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Comparative Analysis of VSC-Based Series Compensator (DVR) and Shunt Compensator (DSTATCOM) Used for Voltage Improvement in Distribution Network

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Abstract

In this paper, the performance of voltage-source converter-based shunt and series compensators used for load voltage control in electrical power distribution network has been analyzed and compared, when a nonlinear load is connected across the load bus. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications. Among these, the distribution static compensator (DSTATCOM) and Dynamic Voltage Restorer (DVR) are most effective devices, both of them based on the VSC principle. A DVR injects a voltage in series with the system voltage and DSTATCOM injects a current into the system to correct the voltage sag, swell, and interruption. Comprehensive results are presented to assess the performances of each device as a potential custom power solution. The effect of various network parameters on the control performance of the compensator can be studied using the proposed analysis. In particular, the performance of the two compensators is compared with the ac supply distribution network. The MATLAB simulation verification of the results derived has been obtained using a model of the three-phase DSTATCOM and DVR.

Keywords- *Distribution static compensator (DSTATCOM), dynamic voltage restorer (DVR), Flexible Alternating Current Transmission System, (FACTS), load voltage control, nonlinear load.*

I. INTRODUCTION

The main objective of this paper is to show that using DISTRIBUTION STATCOM (DSTATCOM) and Dynamic Voltage Restorer (DVR) it is possible to reduce the voltage fluctuations like sag and swell conditions in distribution systems. The DSTATCOM which can be used for improving power quality is modeled and simulated using proposed control strategy and the performance is compared by applying it to a Single-machine infinite bus system. Similarly, DVR which is used for improving power quality is modeled and simulated using proposed control strategy and the performance is compared by applying it to a Single-machine infinite bus system with and without DVR. MATLAB®R2009a version 7.8.0.347(64-bit) is used for Simulation of DVR and DSTATCOM model.

II. DYNAMIC VOLTAGE RESTORER (DVR): A SERIES VOLTAGE CONTROLLER

A series compensator is a dual of the shunt compensator – it protects a sensitive load from the distortion in the supply side voltage. By inserting a voltage of required magnitude and frequency, the series compensator can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted. Usually, a series compensator is used to protect sensitive loads during faults in the supply system.

A power electronic converter based series compensator that can protect critical loads from all supply side disturbances other than outages is called a dynamic voltage restorer (DVR).

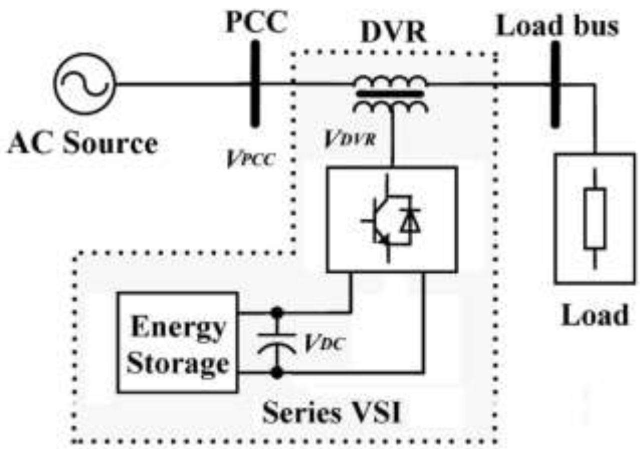


Fig. 1 Schematic diagram of DVR

The series voltage controller is connected in series with the protected load as shown in fig. 1. Usually the connection is made via a transformer, but configuration with direct connection via power electronics also exist. The resulting voltage at the load bus bar equals the sum of the grid voltage and injected voltage from the DVR. The converter generates the reactive power needed while the active power is taken from the energy source.

