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Interline Dynamic Voltage Restoration For Power Quality Compensation

R. Janani

AP/EEE, Department of Electrical and Electronics Engineering,
Nehru Institute of Engineering and Technology,
Anna University, Chennai, India

Abstract: Power quality is one of major concerns in the present era. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipments. One of the major problems dealt here is the power sag. To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (DVR); a custom power device has been proposed to protect sensitive loads from the effects of voltage sags on the feeder. This paper proposes a new concept of interline dynamic voltage restoration (IDVR) where two or more DVRs in different feeders are connected to a common dc link. While one of the DVRs compensates for a voltage sag, the other DVRs connected to a common dc Link replenish the dc-link energy storage .A current mode control strategy is incorporated into the IDVR system in working modes, voltage sag compensation and power flow control.

Index Terms: IDVR – Interline Dynamic Voltage Restorer, DVR – Dynamic Voltage Restorer

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I. INTRODUCTION

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, the dynamic voltage restorer (DVR) is the most technically advanced and economical device for voltage-sag in the distribution systems. The conventional DVR functions by injecting ac voltages in series with the incoming three-phase network, the purpose of which is to improve voltage quality by adjustment in voltage magnitude, wave shape and phase shift. These attributes of the load voltage are very important as they can affect the performance of the protected load. 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.

This paper presents a concept of interline dynamic voltage restoration (IDVR) where two or more voltage restorers are connected such that they share a common dc link. This is in a way similar to the interline power flow controller (IPFC) concept which is still under research for the compensation and effective power flow management of multiline transmission system. The injected voltage of the DVR depends on the accuracy and dynamic behavior of the pulse width-modulated (PWM) synthesis scheme and control system adopted.

It also presents an extensive analysis to develop suitable control schemes for voltage sag compensation and flow control modes. The general requirement of such control scheme is to obtain an ac waveform with low total harmonic distortion (THD) and good dynamic response against supply and load disturbance whether the DVR in the IDVR system operates in voltage sag compensation or power flow control mode.

Usually, the control voltage of the DVR in mitigating voltage sag is derived by comparing the supply voltage against a reference waveform. Although the system stability is

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guaranteed in this type of control, the stability margin can be inadequate and the damping of output voltage would be poor due to the presence of a switching harmonic filter. The only difference in the control systems used for power flow control and voltage compensation modes is the generation of a reference signal for each control system.

The DVR usually consists of an injection transformer, which is connected in series with the distribution line, a voltage sourced PWM Inverter Bridge which is connected to the secondary of the injection transformer and an energy storage device connected at the dc-link of the inverter bridge. The inverter bridge output is filtered before being fed to the injection transformer in order to nullify switching frequency harmonics. The series injected voltage with a variable amplitude, phase and frequency of the DVR is synthesized by modulating pulse widths of the inverter bridge switches. The injection of an appropriate series voltage component in the face of a voltage disturbance requires a certain amount of real and reactive power supply by the DVR. The real and reactive power supplied by the DVR however depends on the type of voltage disturbance experienced as well as the direction of the DVR injected voltage component with reference to pre-sag voltage. The idea of advancing the injected voltage in order to minimize the real power supplied by the DVR has generated a great deal of research interest recently. The necessary conditions for such advance-angle control have been formulated for a given supply voltage disturbance.

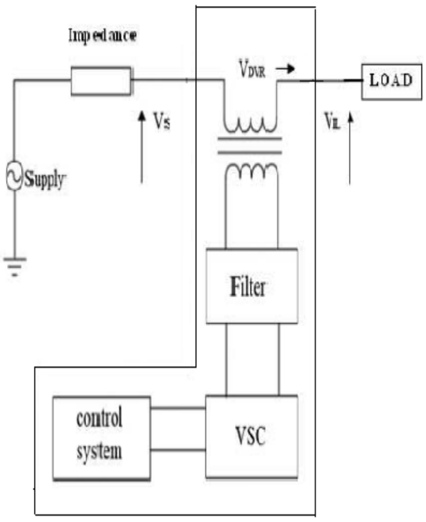

Figure 1: Schematic diagram of DVR

II. IDVR SYSTEM USING DVR

A simple radial system may not be considered suitable for certain concentrated loads as it has the least reliability. The IDVR system proposed in this paper employs two or more DVRs connected to a common dc link .A possible location for an IDVR scheme is an industrial park where several industrial loads are fed electrical power from different feeders emanating from different grid substations, perhaps at different voltage levels.

In order to establish the power exchange between the two systems, it is assumed that DVR1 is mitigating a voltage sag appearing in that line and DVR2 is controlled to provide real power to the dc-link energy storage.

