International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 5893-5903

http://www.ripublication.com

An Integrated Z-Source Inverter For Voltage Sag Compensation Using Matlab/Simulink

J.Singaravelan[1] and Dr. K.Sureshmanic[2]

1. Research scholar,Dept of Electrical Engineering, St.peters University, India
2. Professor, Taylors university,Malaysia
Singvel_eee@yahoo.co.in

Abstract

An integrated Z-source inverter for voltage sag compensator using mat lab Super Conductive Magnetic energy storage (SMES) based Interline DVR. The dynamic voltage restorer provides an advanced and economical solution to voltage-sag problem for open loop systems. As the voltage-restoration process involves the real-power injection into the distribution system, the capability of a DVR, especially for compensating long-duration voltage sags, it depends on the energy storage capacity of the DVR. The interline DVR proposed in this paper provides a way to replenish Dc-link energy storage dynamically. The IDVR consists of several DVRs connected to different distribution feeders in the power system. The DVRs in the IDVR system shares the common energy storage. When one of the DVR compensates for voltage sag appearing in that feeder, the other DVRs replenish the energy in the common dc-link dynamically. Thus, one DVR in the IDVR system works in voltage-sag compensation mode while the other DVRs in the IDVR system operate in power-flow control mode.

Index Terms: Dynamic Voltage Restorer (DVR), Interline Dynamic Voltage Restorer (IDVR), Z- Source Inverter (ZSI), Super Conductive Magnetic Energy Storage, Interline Power Flow Control, Power Quality

I. INTRODUCTION

This project presents a new approach for the dynamic control of a current source inverter (ZSI) using Super Conductive Magnetic energy storage (SMES) based Interline DVR. The dynamic voltage restorer (DVR) provides a technically advanced and economical solution to voltage-sag problem. As the voltage-restoration process involves the real-power injection into the distribution system, the capability of a DVR, especially for compensating long-duration voltage sags, it depends on the

energy storage capacity of the DVR. The IDVR consists of several DVRs connected to different distribution feeders in the power system. The DVRs in the IDVR system shares the common energy storage.The latter approach has two inherent advantages over the more conventional switched capacitor- and reactor-based compensators. Firstly, the power electronics-based voltage sources can internally generate and absorb reactive power without the use of ac capacitors or reactors. Secondly, they can facilitate both reactive and real power compensation and thereby can provide independent control for real and reactive power flow. The family of compensators and power flow controllers based on synchronous voltage sources, which are relevant to this paper, are the Static Synchronous (shunt) Compensator (STATCOM), the Static Synchronous Series
Compensator (SSSC) , Unified Power Flow Controller (UPFC)**.** Where as the STATCOM and SSSC are usually employed as reactive compensators. The Interline Power Flow Controller (IPFC) concept proposed in this paper addresses the problem of compensating a number of transmission lines at a given substation. The IPFC scheme proposed provides, together with independently controllable reactive series compensation of each individual line, a capability to directly transfer real power between the compensated lines. This capability makes it possible to: equalize both real and reactive power flow between the lines; transfer power demand from overloaded to under loaded lines; compensate against resistive line voltage drops and the corresponding reactive power demand; increase the effectiveness of the overall compensating system for dynamic disturbances.

II. BASIC PRINCIPLES OF THE INTERLINE POWER FLOWCONTROLLER

In its general form the Interline Power Flow controller employs a number of dc to ac inverters each providing series Compensation for a different line. In other words, the IPFC comprises a number of Static Synchronous Series Compensators **[2].** However, within the general concept of the IPFC, the compensating inverters are linked together at their dc terminals, as illustrated in Fig. 1. With this scheme, in addition to providing series reactive compensation, any inverter can be controlled to supply real power to the common dc link from its own transmission line. Thus, an overall surplus power can be made available from the underutilized lines which then can be used by other lines for real power compensation. In this way, some of the inverters, compensating overloaded lines or lines with a heavy burden of reactive power flow, can be equipped with full two-dimensional, reactive and real power control capacity, similar to that offered by the UPFC**.** It is designed based on Convertible Static Compensator (ZSC) of FACTS Controllers. As shown in Fig , IPFC consists of two series connected converters with two transmission lines. It is a device that provides a comprehensive power flow control for a multi-line transmission system and consists of multiple number of DC to AC converters, each providing series compensation for a different transmission line. The converters are linked together to their DC terminals and connected to the AC systems through their series coupling transformers. With this arrangement, it provides series reactive compensation in addition any converter can be controlled to supply active power to the common dc link from its own transmission line.

