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Simulation of Voltage Regulation in The Distribution Network Using Distribution Static Compensator

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Abstract

Power electronic converters such as dynamic voltage restorer (DVR), distribution static compensator (DSTATCOM), and unified power quality conditioner (UPQC) can zero voltage regulation, eliminate harmonics, reactive power compensation and unbalancing on both the source and load side of the system. The distribution static compensator is the distribution flexible ac transmission system (FACTS) device. It is an important device in a distribution network that used for maintaining constant distribution voltage, correcting power factor, and mitigating harmonics. This paper describes the application of a distribution static compensator for reactive compensation in electric distribution networks, to regulation voltage. Simulated performance of distribution static compensator is presented at varying conditions. The performance of the system has been considered for two cases: change in the source voltage (variable load is constant) and change in the load (voltage source is constant). At the end, the result of simulation with Matlab Simulink software has been presented.

Keywords: distribution static compensator, regulation voltage, distribution network
Article history: Received 20-Mar-2022; Revised 23-Mar-2022; Accepted 25-Mar-2022. Article Type: Research paper

https://doi.org/10.30495/ijsee.2022.1955401.1185

1. Introduction

The integration of renewable energy, the growth of non-linear industrial and commercial loads leads to various power quality issues [1-7]

Mainly the power quality problems are-high harmonic in distribution system, voltage transients, voltage flicker, low power factor, active power and reactive power [8,9]. The commonly used terms those describe the parameters of electrical power that describe or measure power quality are sags, swells, interruptions, harmonics etc. are shown in Fig. 1 [10].

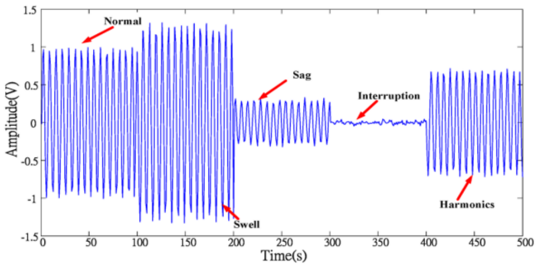

Fig. 1. Power quality problems

In recent years, power quality is one of the most important issues for the proper operation of industrial processthat have sensitive and critical loads [11-13].

Various sources attenuate power quality, such as electric arc furnaces, adjustable speed drives, lightning strikes, large motors, switching power supplies, electronic fluorescent lamp ballasts, electronic power devices, and nonlinear loads [14-18].

To solve the power quality problem, electronic power devices such as FACTS and custom power devices that are used in transmission and distribution control, respectively, should be developed [19-22].

There are many types of custom power devices such as active power filter [23], static var compensator [24], dynamic voltage regulator [25] and uninterruptible power supply [26]. Custom electrical devices can be classified into two main categories: grid configuration type and compensating type.

Static distribution power compensator (DSTATCOM) is used to compensate for reactive power in electrical distribution networks [27,28].

This device has an advantage over conventional capacitors because it prevents power surges. And is able to make a continuous compensation that reaches a power factor close to one.

Various research papers have been done on the subject of improving the power quality of the distribution system using the DSTATCOM [29-31].

An implementation of a three phase DSTATCOM using a back propagation control algorithm for its functions such as harmonic elimination, load balancing and reactive power compensation, and zero voltage regulation is presented in [32], which a prototype of DSTATCOM is developed using a digital signal processor, and its performance is studied under various operating conditions.

Voltage sags are the most important power quality problem facing many industrial customers. The modelling of two types FACTS devices, DSTATCOM and SVC, to minimize the voltage sag induced financial losses is presented in [33], which a real Indian distribution system are used to illustrate the effectiveness of these devices.

A voltage-controlled DSTATCOM-based voltage regulator for low-voltage distribution grids is presented in [34], which the control strategy has three output voltage loops with active damping and two dc bus voltage loops.

An optimal placement and sizing of DSTATCOM in radial distribution networks as multi-objective optimization is presented in [35], which that the objective is power loss reduction, voltage profile improvement and network reliability considering different variable demands using whale optimization algorithm.

A VSC-based DSTATCOM is implemented in [36] using an adaptive neural network-based control algorithm for harmonic suppression, load balancing, and voltage regulation in a three-phase synchronous reluctance generator system with battery power, which this control algorithm is used for extraction of active and reactive power components of distorted load currents.

