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Research Article

VOLTAGE SAG COMPENSATION USING UNIFIED POWER FLOWER CONTROLLER IN MV POWER SYSTEM USING PI CONTROLLER

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ABSTRACT
Due to increasing complexity in the power system, voltage sags are now becoming one of the most significant power quality problems. Voltage sag is a short reduction voltage from nominal voltage, occurs in a short time. Short-lived voltage sags may not cause much harm other than cause a slight flickering of lights; temporary voltage sag is bound to have a greater impact on the industrial customers. This paper deals with voltage sag compensation in MV power system. In other words this research, focused on the avoiding of propagating the occurred voltage sag in transmission lines to distribution system. Therefore to achieve this purpose, the voltage sag mitigation using unified Power flow Controller (UPFC) based PI controller is investigated and analysed.

INTRODUCTION
Power quality in distribution systems has been attracting an increasing interest during recent years. Research studies include the quality of voltage supply with respect to temporary interruptions, voltage dips, harmonics, and voltage flicker (O'Kelly *et al.*, 1992). So these are the most common and important problems affecting low and medium voltage customers. The voltage sags are usually associated with faults in the power grid but can also be caused by switching of heavy loads, starting of large motors, and by transformer energizing. Anyhow the voltage sag, which is one of the important parameters of power quality, has been great concern for both suppliers and customers. The value power quality is strictly related to the economic consequences associated with the equipment and should therefore be evaluated considering the customers point of view (Tang *et al.*, 1997). So the need for solutions dedicated to single customers with highly sensitive loads is great since a fast response of voltage regulation is required. Further it needs to synthesize the characteristics of voltage sags both in domestic and industrial distributions (Amit *et al.*, 2004). In order to meet this challenge, it needs a device capable of injecting minimum energy (Hingorani and Gyugyi, 2004) so as to regulate load voltage at its predetermined value. The STATCOM, which is vital device in field of power quality, has several applications such as power factor corrector; harmonic compensator and voltage mitigation etc. Authors have used PWM-based distribution STATCOM for voltage mitigation (Sun *et al.*, 2002).

By (Ding *et al*, 2002) STATCOM have been implemented with space vector PWM as voltage injector in line (i.e, so called DVR) for unbalanced condition. Now the DVR, which has been utilized in optimized way so as to improve performance, has been put under new technique of sag detection (Vilathgamuwa *et al.*, 2002; Fitzer *et al.*, 2004). Power flow is one of the main problems in a transmission system. Due to objective of this research for voltage sag compensation in transmission network the UPFC with its capability on power flow is selected. When a fault occurs in a transmission system there is said to be a drop in the voltage. Decease/increase of reactive power is also one of the main problems. UPFC device is also could be used to control the power flow to increases the transmission capacity and to optimize the stability of the power system.

Subtransmission Loops
At sub transmission level, the networks often consist of several loops-a typical example is shown in Figure 1. The transmission system is connected to the sub transmission system through two or three

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transformers. From the busses at the low-voltage side of these transformers a number of substations are fed via a loop. Such a network configuration is also found in industrial power systems. Often the loop only consists of two branches in parallel. The mathematical expressions that will be derived below can also be used to calculate voltage sags due to faults on parallel feeders.