The energy storage can be different depending on the need of compensation. The DVR often has limitations on the depth and duration of the voltage dip that it can compensate. In figure 1, the circuit on the left hand side of the DVR represents the Thevenin equivalent circuit of the system. The system impedance Z_{th} depends on the fault level of the load bus. When the system voltage (V_{th}) drops, the DVR injects a series voltage V_{dvr} through the injection transformer so that the desired load voltage magnitude V_L can be maintained.

III.DISTRIBUTION STATIC COMPENSATOR (DSTATCOM) : A SHUNT VOLTAGE CONTROLLER

The shunt compensator is represented by ideal current sources. In practice, however these current sources are implemented using voltage source inverters. The inverter circuit along with interface transformers/inductors is called a distribution static compensator (DSTATCOM). DSTATCOM may have to inject a set of three unbalanced currents that may also contain harmonics. The VSI associated with a DSTATCOM must be able to inject currents in one phase independent of the other two phases. The shunt compensator can measure the PCC voltages and use them in the reference current generation algorithms without any problem as these voltages are pure sinusoids. The DSTATCOM is a shunt device. It should therefore be able to regulate the voltage of a bus to which it is connected. DSTATCOM used in both current control and voltage control mode is the same; its operating principle is different. In the current control mode it is required to follow a set of reference currents while in the voltage control mode it is required to follow a set of reference voltages.

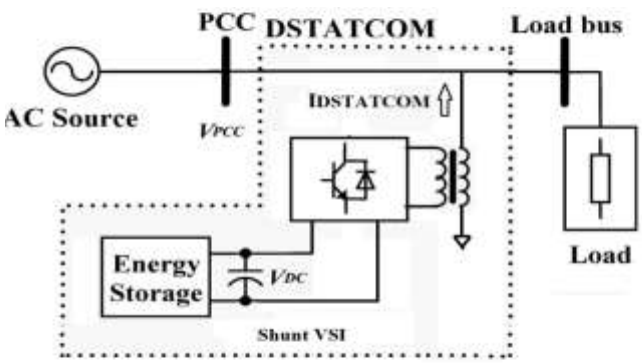


Fig. 2 Schematic diagram of DSTATCOM

A DSTATCOM is schematically shown in figure 2, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to distribution network. 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 DSTATCOM output voltages allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.

IV.RESULTS AND DISCUSSION DVR: A SERIES VOLTAGE CONTROLLER

A. Single line to ground fault Without DVR

The first simulation contains no DVR and a single line to ground fault is applied as shown in below Fig.3, during the period 300-600 ms. The voltage sag at the load point is 30% with respect to the reference voltage.

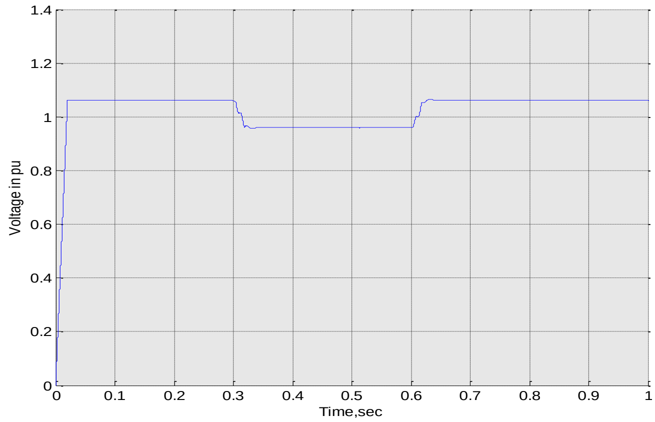


Fig. 3 Single line to ground fault without DVR

B. Single line to ground fault With DVR

Now when the DVR is in operation the voltage sag is mitigated almost completely and the r.m.s voltage at the sensitive load point is maintained at 98%, as shown in Fig.4.

