Simulation of STATCOM Devices in PSCAD for Voltage Regulation

Kshatriya krishnakumar v, Prof. H. S. DARJI
U.V. Patel college of engineering Ganpat university

Abstract

This paper addresses the timely issue of modeling and analysis of custom power controllers, a new generation of power electronics-based equipment aimed at enhancing the reliability and quality of power flows in low-voltage distribution networks. The modeling approach adopted in the paper is graphical in nature, as opposed to mathematical models embedded in code using a high-level computer language. The well-developed graphic facilities available in an industry standard power system package, namely PSCAD/EMTDC, are used to conduct all aspects of model implementation and to carry out extensive simulation studies. Graphics-based models suitable for electromagnetic transient studies are presented for the following three custom power controllers: the distribution static compensator (D-STATCOM), the dynamic voltage restorer (DVR), and the solid-state transfer switch (SSTS). Comprehensive results are presented to assess the performance of each device as a potential custom power solution.

1. Introduction

The last decade has seen an increase on the extension of equipment that is highly sensitive to poor quality electricity supply. Several large industrial users are reported to have experienced large financial losses as a result of even minor lapses in the quality of electricity supply[1]. Many efforts have been made to remedy the situation with solutions based on the use of the latest power electronic technology [2]. At present, a wide range of very flexible controllers are emerging for power system applications. Among these, the distribution Static Compensator (D-STATCOM) and the Dynamic Voltage Restorer (DVR), both of them based on the VSC principle has been used in this paper to perform the modeling and analysis of such controllers for a wide range of operating conditions .

PSCAD/EMTDC's highly developed graphical interface has proved instrumental in implementing the graphics-based PWM control reported in this paper for the D-STATCOM and DVR. It relies only on voltage measurements for its operation, i.e., it does not require reactive power measurements. A sensitivity analysis is carried out to determine the impact of the dc capacitor size on D-STATCOM performance. In the case of the DVR, a constant dc source is assumed to provide the dc voltage; therefore, this analysis is not considered. With respect to the SSTS, the control scheme is implemented based on the detection of a fault condition developing in the energy supply system.

2. PSCAD/EMTDC SIMULATION TOOL

PSCAD/EMTDC is an industry standard simulation tool for studying the transient behavior of electrical networks. Its graphical user interface enables all aspects of the simulation to be conducted within a single integrated environment including circuit assembly, run-time control, analysis of results, and reporting. Its comprehensive library of models supports most ac and dc of power plant components and controls, in such a way that FACTS, custom power, and HVDC systems can be modeled with speed and precision. It provides a powerful resource for assessing the impact of new power technologies in the power network.

Simplicity of use is one of the outstanding features of PSCAD/EMTDC. It's great many modeling capabilities and highly complex algorithms and methods are transparent to the user, leaving him free to concentrate his efforts on the analysis of results rather than on mathematical modeling. For the purpose of system assembling, the user can either use the large base of built-in components available in PSCAD/EMTDC or to its own user-defined models. Indeed, the thrust of this paper is to share with the large PSCAD/EMTDC user community our user-defined models for custom power applications, which are not yet available as standard models within PSCAD/EMTDC. In this respect, one of the aims of the paper is to act as a tutorial in the subject of custom power modeling using PSCAD/EMTDC[3].

IJERT

3. FACTS DEVICES

A. D-STATCOM

In its most basic form, the D-STATCOM configuration consists of a VSC, a dc energy storage device, a coupling transformer connected in shunt with the ac system, and associated control circuits. Fig.1 shows the basic configuration of D-STATCOM[1,4].

The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system.

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes[1]:

1) Voltage regulation and compensation of reactive power
2) Correction of power factor
3) Elimination of current harmonics.

The design approach of the control system determines the priorities and functions developed in each case. In this paper, the D-STATCOM is used to regulate voltage at the point of connection. The control is based on sinusoidal PWM and only requires the measurement of the rms voltage at the load point as explained in Section 4.

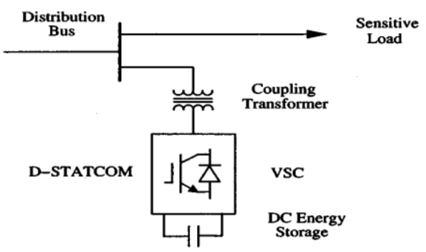


Fig.1 Schematic representation of the D-STATCOM as a custom power device

B. Dynamic Voltage Restorer (DVR)

The DVR is a powerful controller that is commonly used for voltage sags mitigation at the point of connection. The DVR employs the same blocks as the D-STATCOM, but in this application the coupling transformer is connected in series with the ac system, as shown in Fig 2

The VSC generates a three-phase ac output voltage which is controllable in phase and magnitude. These voltages are injected into the ac distribution system in order to maintain the load voltage at the desired voltage reference.