Characteristics of IPFC

To avoid the control of power flow problem in one system with synchronous of power in other system, installation of IPFC system in additional parallel inverter is required to meet the active power demand.

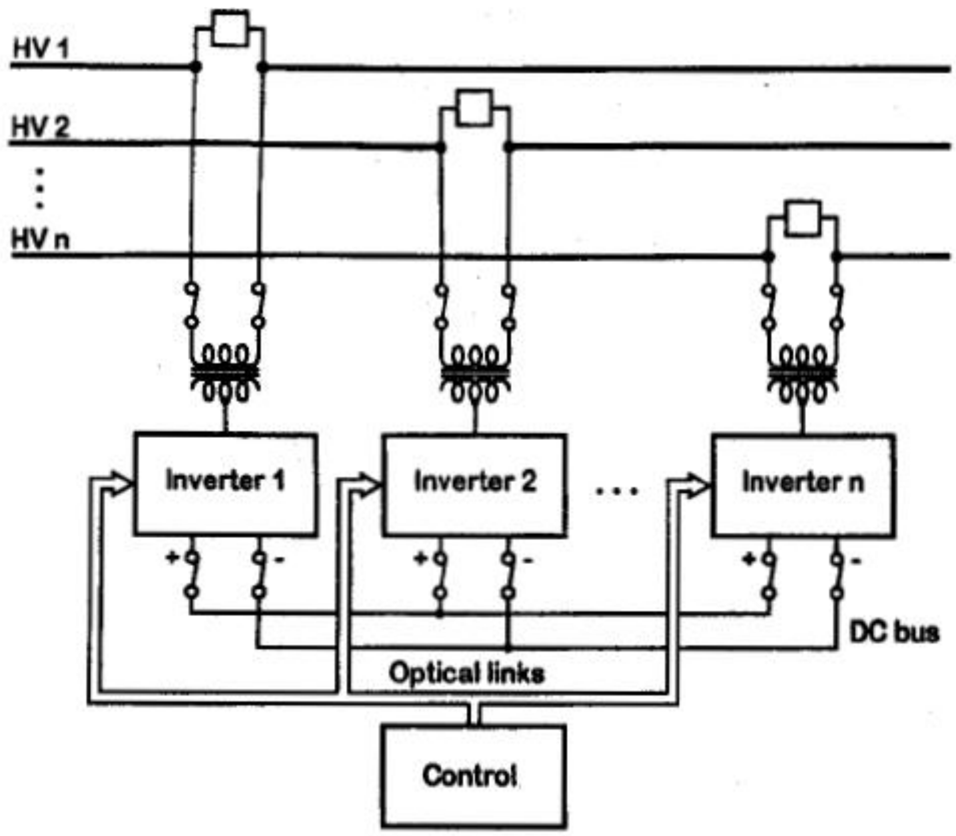


Fig. 1 'n' Inverters Configured for an Interline Power Flow Controller

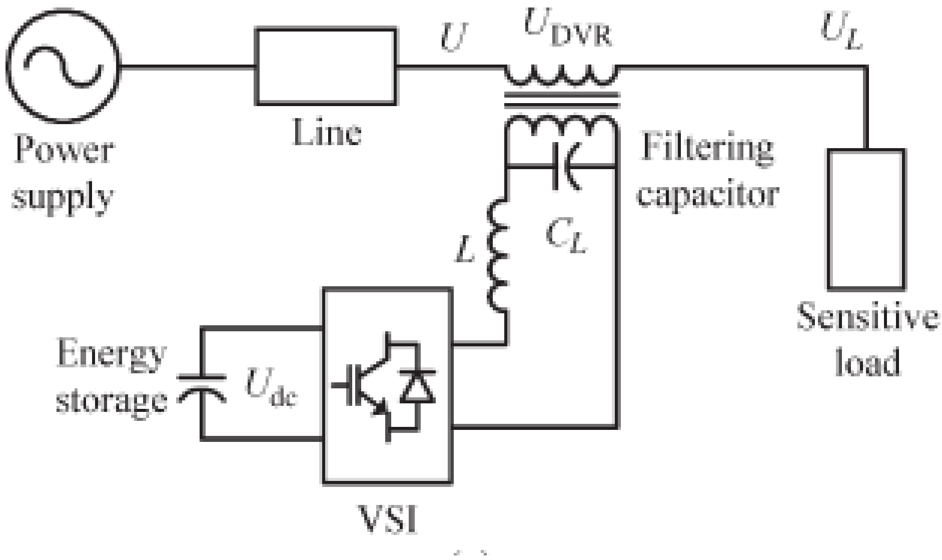
Thus, an overall surplus power can be made available from the underutilized lines which then can be used by other lines for real power compensation. In this way, some of the inverters, compensating over loaded lines or lines with a heavy burden of reactive power flow, can be equipped with full two-dimensional, reactive and real power control capability, similar to that offered by the UPFC. Evidently, this arrangement mandates the rigorous maintenance of the overall power balance at the common dc terminal by appropriate control action, using the general principle that the under loaded lines are to provide help, in the form of appropriate real power transfer, for the overloaded lines.