A method to optimize dc-link voltage of DSTATCOM based on load compensation requirement using reduced switch count multilevel converter integrated with photovoltaic system is proposed in [37]. Which, this method is capable of compensating reactive power, unbalance, and harmonics demanded by three-phase unbalanced and nonlinear loads connected to the distribution side, leading to improvement of power quality.

In [38] utilizes interval type-2 fuzzy logic controller with recursive least square filter for generating switching pulses for IGBT switches in the DSTATCOM to improve power quality in the local distribution grid, which, he proposed approach shows superior performance over type 1 fuzzy logic controller and conventional PI controller in mitigating harmonics.

The functions of DSTATCOM are current harmonics elimination, compensation of reactive power, and load balancing in power factor correction and voltage regulation modes. This paper investigates the use of a DSTATCOM for regulating voltage in a distribution network. The performance of the system has been considered with linear and non-linear loads.

2. Distribution Static Compensator

DSTATCOM is a shunt-connected voltage source converter (VSC) used to compensate for bus voltages in distribution networks to improve power factor and reactive power control. DSTATCOM has the ability to quickly and continuously compensate for capacitive and inductive states [39,40]. it is controlled as a current source by use of PWM switching. Also, it can act as either a source or sink of reactive ac power to an electricity grid. If connected to a source of power, it can also provide active ac power. It is inherently modular and electable [41,42].

3. Description Power System

DSTATCOM is connected in shunt at the near load to protect critical loads from all load side disturbances. The block diagram of a DSTATCOM coupled with a 25 KV distribution system simulated in Matlab Simulink is show in Fig. 2.

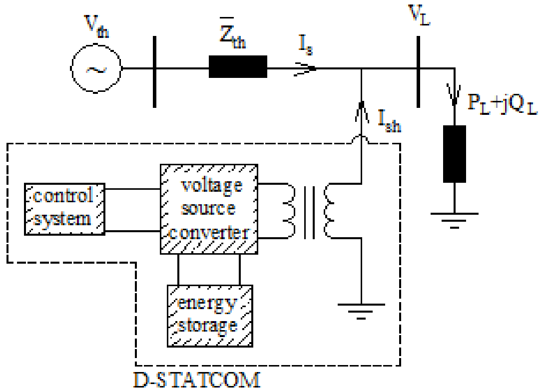

Fig. 2. Shunt D-STATCOM schematic diagram

A shunt capacitor is used for power factor correction at bus B2. Two feeders 21 Km and 2 Km transmit power to loads connected at bus B3 through a 25 KV/600V transformer. The DSTATCOM regulates bus B3 voltage by absorbing or generating reactive power. This reactive power transfer is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage. This voltage is provided by a voltage-sourced PWM inverter. When the secondary voltage is lower than the bus voltage, the DSTATCOM acts like an inductance absorbing reactive power. When the secondary voltage is higher than the bus voltage, the DSTATCOM acts like a capacitor generating reactive power. DST-ATCOM modeled in Matlab Simulink is show in Fig. 3. It consists of a dc capacitor, ac filter, coupling transformer, three-phase inverter and a control strategy.

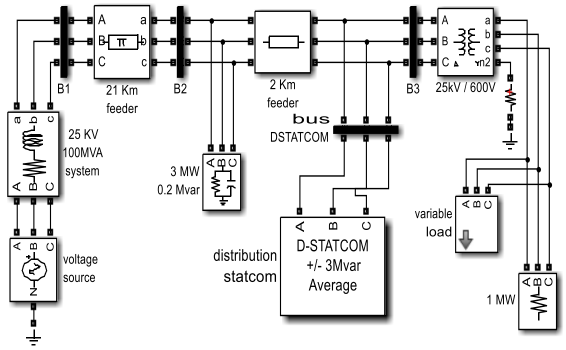

Fig. 3. Block diagram of a DSTATCOM simulated in Matlab Simulink software

4. Simulation Results

Three cases of a distribution system were simulated using Matlab software Simulink. The performance of the system has been considered for two cases: change in the source voltage and change in the load. The dc link voltage is 2.4 KV. The sample time is 40 μs and PWM switching frequency is 1.68 KHz.