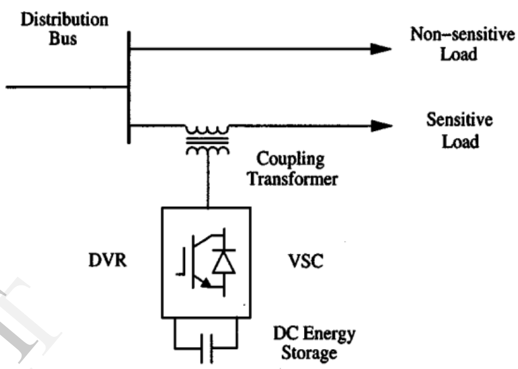


Fig.2 Schematic representation of the DVR for a typical custom power application.

C. Solid -State Transfer Switch (SSTS)

The SSTS can be used very effectively to protect sensitive loads against voltage sags, swells and other electrical disturbances [1]. The SSTS ensures continuous high-quality power supply to sensitive loads by transferring, within a time scale of milliseconds, the load from a faulted bus to a healthy one. The basic configuration of this device consists of two three-phase solid-state switches, one for the main feeder and one for the backup feeder as shown in schematic diagram of Fig.3

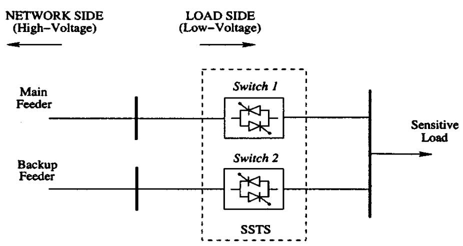


Fig.3 Schematic representation of the SSTS as a custom power device.

Each time a fault condition is detected in the main feeder, the control system swaps the firing signals

IJERT

to the thyristors in both switches, i.e., Switch 1 in the main feeder is deactivated and Switch 2 in the backup feeder is activated. The control system measures the peak value of the voltage waveform at every half cycle and checks whether or not it is within a prespecified range. If it is outside limits, an abnormal condition is detected and the firing signals to the thyristors are changed to transfer the load to the healthy feeder.

4.Simulation of D-STATCOM

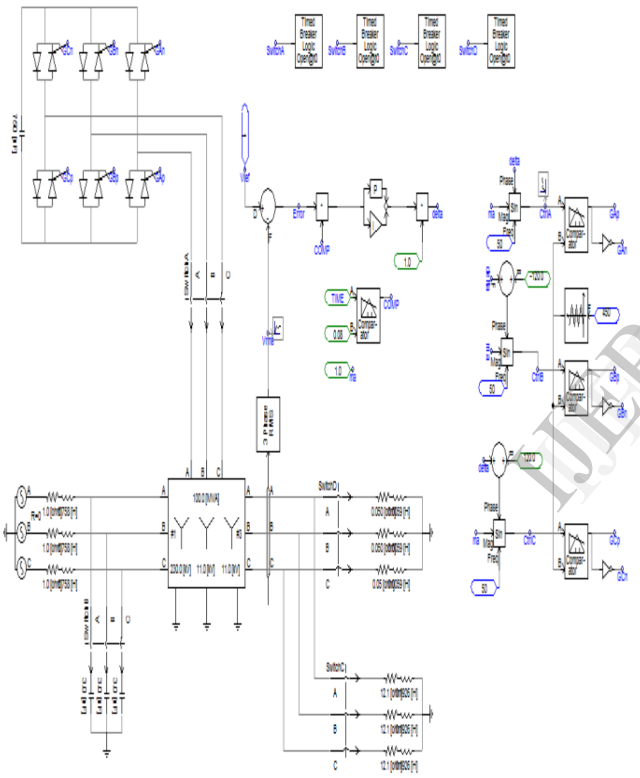
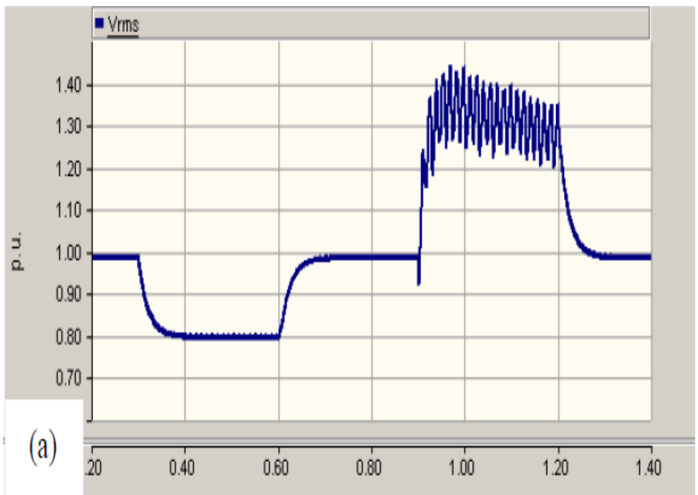


Fig 4. Control scheme and test system implemented in PSCAD/EMTDC to carry out the D-STATCOM simulations.