III. DYNAMIC VOLTAGE RESTORER

With the widespread use of electronic equipment, Loads are becoming more sensitive and less tolerant to short-term voltage disturbances in the form of voltage sags. Custom power is a technology-driven product and service solution which embraces a family of devices to provide power-quality enhancement functions. Among the several novel custom-power devices [7], the dynamic voltage restorer (DVR) is the most technically advanced and economical device for voltage-sag mitigation in the distribution systems

A. DVR operation

The voltage-sag compensation involves injection of real and reactive power to the distribution system and this determines the capacity of the energy storage device required in the restoration scheme. The reactive power requirement can be generated electronically within the current source inverter of the DVR. External energy storage is necessary to meet the real-power requirement. Thus, the maximum amount of real power that can be supplied to the load during voltage-sag compensation is a deciding factor of the capability of a DVR, especially for mitigating long-duration voltage sags. However the energy requirement cannot be met by the application of such phase advance technique alone for mitigating deep sag of long duration, as it is merely a way of optimizing existing energy storage. If the dc link of the DVR can be replenished dynamically by some means, the DVR will be capable of mitigating deep sags with long durations.



Dynamic voltage restorer are mainly used to protect sensitive loads from the electrical network voltage disturbances such as sags or swells and could be used to reduce harmonic distortion of ac voltages.

Purpose of DVR

Voltage sags are abrupt reductions (between 10% and 99%) in the ac voltage root mean-square value, lasting less than 60 s. Typical sag depths range from 50% to 90% of the nominal voltage and span from 10 ms to a few seconds. Voltage sags are given a great deal of attention because of the wide usage of voltage-sensitive loads such as adjustable speed drives, process control equipment, and computing devices [1], [2]. Voltage sags can cause extensive interruption or disruption to the industrial process sector [3], being, in many cases, the most severe power quality issue.

IV. INTERLINE DYNAMIC VOLTAGE RESTORER

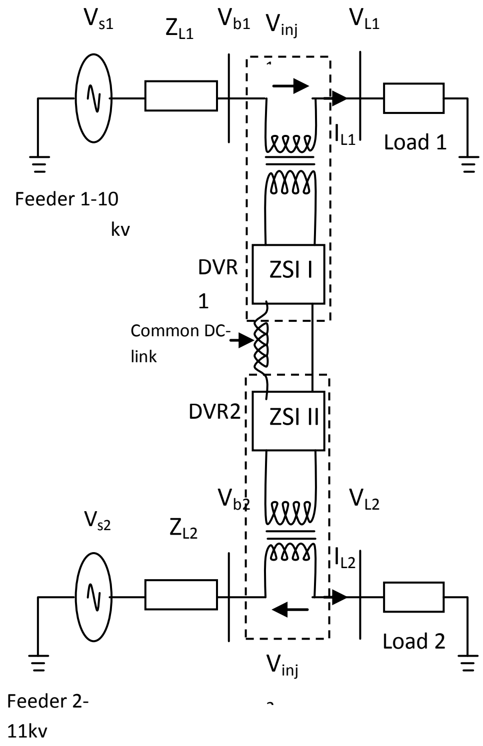
The Interline Power Flow Controller (IPFC) concept proposed in this paper addresses the problem of compensating a number of transmission lines at a given substation. Conventionally, series capacitive compensation (fixed, thyristor -controlled or SSSC based) is employed to increase the transmittable real power over a given line and also to balance the loading of a normally encountered multi-line transmission system. However, independent of their implementation, series reactive compensators are unable ***to*** control the reactive power flow in and thus the proper load balancing of, the lines. The IPFC scheme proposed provides, together with independently controllable reactive series compensation of each individual line, a capability to directly transfer real power between the compensated lines. This capability makes it possible to: equalize both real and reactive power flow between the lines; transfer power demand from overloaded to under loaded lines; compensate against resistive line voltage drops and the corresponding reactive power demand; increase the effectiveness of the overall compensating system for dynamic disturbances.