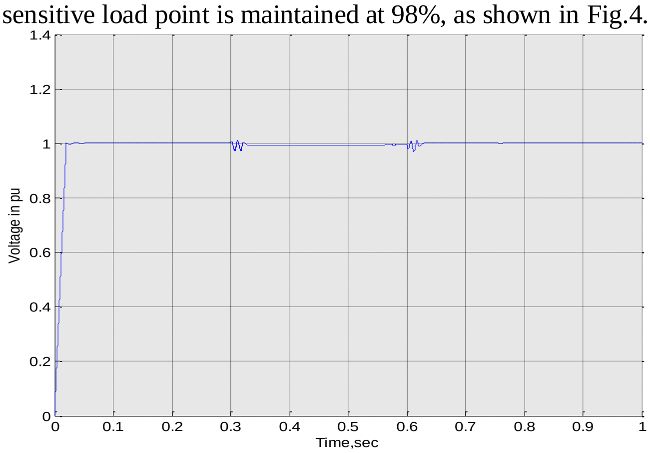


Fig. 4 Single line to ground fault with DVR

C. Double line to Ground Fault Without DVR

The first simulation contains no DVR and a double line to ground fault is applied as shown in below fig.6.3, via a fault resistance of 0.2 Ω during the period 300-600 ms. The voltage sag at the load point is 40% with respect to the reference voltage.

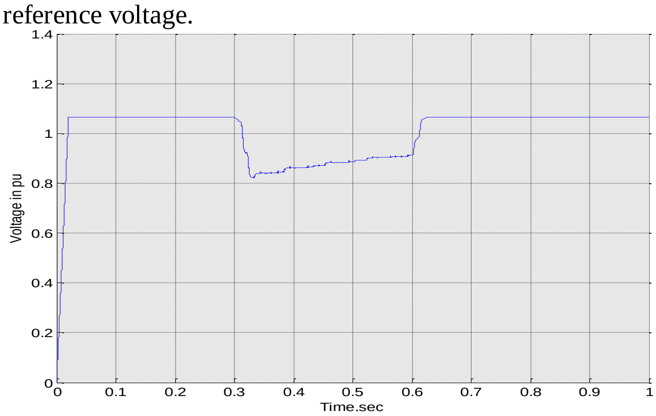


Fig. 5 Double line to Ground Fault without DVR

D. Double line to Ground Fault With DVR

When the DVR is in operation the voltage sag is mitigated almost completely and the r.m.s voltage at the load point is maintained at 99.99%, as shown in fig. 6.

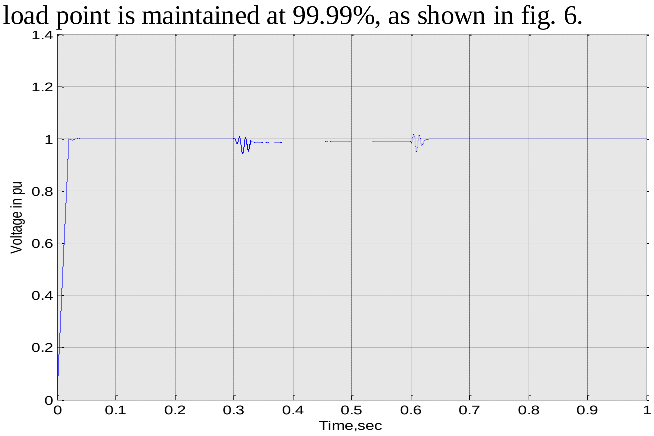


Fig. 6 Double line to Ground Fault with DVR

E. Triple line to Ground Fault Without DVR

The first simulation contains no DVR and three phase fault is applied at a point during the period 300-600 ms as shown in fig.7. The voltage at the load during fault condition is 50% with respect to the reference voltage.

