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Improving the Performance of Interline Dynamic Voltage Restorer Based on Cascaded H-Bridge fed induction motor drive

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Abstract- *An Interline Dynamic Voltage Restorer (IDVR) is invariably employed in distribution systems to mitigate voltage sag/swell problems. An IDVR merely consists of several dynamic voltage restorers (DVRs) sharing a common dc link connecting independent feeders to secure electric power to critical loads. While one of the DVRs compensates for the local voltage sag in its feeder, the other DVRs replenish the common dc-link voltage. The proposed IDVR employs two cascaded H-bridge multilevel converters to inject AC voltage with lower THD and eliminates necessity to low-frequency isolation transformers in one side. The performance of designed MLI fed induction motor drives is investigated extensively for various operating conditions through MATLAB simulation.*

Key words- Back-to-back converter, cascaded H-bridge, interline dynamic voltage restorer (IDVR), minimum energy, power quality (PQ), voltage sag.

I. INTRODUCTION

In modern Industrial setups, several electronic devices are used to enhance production. These electronic devices are susceptible to failure due to sudden change in quality of power supply. Power quality is the set of limits of electrical properties that allows electrical/electronic system to function in their intended manner without significant loss of performance or life. Voltage sags & voltage swell, poor voltage and frequency regulation, harmonics and switching transients are frequently encountered power quality issues.Voltage sag is a sudden reduction of utility supply voltage from 90% to 10% of its nominal value, whereas, voltage swell is a sudden rise of supply voltage from 110% to 180%of its nominal value. The main requirement of any system is to maintain the load side voltage at constant level. DynamicVoltage Restorer (DVR) provides effective solution to the power quality problems such as voltage sag and voltage swell.[1] DVR is mostly used for Low Voltage (LV) and Medium Voltage (MV) applications. Dynamic Voltage Restorer (DVR) is the one of such power quality device usedin power distribution networks. It has lower cost, smaller size and fast dynamic response to the disturbance. An interline DVR (IDVR) has been proposed.The structure of IDVR consists of several DVRs with a common DC link which protect sensitive loads against voltage sags, where as each DVR has been located in an independent feeder. When one of the DVRs in IDVR structure starts to compensate the voltage sag by absorbing active power from the common DC link, the other ones operate in rectification mode and supply the DC link to maintain its voltage at a certain level. A new control strategy for IDVR has been proposed which minimizes the rating of the power devices. Based on this strategy, a reduction in the cost and size of the IDVR without compromising its performance has been achieved. An IDVR has been presented and instead of bypassing the DVRs in normal conditions, the DVRs are employed to improve the displacement factor (DF) of a specific feeder. This function is achieved by active and reactive power exchange (PQ sharing) between independent feeders. A new configuration has been proposed which extends the capability of DVR to mitigate deeper voltage sags. This approach utilizes a shunt reactance parallel with the load to decrease the load power factor during the sag condition.

In recent times, multilevel inverters (MLI) are gaining popularity and widely used for induction motor drive applications [1-3]. It is especially used for medium to high voltage and high current drive applications. There are many advantages of multilevel inverters as compared to conventional inverters. Main advantages are low total harmonics distortion (THD), low switching losses, good power quality and reduced electromagnetic interference (EMI). Main feature of multilevel inverter is that it reduces voltage stress on each component [4-8]. The topologies of multilevel inverters are classified into three types. They are flying capacitor, diode clamped and H-bridge cascaded multilevel inverters.

II. OPERATING PRINCIPLE OF IDVR

A simple IDVR which is shown in Fig.1 consists of two back-to-back voltage-source converters (VSC) with a commondc link. By using this topology, it is possible to transfer active power from a feeder to another one during the sag condition and to mitigate deeper and longer voltage sags (Fig. 1).