A. Selection of IDVR

The Interline Dynamic Voltage Restorer (IDVR) proposed in this paper provides a way to replenish the energy in the common dc-link energy storage dynamically using SMES [4]. The IDVR system consists of several DVRs protecting sensitive loads in different distribution feeders emanating from different grid substations, and these DVRs share a common dc link. The IPFC scheme provides a capability to transfer real power directly between the compensated lines, while the reactive power is controllable within each individual line. However, the lines in the IPFC originate from a single grid substation while the lines in the IDVR system originate from different grid substations.

B. Operational diagram

When one of the DVRs in IDVR system compensates for voltage sag by importing real power from the dc link, the other DVRs replenish the dc-link energy to maintain the dc-link voltage at a specific level using Z- source Inverter. The sensitive loads in this park may be protected by DVRs connected to respective loads. The dc links of these DVRs can be connected to a common terminal, there by forming an IDVR.



The IDVR system consists of several DVRs in different feeders sharing a common dc link. A two-line IDVR system shown in Fig. 1 employs two DVRs connected to two different feeders originating from two grid substations. These two feeders could be of the same or different voltage level.

V. Z SOURCE INVERTER

The Voltage Source Inverter (VSI) is the dominant topology in reactive power control, with several VSI-based facts now operating in transmission systems. While most of the literature focuses on the VSI or CSI , but this paper focuses on ZSI.

A. Application of ZSI

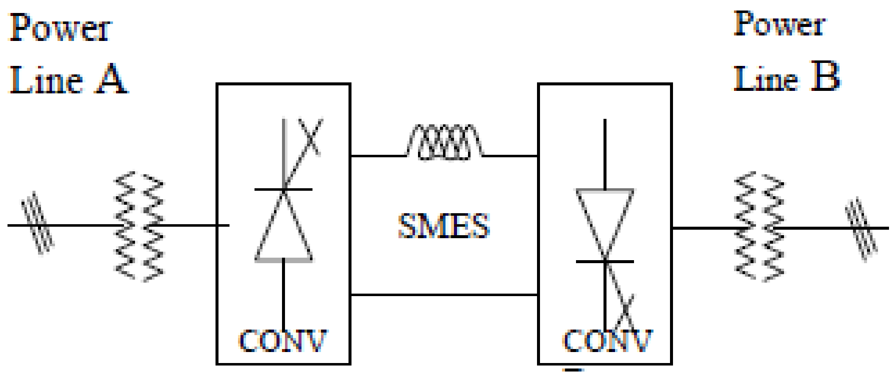
Compared with the VSI, the ZSI [9] topology offers a number of inherent advantages: including: 1) directly controlling the output current of inverter 2) implicit short-circuit protection, the output current being limited by the dc inductor 3) high converter reliability, due to the unidirectional nature of the switches and the inherent short-circuit protection 4) fast start-up, where no additional start-up rectifier is needed The common dc link current is ripple free 6) the magnitude of frequency varies by controlling the Id current using SCR 7) it act as the active filter 8) it act as the super conducting magnet energy storage.

These devices can be used to control power flow on a transmission line by injecting a series voltage into the line or they can also support the voltage at a bus through shunt voltage injection. The addition of more substantial energy storage, such as a battery or capacitor bank makes these devices capable of maintaining voltage magnitude during a voltage sag or brief outage.

VI. SUPER CONDUCTIVE MAGNETIC ENERGY STORAGE

The voltage disturbance correction requires a certain amount of real and reactive power supply from the DVR. The DVR is required to inject active power into the distribution line during the period of compensation; the capacity of the energy storage unit can become a limiting factor in the voltage sag compensation process [8]. They can also be used for load leveling by charging them when excess generation is available and discharging them during high demand periods. Small SMES coils can act as an uninterruptible power supply to help loads ride through short outages and voltage sags [13]. One of the difficulties in adding a SMES coil to an ac System is the power converter interface needed to properly synchronize with the ac system and transfer energy in and Out of the coil.