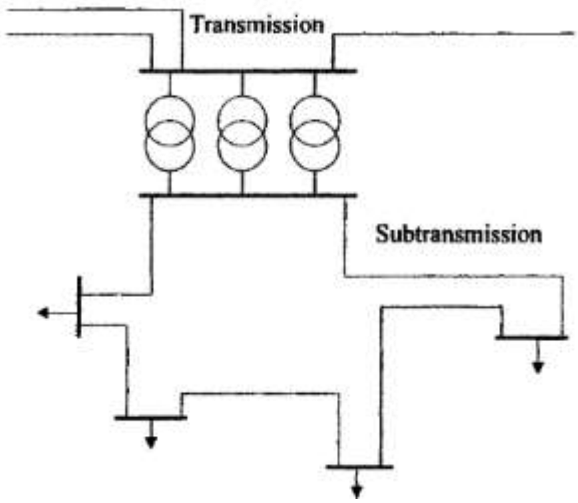

Figure 1: Example of sub transmission loop

To calculate the sag magnitude we need to identify the load bus, the faulted branch, and the non-faulted branch. Knowing these the equivalent scheme in Figure 2 is obtained, where Z_o is the source impedance at the bus from which the loop is fed; Z_l is the impedance of the faulted branch of the loop; Z_2 is the impedance of the non-faulted branch; and p is the position of the fault on the faulted branch (p=0 corresponds to a fault at the bus from which the load is fed, p=1 corresponds to a fault at the load bus). The voltage at the load bus can be calculated, resulting in the following expression (Bollen *et al.*, 2004).

$$V_{Sag} = \frac{\rho(1-\rho)Z_1^2}{Z_0(Z_1+Z_2)+\rho Z_1 Z_2+\rho(1-\rho)Z_1^2} \quad (1)$$

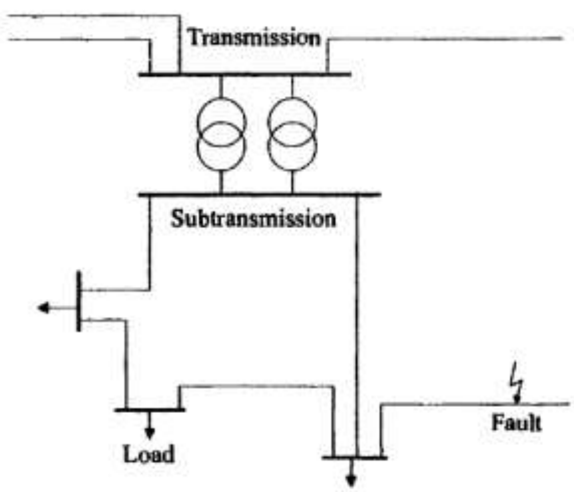

Figure 2: System with a branch away from a loop

When a load is fed from a loop, like the ones discussed above, a fault on a branch away from that loop will also cause voltage sag. In that case it is often possible to model the system as shown in Figure 2. The feeder to the fault does not necessarily have to be a single feeder, but could, e.g., represent the effective impedance of another loop.

The voltage at the load bus is found from:

$$V_{Sag} = \frac{Z_5Z_2 + Z_5Z_3 + Z_5Z_4 + Z_4Z_3}{Z_1Z_2 + Z_1Z_3 + Z_1Z_4 + Z_5Z_2 + Z_5Z_3 + Z_5Z_4 + Z_4Z_2 + Z_4Z_3} \qquad (2)$$

Z_1 is the source impedance at the main sub-transmission bus; Z_2 is the impedance between that bus and the bus from which the load is fed; Z_3 is the impedance between the bus from which the load is fed and the bus from which the fault is fed; Z_4 and Z_5 are the impedances between the latter bus and the main sub-transmission bus and the fault, respectively.

Unified Power Flow Controller (UPFC)

This FACT device is consisted of two converters. As presented in Figure 3 the converter-1 is to supply or absorb the real power demanded by converter-2 at the common dc link to support the real power exchange resulting from the series voltage injection. Converter-1 can generate or absorb controllable reactive power if desired, and thereby provide independent shunt reactive compensation for the line. The superior operating characteristic of UPFCConverter-2 provides the main function the UPFC by injecting a voltage V_{pq} with controllable magnitude and phase angle ρ in series with the line via an insertion transformer (Dhas *et al.*, 2012).