Fig. 4 shows the test system implemented in PSCAD/EMTDC to carry out simulations for the D-STATCOM. The test system comprises a 230 kV transmission system, represented by a Thévenin equivalent, 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 D-STATCOM is connected to the 11 kV tertiary winding to provide instantaneous voltage support at the load point. A 750µ F capacitor on the dc side provides the D-STATCOM energy storage capabilities. The set of switches shown in Fig. 4 were used to assist different loading scenarios being simulated with ease. To show the effectiveness of this controller in providing continuous voltage regulation, simulations were carried out with and with no D-STATCOM .connected to the system. A set of simulations were carried out for the test system shown in Fig. 4. The simulations relate to three main operating conditions.

1) In the simulation period 300–600 ms, the load is increased by closing Switch D. In this case, the voltage drops by almost 27% with respect to the reference value.
2) At 600 ms, the switch D is opened and remains so throughout the rest of the simulation. The load voltage is very close to the reference value, i.e., 1 pu.
3) In the simulation period 900–1200 ms, *Switch B* is closed, connecting a capacitor bank to the high voltage side of the network. The root mean square (RMS)voltage increases 27% with respect to the reference voltage.



IJERT

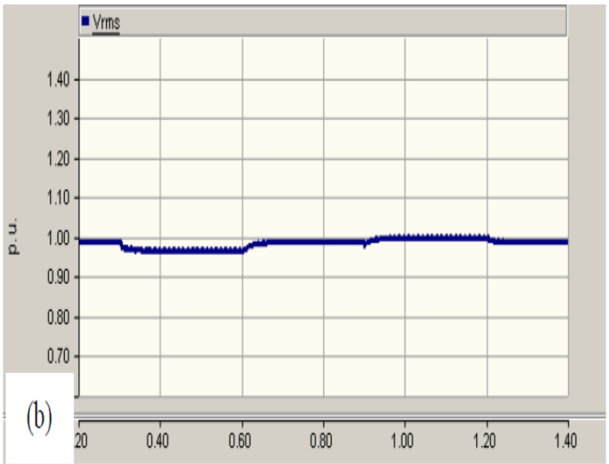


Fig.5 Voltage V_{rms} at the load point: (a) with no D-STATCOM and (b) with D-STATCOM; capacitor size: 750µF

Fig. 5(a) shows the rms voltage at the load point for the case when the system operates without D-STATCOM. Similarly, a new set of simulations were carried out but now with the DSTATCOM connected to the system. The results are shown in Fig. 5(b). Here the very effective voltage regulation provided by the D-STATCOM can be clearly appreciated. When the Switch D closes, the D-STATCOM supplies reactive power to the system, and when Switch D opens and Switch B closes, the D-STATCOM absorbs reactive power in order to get the voltage back to reference. In spite of sudden load variations, the regulated rms voltage shows a reasonably smooth profile, where the transient overshoots are almost nonexistent. The magnitude of these transients is kept very small with respect to the reference voltage. In fact, they do not last for more than two cycles.

5. Conclusions

This paper presented the operation of D-STATCOM for voltage control. The simulation is done using PSCAD software. A new PWM-base control scheme has been implemented to control the electronic values in the VSC used in the DSTATCOM. As opposed to fundamental frequency switching schemes already available in the PSCAD, this PWM control scheme only requires voltage measurement. This characteristic makes it ideally suitable for low-voltage custom power applications. The control scheme was tested under a wide range of operating conditions, and it was observed to be very robust in every case. The simulations showed for variation of sensitive load rms voltage with D-STATCOM and without D-STATCOM. The simulations carried out shows that the D-STATCOM provides excellent voltage regulation capabilities. Similarly, the other FACTS devices described in the paper can be used for voltage control purpose like D-STATCOM.

6. References

[1]O. Anaya-Lara, E. Acha, “Modeling and analysis of custom power systems by PSCAD/EMTDC”, *IEEE Trans. on Power Delivery*, Vol. 17, No. 1, pp.266-272, January 2002.

[2] Hojat Hatami, Farhad Shahnia, Afshin Pashaei, S.H. Hosseini, “Investigation on D-STATCOM and DVR Operation for Voltage Control in Distribution Networks with a New Control Strategy”

[3]Manitoba HVDC Research Centre, “PSCAD/EMTDC: Electromagnetic transients program including dc systems,” 1994.

[4] Dipesh. M .Patel, Dattesh Y. Joshi, Sameer H. Patel, Hiren S. Parmar, “Operation of D-STATCOM for Voltage Control in Distribution Networks with a New Control Strategy”, *National Conference on Recent Trends in Engineering & Technology* 13th & 14th May-2011.

IJERT