The power conditioning for a SMES coil has the added difficulty in that a wide range of voltages may be Necessary in addition to a wide range of currents. The voltage will need to reverse, although the current can stay unidirectional. Most power conversion options do better if either voltage or current has a somewhat smaller range of variation.



The system is composed of two convertors connected to ac power transmission lines and a super conducting magnet connected in series in the DC section as shown in Fig.3. The voltage source inverter needs polarity reversal element to obtain reverse voltage where as in the current source inverter there is no need for the polarity reversal element. The system has higher freedom of control which enables to stabilize each part of AC line independently as well as to control power f low from one side to other. The power flow from one side to the other can be controlled. It follows that balancing of power flow in parallel lines or power line network system becomes possible, which leads to the effective use of the power line system.

VII. POWER QUALITY

Today most of the electrical power systems in the world are widely interconnected due to economic reasons to reduce the cost of electricity and to improve system stability and reliability. Because of the increasing complexity of power system design, the challenge to meet the high quality power supply in a power system is highly desirable.

Factors considered for the smooth functionality of power system operation and control as follows:

- Power system operating in a synchronous mode maintains the power quality with a controlled phase between all the interconnected networks.
- The voltage level in a power system should maintain within limits. Any variations in the voltage level cause damage to electric motors and dielectric components, which is not acceptable and leads to overloading of many electric components.

Task or Area	**IDVR using CSI**	**IDVR using ZSI**
Fundamental (50 Hz)	**0.4569**	**0.395**
THD	**4.51%**	**2.36 %**

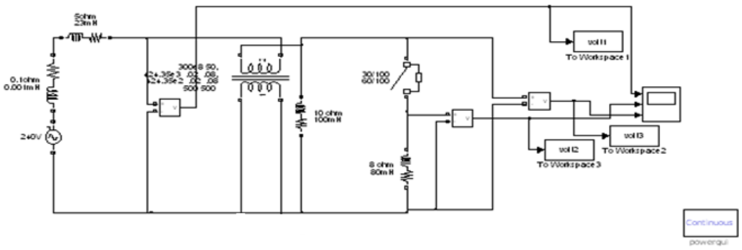
From the table, it is observed that the harmonic content has reduced with the use of ZSI with SMES. It also shows that the IDVR using ZSI with SMES does not require polarity reversal element.