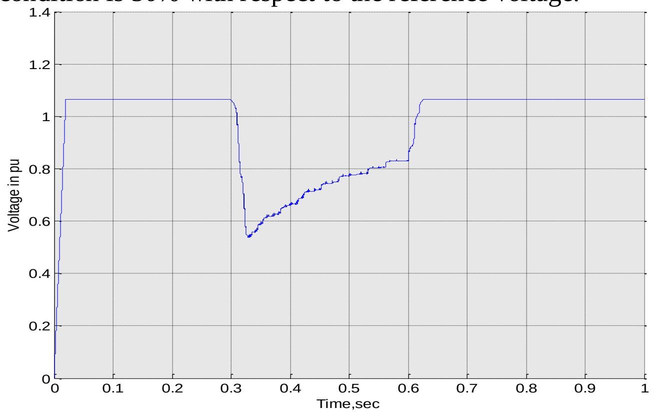


Fig. 7 Triple line to Ground Fault without DVR

F. Triple line to Ground Fault With DVR

By using DVR is in operation the reactive power is injected to the system for same fault duration. And hence the voltage sag is mitigated almost completely and the r.m.s voltage at the sensitive load point is maintained at 98%, as shown in fig. 8.

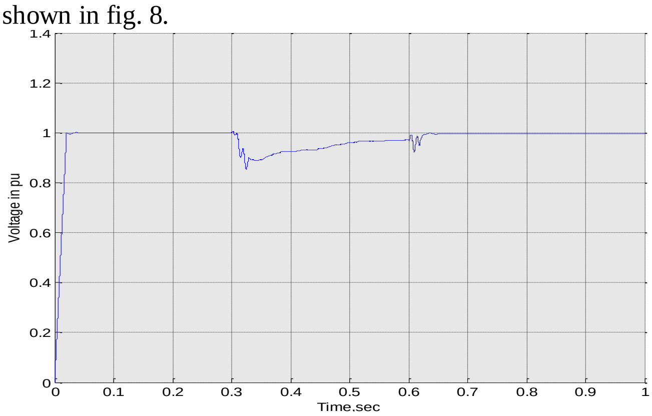


Fig. 8 Triple line to Ground Fault with DVR

V. RESULTS AND DISCUSSION DSTATCOM : A SHUNT VOLTAGE CONTROLLER

A. Single line to ground fault Without DSTATCOM

The first simulation contains no DSTATCOM and a single line to ground fault is applied as shown in Fig.9, via a fault resistance during the period 300-600 ms. The voltage sag at the load point is 70% with respect to the reference voltage.

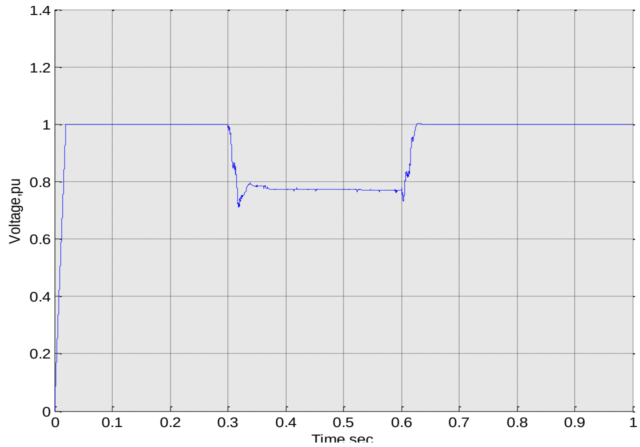


Fig. 9 Single line to ground fault without DSTATCOM

B. *Single line to ground fault With DSTATCOM*

Now with the DSTATCOM in operation, the total simulation period is 1000 ms. When the DSTATCOM is in operation the voltage sag is mitigated almost completely and the r.m.s voltage at the sensitive load point is maintained at 99.99%, as shown in figure 10.