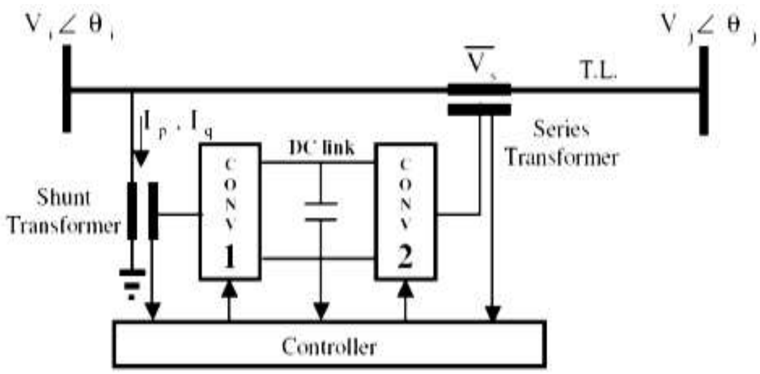

Figure 3: Basic structure of UPFC

RESUTS AND DISCUSSION

Simulation and Results

At first to investigate the effect of short cicuit as a fault in transmission network, the system without any compensator is simulated.

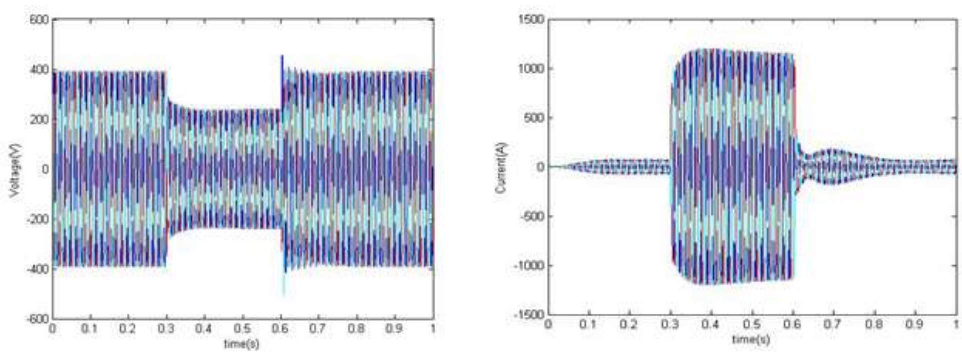

Figure 4: The voltage and current of system without UPFC

The voltage and current system is shown in Figure 4.

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Due to fault occurred in network, the active and reactive power in bus 6 of system is changed and faced with a transient variation. This is presented in Figure 5.

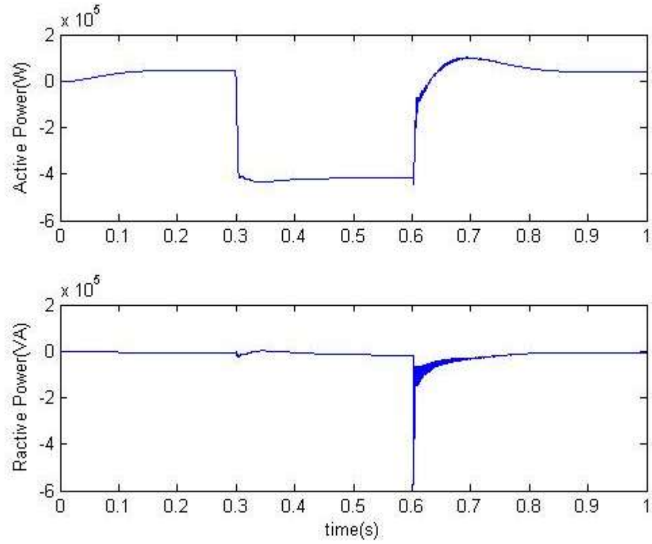

Figure 5: The active and reactive power variation without UPFC

In this section to find out the effects of UPFC on voltage sag compensation, the unified power flow controller through a PI controller is applied to transmission level of network.The UPFC configuration and its controller based PI controller is shown in Figure 6.