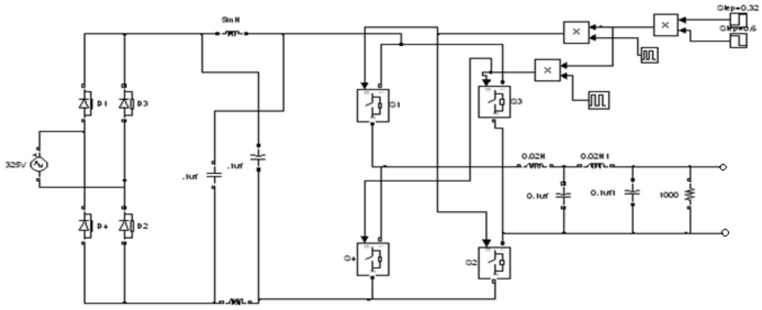
VIII. SIMULATION RESULTS

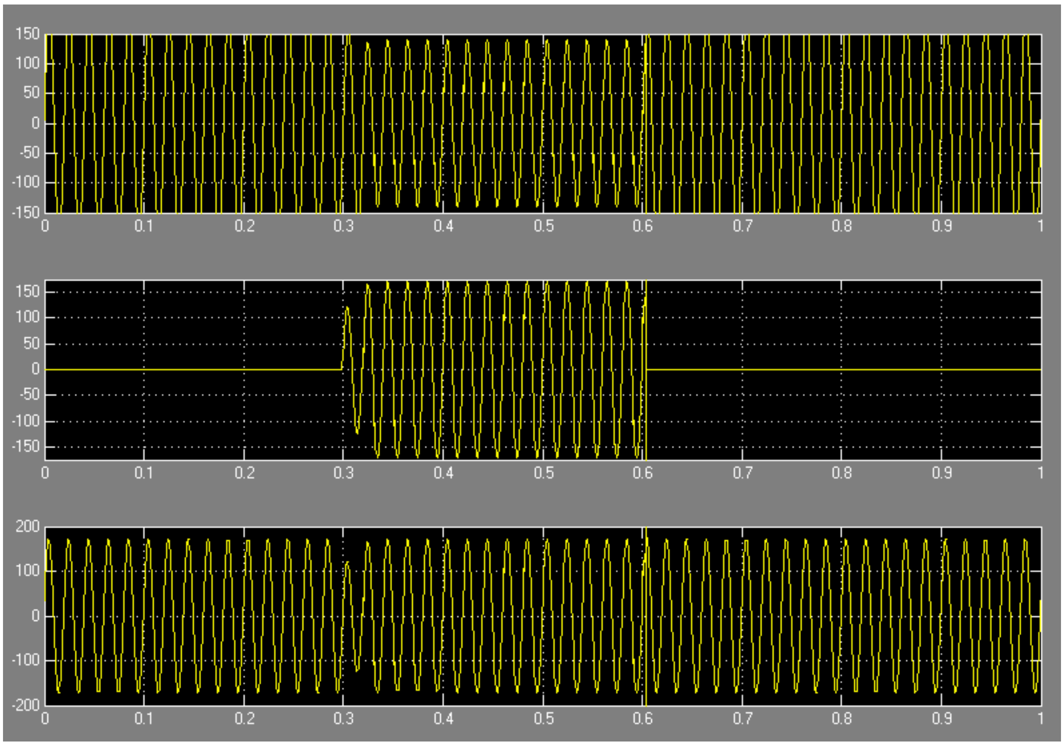
The proposed system was simulated between circuit model with IDVR and without IDVR operations in practical wise.

A. Simulation in transmission line without IDVR

All the switches s1,s2,s3 and s4 are low before connected with IDVR. Now the transmission line isolated.