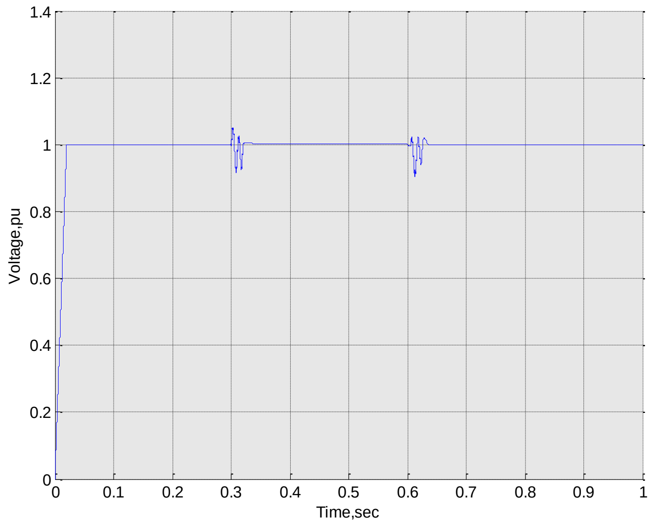


Fig. 10 Single line to ground fault With DSTATCOM

C. Double line to ground fault With DSTATCOM

The first simulation contains no DSTATCOM and a double line to ground fault is applied as shown in below fig.6.9 via a fault resistance of 0.2 Ω during the period 300 to 600 ms. The voltage sag at the load point is 40% with respect to the reference voltage.

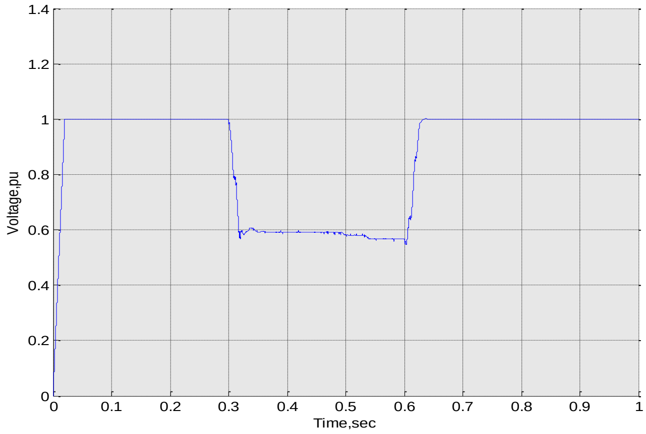


Fig. 11 Double line to ground fault without DSTATCOM

D. Double line to Ground Fault With DSTATCOM

Now with the DSTATCOM in operation and simulation period is 1000 ms. When the DSTATCOM is in operation the voltage sag is mitigated almost completely and the r.m.s voltage at the sensitive load point is maintained at 99.99% as shown in fig.12.

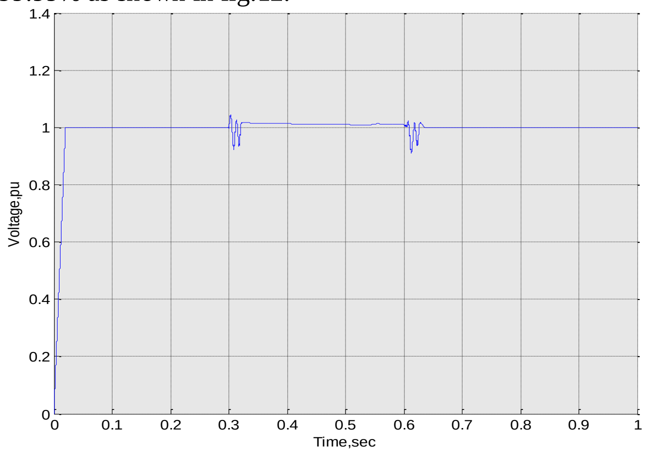


Fig. 12 Double line to ground fault with DSTATCOM

E. Triple line to Ground Fault Without DSTATCOM

Here in this simulation test system we observe the behaviour of system for triple line to ground fault. The first simulation is carried out without DSTATCOM and three phase fault is applied at point A via a fault resistance of 0.02 Ω during the period 300 to 600 ms. The voltage at the load point is just only 30% with respect to the reference voltage is shown in fig.-13