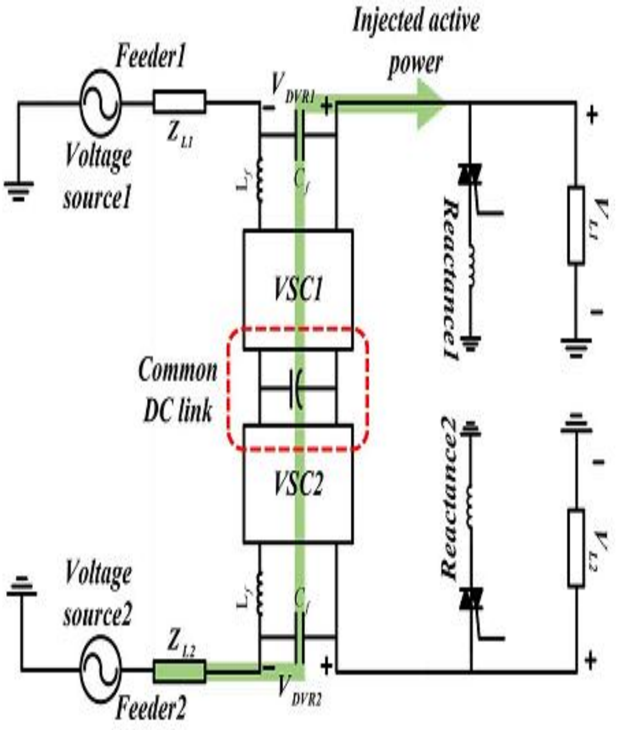

Fig.1. Power circuit schematic of the IDVR with active power-exchangingcapability.

Consider, for example, the condition in which voltage sag occurs in feeder1 and DVR1 starts to compensate it. Assuming $P_{S1}$and P_{L1} are source1 and load1 active powers, then the injected active power by DVR1 would be

$$P_{DVR1} = P_{L1} - P_{S1} \qquad (1)$$

Using the demonstrated phasor diagram in Fig. 2(a), (1) can be written as

$$P_{DVR1} = V_{L1} I_{L1} \cos(\varphi_1) - V_{S1} I_{L1} \cos(\varphi_1 - \alpha) \qquad (2)$$

Where it is obvious that load current is equal to source current due to series connection of DVR1 with load1. When minimum energy method is adopted for sag compensation, (2) is modified as shown in (3) at the bottom of the page. Moreover, active power, which is drawn by DVR2 from feeder2, can be derived from Fig. 2(b) as follows:

$$P_{\mathrm{DVR1}}^{ME} = \begin{cases} 0, & \text{if } V_{S_1} \geq V_{L_1}\mathrm{Cos}(\varphi_1) \\ V_{L_1} I_{L_1} \left(\mathrm{Cos}(\varphi_1) - V_{S_1}/V_{L_1}\right), & \text{if } V_{S_1} < V_{L_1}\mathrm{Cos}(\varphi_1) \end{cases} \qquad (3)$$

$$P_{DVR2} = V_{L2} I_{L2} (\cos(\varphi_2 - \beta) - \cos(\varphi_2)) \qquad (4)$$

Where injected voltage by DVR2 during the sag period leads to a phase difference between and which is defined asβ. According to (4) and [9], the maximum transferable active.

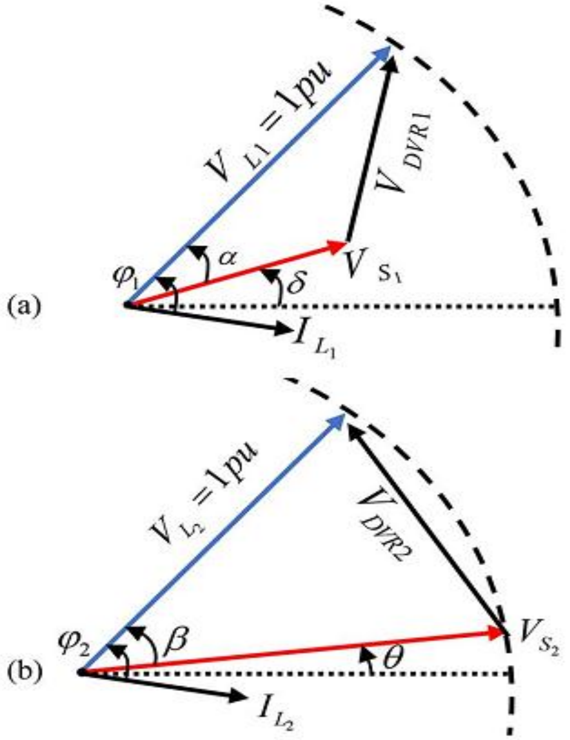

Fig. 2. Phasor diagram of the IDVR during voltage sag compensation: (a) DVR1 injected voltage and (b) DVR2 injected voltage.