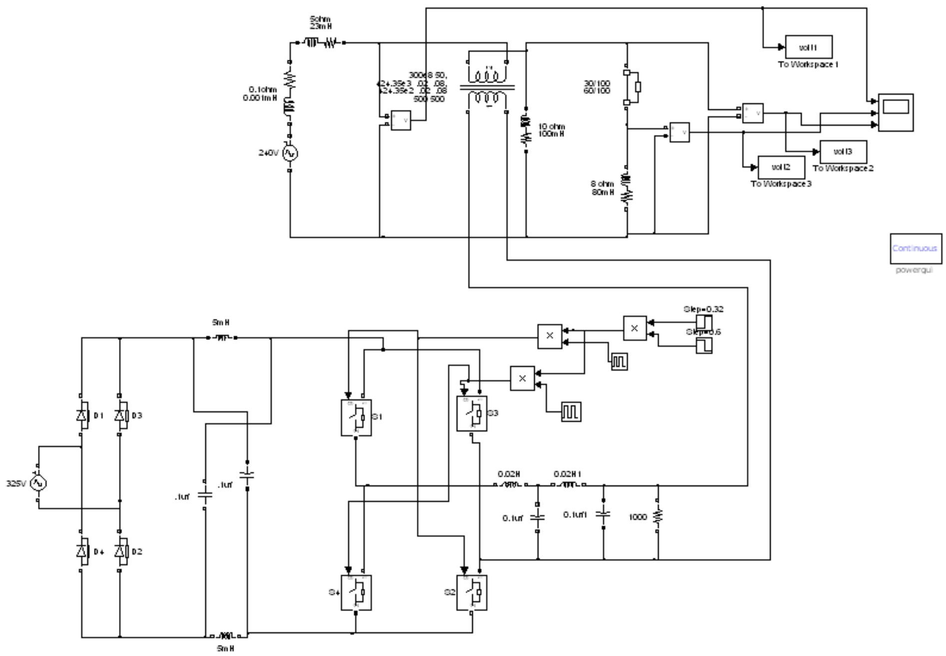


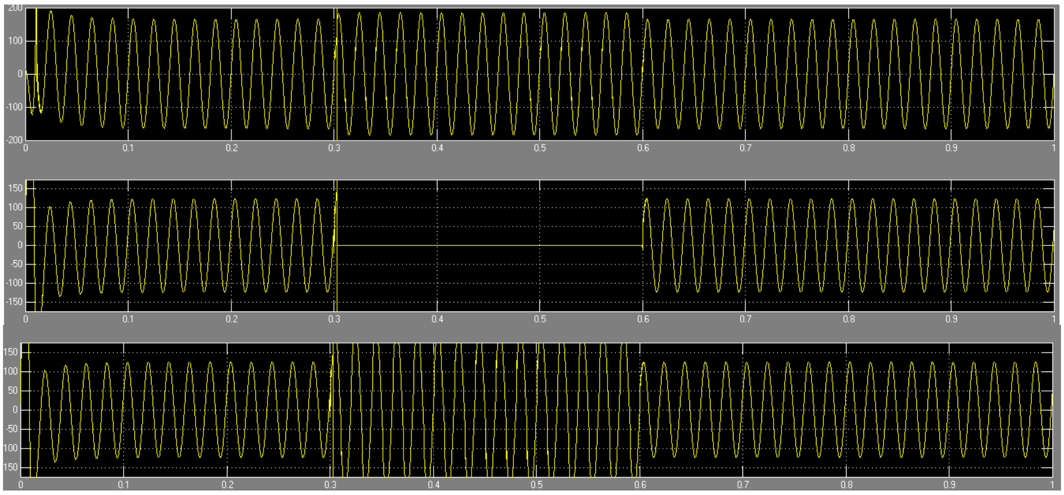




B. Simulation of transmission line with IDVR

All the switches s1, s2, s3 and s4 are high when connected with IDVR. It will connect with phases when transmission.





IX. CONCLUSION

In this project a detailed explanation is given on how to reduce sags and swells voltages in transmission lines when transmit power from generating station to substation through Mat lab /Simulink simulation. With the help of IDVR we can obtain constant nominal voltage through out the system. The DVR is used to inject the voltage and DC link delivers the power through DVRs. The proposed optimal predictive controllers optimize the overall DVR feedback control system, being able to mitigate balanced and unbalanced sags and short interruptions with

Balanced or unbalanced loads. Using a multilevel Inverter (ZSI) and choosing the line-side connected filter capacitor, the ac sensitive load voltage THD is reduced to values lower than 1%, with the

DVR behaving as a series APF for the ac load voltages. Thus, the optimal predictive DVR improves twofold the power quality of sensitive loads. The basic IPFC structure mandates zero net power at the common dc terminals with the assumption that in the overall system there are available capacity in the strong and under loaded lines to provide appropriate real power compensation for the weak and overloaded lines. In some applications this condition is not true, the basic IPFC structure can be complemented with an additional shunt inverter to provide the differential power from a suitable shunt bus. If required, this inverter can also provide shunt reactive compensation.

X. REFERENCES

[1] Gyugyi, L., Dynamic Compensation of AC Transmission Lines by Solid-state Synchronous Voltage Sources, IEEE Transactions on Power Delivery, Vol. 9, No. 2, April 1994.

[2] M. F. McGranaghan, D. R. Mueller, and M. J. Samotyj, "Voltage sags in industrial systems," IEEE Trans. Ind. Appl., vol. 29, no. 2, pp. 397–403, Mar./Apr. 1993.

[3] D.-M. Lee, T. G. Habetler, R. G. Harley, T. L. Keister, and J. R. Rostron, "A voltage sag supporter utilizing a PWM-switched autotransformer," IEEE Trans. Power Electron., vol. 22, no. 2, pp. 626–635, Mar. 2007.

[4] C. Fitzer, M. Barnes, and P. Green, "Voltage sag detection technique for a dynamic voltage restorer," IEEE Trans. Ind. Appl., vol. 40, no. 1, pp. 203–212, Jan./Feb. 2004.

[5] N. H. Woodley, L. Morgan, and A. Sundaram, "Experience with an inverter-base dynamic voltage restorer," IEEE Trans. Power Delivery, vol.14, pp. 1181–1185, July 1999.

[6] A. Campos, G. Joos, P. D. Ziogas, and J. F. Lindsay, "Analysis and design of a series voltage unbalance compensator based on a three-phase VSI operating with unbalanced switching functions," IEEE Trans.Power Electron., vol. 9, pp. 269–274, May 1994.

[7] R. S. Weissbach, G. G. Karady, and R. G. Farmer, "Dynamic voltage compensation on distribution feeders using flywheel energy storage," IEEE Trans. Power Delivery, vol. 14, pp. 465–471, Apr. 1999.