A. *Change in the source voltage*

During this case the variable load is constant. The dynamic response of a DSTATCOM to step changes in source voltage is shown. The constant resistive load (600 V and 1 MW) connected to bus B3 represents a plant absorbing continuously changing currents, similar to an arc furnace, thus producing voltage flicker. Three steps are programmed at 0.15 s, 0.3 s, and 0.45 s to successively increase the source voltage by 6%, decrease it by 6% and bring it back to its initial value 1 pu. The DSTATCOM controller is in the voltage regulation mode. At 0.15 s, the DSTATCOM compensates for this voltage increase by absorbing reactive power from the network (+2.7 MVAR) as shown in Fig. 4. At 0.3 s, the DSTATCOM must generate reactive power to maintain a 1.07 pu voltage. The reactive power is change from +2.7 MVAR to -2.8 MVAR. When the DSTATCOM changes from inductive to capacitive operation, the modulation index of the PWM inverter as shown in Fig. 5 is increased from 0.56 to 0.9 which corresponds to a proportional increase in inverter voltage. Reversing of reactive power is very fast, about one cycle, as observed on DSTATCOM current (Fig. 6). The DSTATCOM regulates bus B3 voltage by absorbing or generating reactive power (Fig. 7).

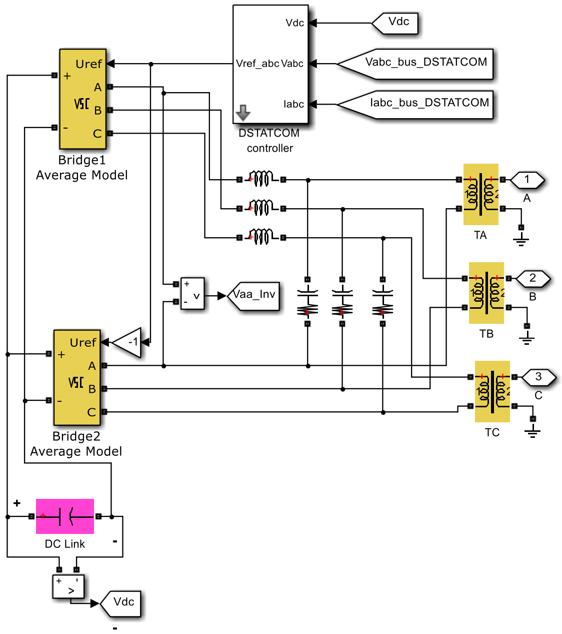

Fig. 4. DSTATCOM average model in Matlab Simulink software

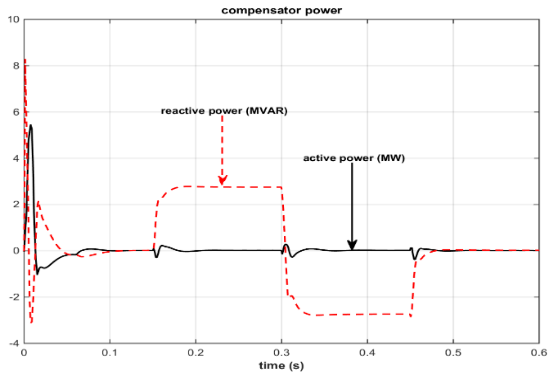

Fig. 5. Active and reactive power for DSTATCOM under source voltage change

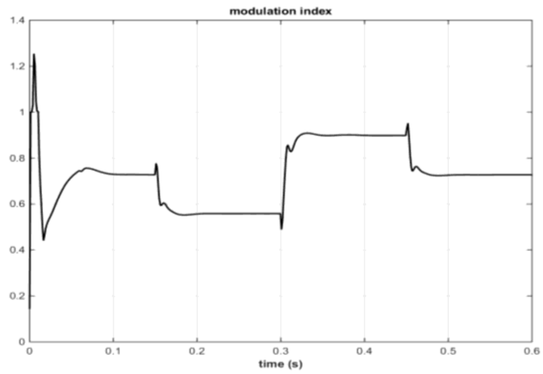

Fig. 6. Modulation index under source voltage change

 ISSN: 2251-9246
EISSN: 2345-6221

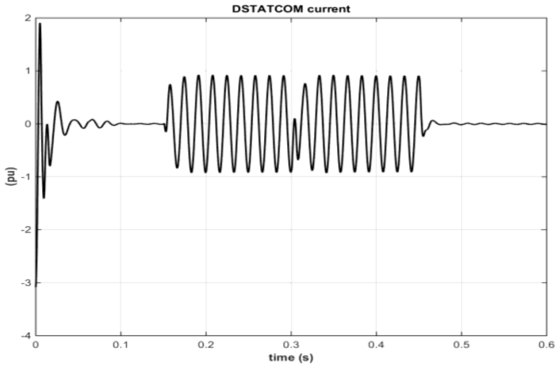

Fig. 7. DSTATCOM current under source voltage change

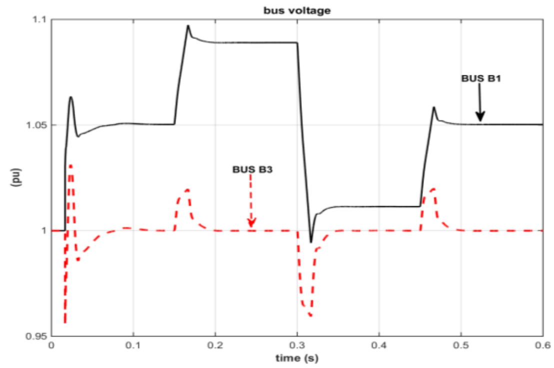

Fig. 8. Voltage at buses 1 and 3 under source voltage change