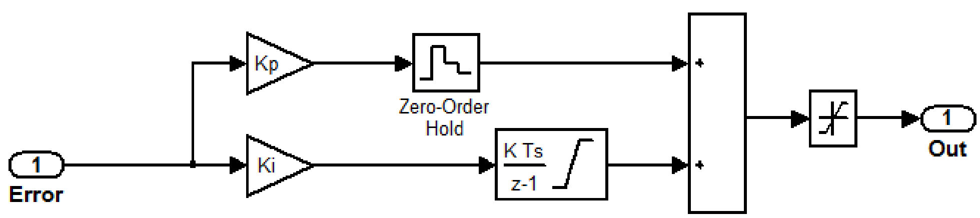

Figure 6: The PI controller of UPFC

The voltage and current at bus 6 with presence of UPFC as a compensator is obtained. As seen in this figure the voltage sag is improved. This is indicated in Figure 7 and it is seen that the suddenly increase in current due to short circuit has been removed after compensation.

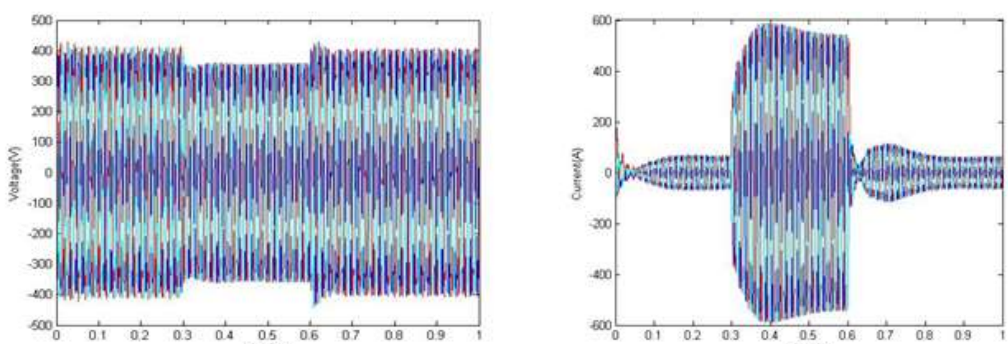

Figure 7: The voltage and current of system with UPFC

The active and reactive current of system with UPFC compensator is improved and is presented in Figure 8.

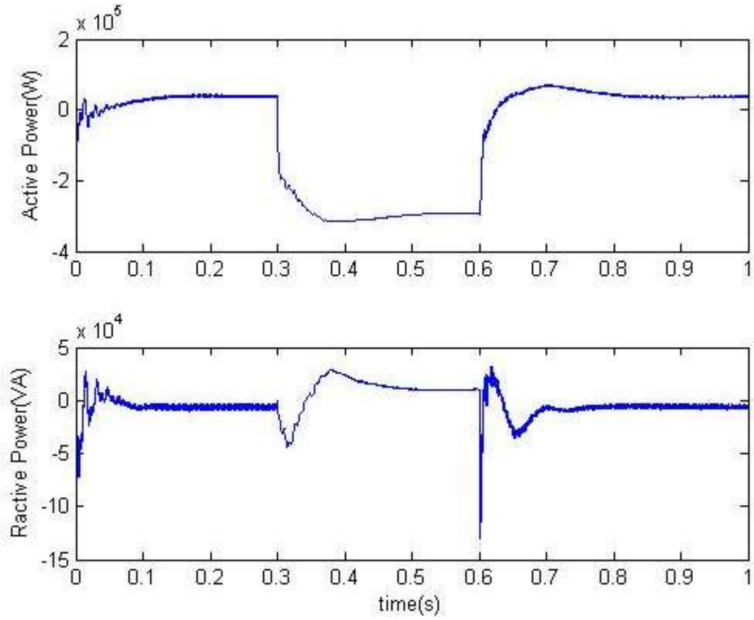

Figure 8: The active and reactive power variation with UPFC

CONCLUSION

In this paper voltage sag compensation in transmission network using unified power controller is analysed. At first the system without any compensator is analysed and the effect of a short circuit in a bus of system is investigated. It is obvious that without any compensator, after fault in system, the voltage of load is decreased and also the current which drawn with load located in this bus is suddenly increased. In this research to compensate the voltage sag using UPFC a PI based controller is presented and analysed. It is clear that using UPFC the voltage sag in mentioned bus has improved and also it is avoided of the suddenly increase in current. Also the variation of active and reactive power with presence of UPFC is improved.

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