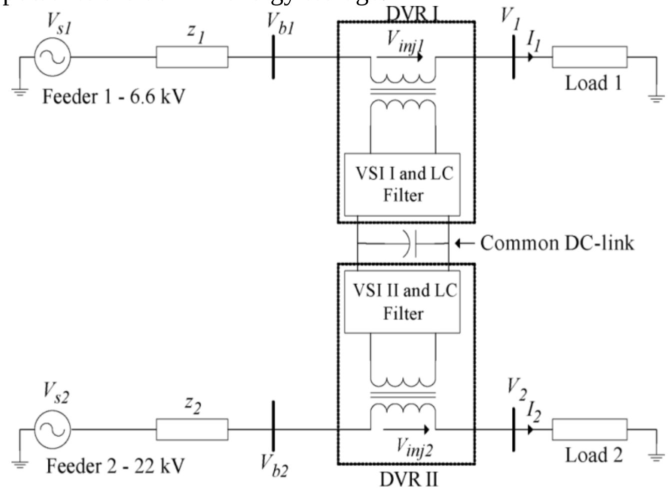

Figure 2: A simplistic IDVR system with two DVRs connected to dc link

III. SIMULATION RESULTS

A detailed simulation has been carried out for a simple IDVR system consisting of two lines of 6.6-kV voltage and 22-kV voltage using MATLAB 6.5 for four cases

- ✓ Applying Fault on Line1 (Phase A) with two DVRs. (In this case the power injection is depending upon the load power factor. There is no disturbance on the source voltages.)
- ✓ Applying Fault on Line2 (Phase A) with two DVRs
- ✓ Applying Fault on Line1 (Phase A) without DVR2 (The line 1 gets more DC voltage which enables the DVR1 to compensate for the long duration voltage sags)
- ✓ Removing Fault on Line1 (Phase A) with two DVRs.(In this case; without fault there is need for compensation but the power flow may be get disturbed because there is no DVR2 for providing the optimum power flow.)

CASE 1 & CASE 2

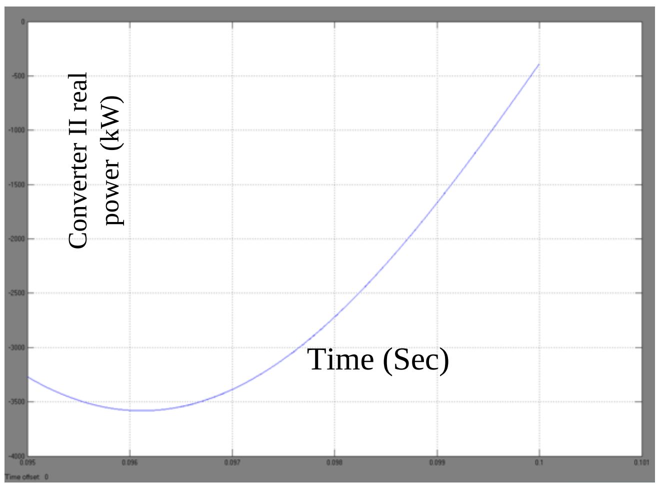

Figure 3 (a)

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CASE 3

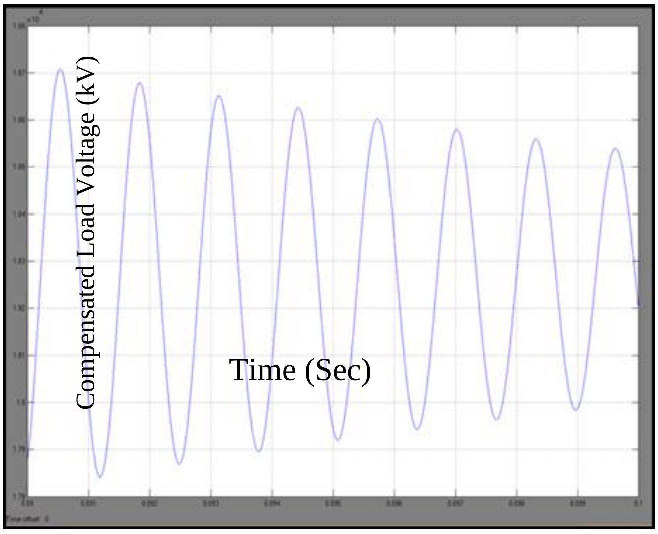

Figure 3 (b)