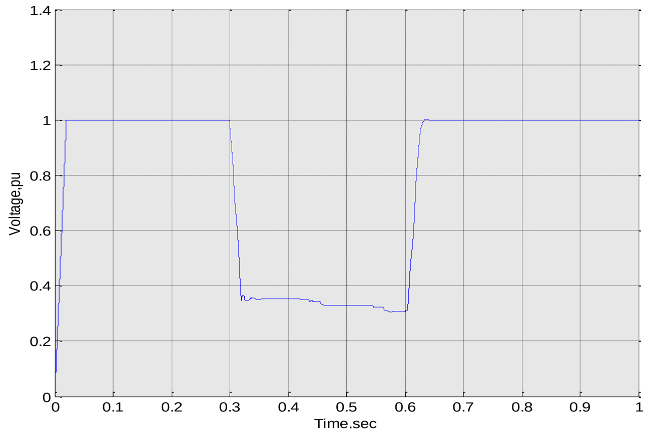


Fig. 13 Triple line to ground fault without DSTATCOM

F. Triple line to Ground Fault With DSTATCOM

Now a new set of simulations was carried out with the DSTATCOM connected to the system the load voltage shown in fig.14 is compensated almost 99.99%.

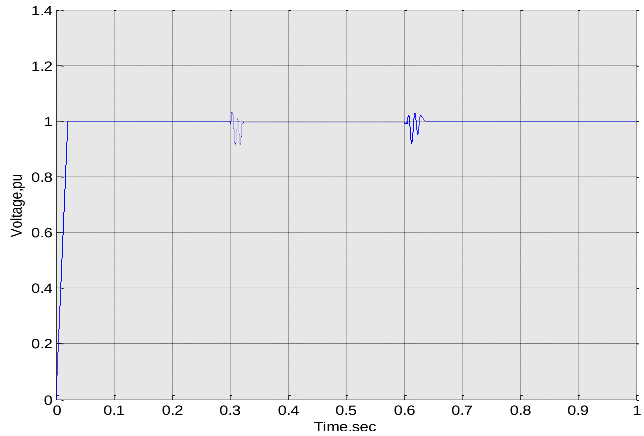
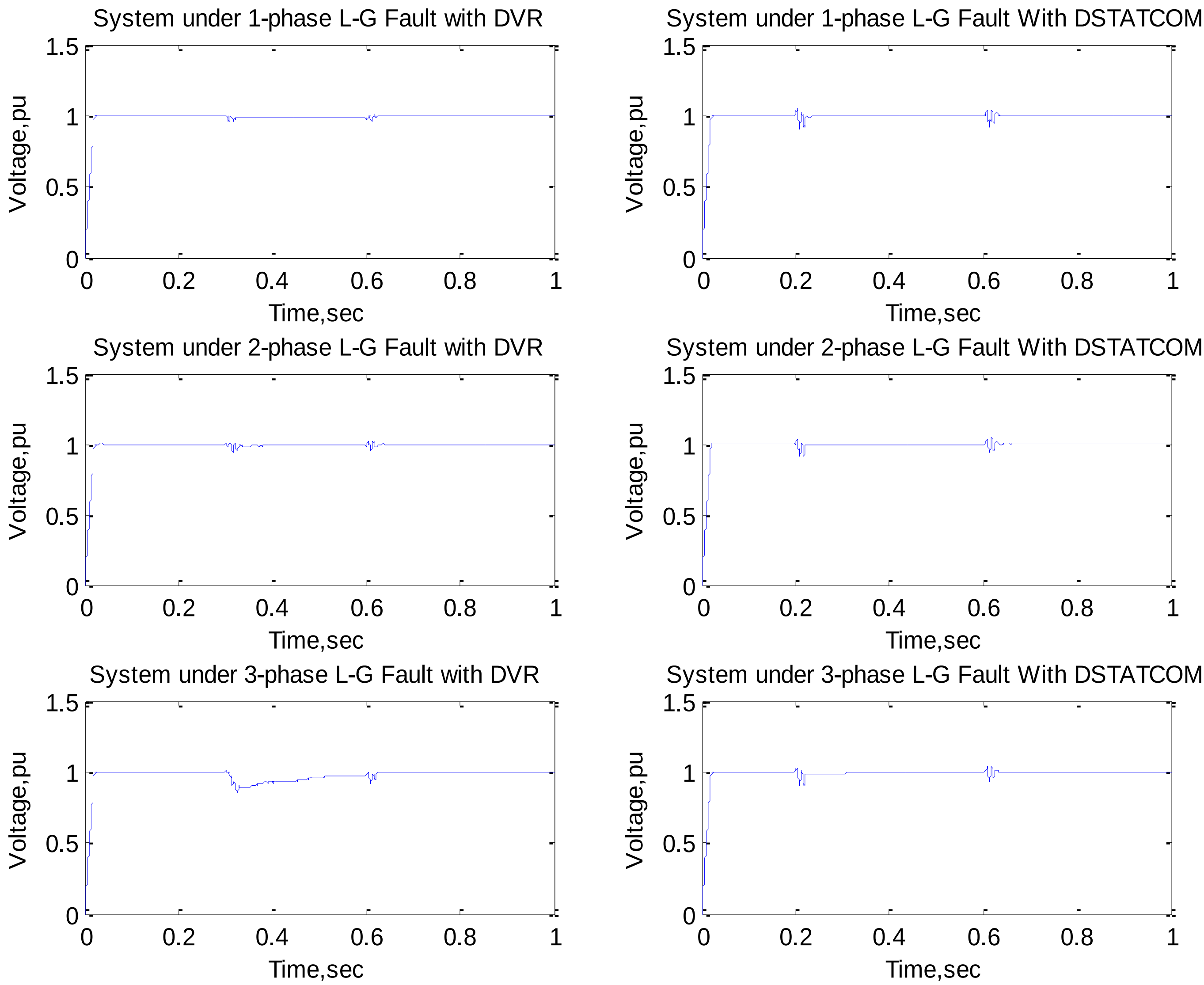


