the fault occurring at 2000 – 2850ms. The rms voltage is almost equal to the reference value as shown in Figure 3f, where the effective voltage regulation provided by the DSTATCOM can be clearly appreciated.

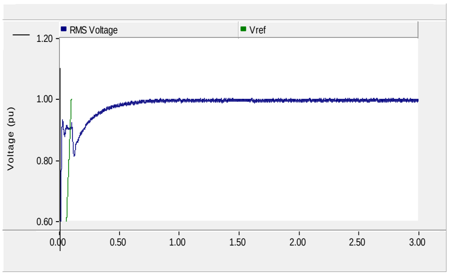

Fig.3f: RMS voltage after DSTATCOM

In spite of sudden load variations, the regulated rms voltage shows a reasonably good result, where the transient overlaps is almost omitted.

The graph indicating DC voltage, active power and reactive power after DSTATCOM is connected to the system is shown in Figure 3g respectively.

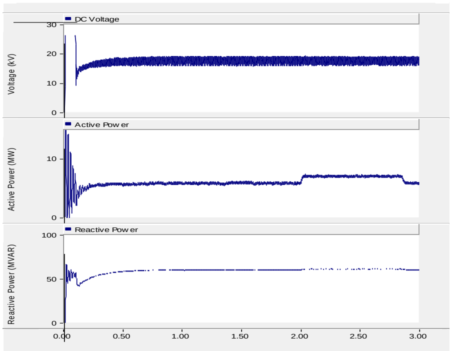

Fig. 3g: DC voltage, P, &Q after DSTATCOM.

4. Conclusions

This paper has presented electromagnetic transient modelsof capacitor bank and DSTATCOM and applied them to the study of power quality and reliability. A new PWM-based control scheme has been implemented to control the electronic valves in the two-level VSI used in theDSTATCOM. The control scheme was tested under a wide range of operating conditions, and it was observed to be very efficient in every case. The fault detection technique used in the paper is very simple and has proved to be very effective. The DSTATCOM eliminated the voltage sag and swell conditions of the ac bus voltage at the point of common connection, thus improving the quality and reliability of power supply at the distribution side. It is also hope that this study if implemented in Akuapim Ridge area will provide solutions to the concern of voltage regulation leading to power quality and reliability improvements to consumers.

5. References

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