CASE 4

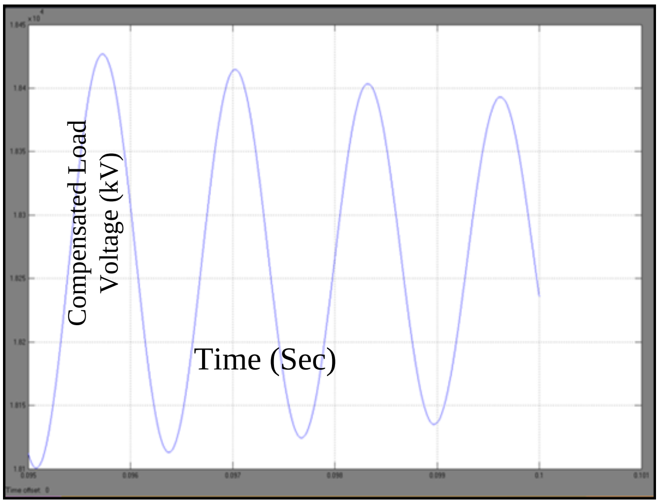

Figure 3(c)

IV. HARDWARE RESULTS

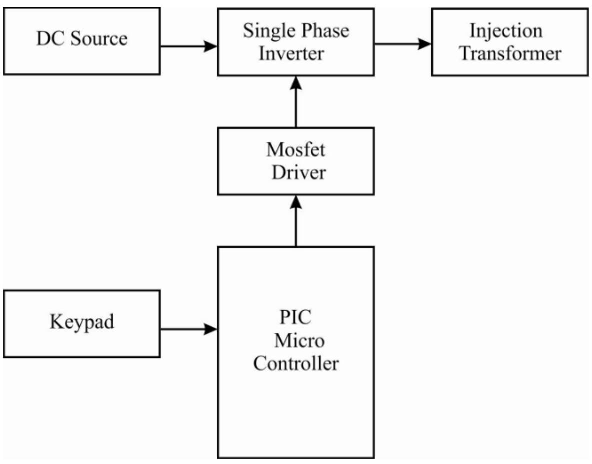

Figure 4: Block Diagram of Proposed Hardware Model

The voltage source inverter used in the DVR circuit makes the induction of required voltage with required phase possible. An inverter is a circuit which converts a DC power into an AC power at desired output voltage and frequency. The AC output voltage could be fixed or variable voltage and frequency. This conversion can be achieved either by controlled turn on and turnoff devices (e.g. BJT, MOSFET, IGBT, and MCT etc.) or by forced commutated thyristors, depending on application. The purpose of injection transformers is to accurately couple an oscillator signal into a feedback loop with minimum distortion and/or capacitive coupling. An injection transformer is a special type of transformer that is connected between a network analyzer and a DC-DC converter or voltage regulator in order to both inject a perturbing signal into the control loop and to record the response of the loop over a wide frequency range .It limits the coupling of noise and transient energy from the primary side to the secondary side.

Optocouplers are capable of transferring an electrical signal between two circuits while electrically isolating the circuits from each other. They generally consist of an infrared LED, light emitting section at the input and a silicon photo detector at the output. The input for opto couplers can be either AC or DC, which can drive the LED. Although there are many ways to drive MOSFET/IGBTs using hard wired electronic circuits, IC Drivers offer convenience and features that attract designers. The foremost advantage is compactness. IC Drivers intrinsically offer lower propagation delay. In this proposed system the voltage is injected to the minimum range of 14V.For minimum Energy injection in the phase advance injection there is need of maximum voltage injection.

V. CONCLUSION

The capability of a particular DVR to compensate long duration voltage sags mainly depends on the amount of energy stored within the DVR. This paper has proposed a new concept of IDVR which can minimize the dc-link energy storage connecting two or more DVRs to a common dc link. When one of the DVRs is compensating for voltage sag, converters of the other DVRs replenish the dc-link energy storage to maintain the dc-link voltage. Simulation results have been presented to demonstrate the efficacy of the proposed IDVR system to mitigate long-duration voltage sags. The limiting factor of the proposed IDVR system is that the amount of real power that one line can transfer to the dc-link energy storage depends on the load PF.

In Hardware, the voltage injection (in-phase) for minimum range has been discussed. The limiting factor of the proposed IDVR system is that the amount of real power that one line can transfer to the dc-link energy storage depends on the load PF. For minimum voltage injection, in-phase injection compensation is the best. For minimum energy injection by the DVR, phase advance compensation is best but requires more voltage injection. The proposed methodology allows for a detailed and realistic modeling of DVR components and their characteristics such as voltage dependent loads and generator reactive limitations.

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