B. *Variable load*

The variable load current magnitude is modulated at a frequency of 5 Hz so that its apparent power varies approximately between 1 MVA and 5.2 MVA, while keeping a 0.9 lagging power factor. During this case, voltage source is constant and the effect of DSTATCOM on mitigate voltage flicker is shown. The variable load applied between 0.2 s and 0.8 s. The variation voltages at buses B1 and B3 are show in Fig. 8 and power variation at bus B3 is show in Fig. 9. Without DSTATCOM, B3 voltage varies between 0.96 pu and 1.04 pu (+/- 4% variation). The voltage fluctuation at bus B3 is reduced to +/-0.7%. The DSTATCOM compensates voltage by injecting a reactive current modulated at 5 Hz as shown in Fig. 10 and varying between 0.6 pu capacitive when voltage is low and 0.6 pu inductive when voltage is high.

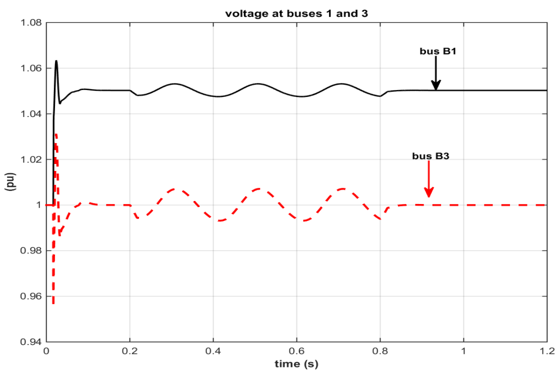

Fig. 9. Voltage at buses 1 and 3 under variable load

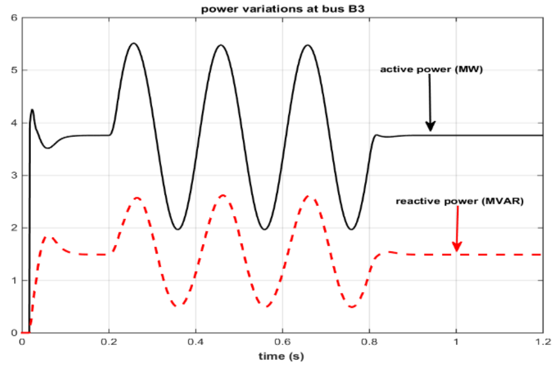

Fig. 10. Power variation at bus B3 under variable load

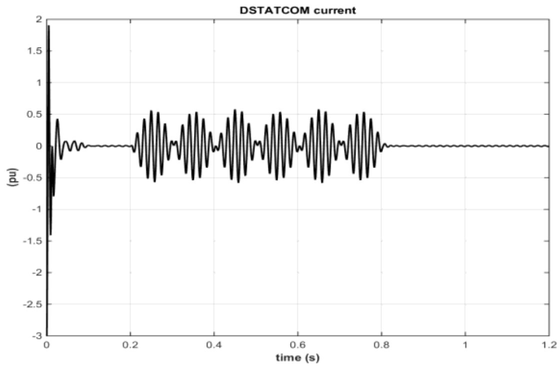

Fig. 11. DSTATCOM current under variable load

5. Conclusion

DSTATCOM is used as a solution for harmonic reduction, load balancing, reactive power imbalance and neutral current compensation in the distribution network. It is a shunt compensator device that is fast and continuous adjustable device. In this paper the applications of DSTATCOM to regulate voltage on a distribution network is studied. According to the simulation results the capability of the DSTATCOM in presence of variable load and change in voltage source are investigated and the ability of the compensation system is highlighted. To evaluate the compensatory effect, the proposed system is simulated using MATLAB software.

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