III. INDUCTION MOTOR

An asynchronous motor type of an induction motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor can therefore be made without electrical connections to the rotor as are found in universal, DC and synchronous motors. An asynchronous motor’s rotor can be either wound type or squirrel-cage type.

Three-phase squirrel-cage asynchronous motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and variable-frequency drive (VFD) applications. Variable voltage and variable frequency drives are also used in variable-speed service.

In both induction and synchronous motors, the AC power supplied to the motor's stator creates a magnetic field that rotates in time with the AC oscillations. Whereas a synchronous motor's rotor turns at the same rate as the stator field, an induction motor's rotor rotates at a slower speed than the stator field. The induction motor stator's magnetic field is therefore changing or rotating relative to the rotor. This induces an opposing current in the induction motor's rotor, in effect the motor's secondary winding, when the latter is short-circuited or closed through external impedance. The rotating magnetic flux induces currents in the windings of the rotor; in a manner similar to currents induced in a transformer's secondary winding (s). The currents in the rotor windings in turn create magnetic fields in the rotor that react against the stator field. Due to Lenz's Law, the direction of the magnetic field created will be such as to oppose the change in current through the rotor windings. The cause of induced current in the rotor windings is the rotating stator magnetic field, so to oppose the change in rotor-winding currents the rotor will start to rotate in the direction of the rotating stator magnetic field. The rotor accelerates until the magnitude of induced rotor current and torque balances the applied load. Since rotation at synchronous speed would result in no induced rotor current, an induction motor always operates slower than synchronous speed.The difference, or "slip," between actual and synchronous speed varies from about 0.5 to 5.0% for standard Design B torque curve induction motors. The induction machine's essential character is that it is created solely by induction instead of being separately excited as in synchronous or DC machines or being self-magnetized as in permanent magnet motors.

For rotor currents to be induced the speed of the physical rotor must be lower than that of the stator's rotating magnetic field (n_s); otherwise the magnetic field would not be moving relative to the rotor conductors and no currents would be induced. As the speed of the rotor drops below synchronous speed, the rotation rate of the magnetic field in the rotor increases, inducing more current in the windings and creating more torque. The ratio between the rotation rate of the magnetic field induced in the rotor and the rotation rate of the stator's rotating field is called slip. Under load, the speed drops and the slip increases enough to create sufficient torque to turn the load. For this reason, induction motors are sometimes referred to as asynchronous motors.[25] An induction motor can be used as an induction generator, or it can be unrolled to form a linear induction motor which can directly generate linear motion.

Synchronous Speed:

The rotational speed of the rotating magnetic field is called as synchronous speed.

$$Ns = \frac{120 \text{ x } f}{P} \quad (\text{RPM}) \tag{5}$$

Where, f = frequency of the supply
P = number of poles

Slip:

Rotor tries to catch up the synchronous speed of the stator field, and hence it rotates. But in practice, rotor never succeeds in catching up. If rotor catches up the stator speed, there won’t be any relative speed between the stator flux and the rotor, hence no induced rotor current and no torque production to maintain the rotation. However, this won't stop the motor, the rotor will slow down due to lost of torque, and the torque will again be exerted due to relative speed. That is why the rotor rotates at speed which is always less the synchronous speed.

The difference between the synchronous speed (Ns) and actual speed (N) of the rotor is called as slip.

$$\%\text{ slip} \quad s = \frac{Ns - N}{Ns} \text{ x } 100 \tag{6}$$

IV. MATLAB/SIMULATION RESULTS

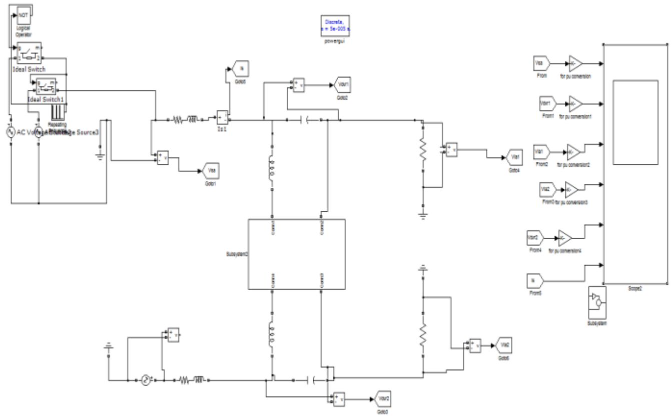
Fig.3. Investigating the IDVR performance when the proposed method is applied for a sag with a depth of 0.4 p.u.