Fig. 14 Triple line to ground fault without DSTATCOM

VI. COMPARISION OF DVR AND DSTATCOM

MATLAB SIMULATION RESULTS OF DVR	MATLAB SIMULATION RESULTS OF DSTATCOM
➢ It is connected in series with line, so, compensator is removed for outage so other parallel line will be overloaded.	➢ It is connected in shunt.
➢ It will work as series voltage source.	➢ It can work as Shunt synchronous voltage source.
➢ Under L-G fault it can compensate 98% voltage sag.	➢ Under L-G fault it can compensate 100% voltage sag.
➢ Under 2L-G fault it can compensate 97% voltage sag.	➢ Under 2 L-G fault it can compensate 99.8% voltage sag.
➢ Under 3L-G fault it can compensate 85% voltage sag.	➢ Under 3 L-G fault it can compensate 99.99% voltage sag.



VII. CONCLUSIONS

Since, from above comparison the basic difference of DSTATCOM to have overall superior functional characteristics, better performance with greater flexibility make more adoptable for large power network. A key feature of this control scheme is its simplicity; only one controller is required to eliminate three PQ disturbances, namely, voltage sags, harmonic voltages, and voltage imbalances. The controller can be implemented by using either a stationary reference frame or a rotating reference frame.This paper has presented the power quality problems such as voltage dips, swell, and interruption, consequences and mitigation techniques of custom power electronic devices DVR and DSTATCOM. The design and applications of DVR and DSTATCOM for voltage sags, interruptions and swells and comprehensive results are presented. This characteristic makes it ideally suitable for low-voltage custom power applications.

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