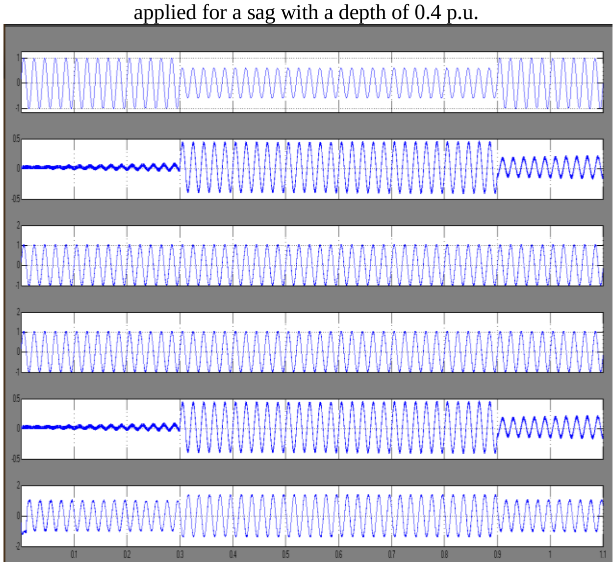

Fig.4 Source1 voltage, DVR1 voltage, Load1 voltage, Load2 voltage, DVR2 voltage, Load1 and shunt1 current

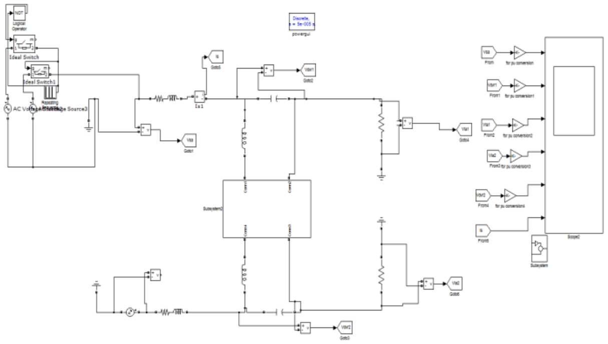
Fig.5 Investigating the IDVR performance when the proposed method is applied for a sag with a depth of 0.6 p.u.

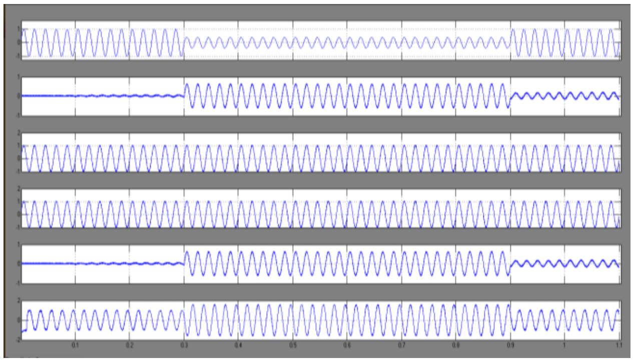
Fig.6 Source1 voltage, DVR1 voltage, Load1 voltage, Load2 voltage, DVR2 voltage, Load1 and shunt1 current

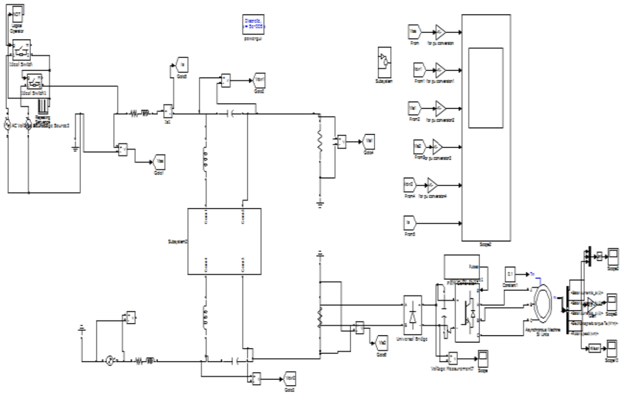
Fig.7 Investigating the IDVR performance when the proposed method fed induction motor drive

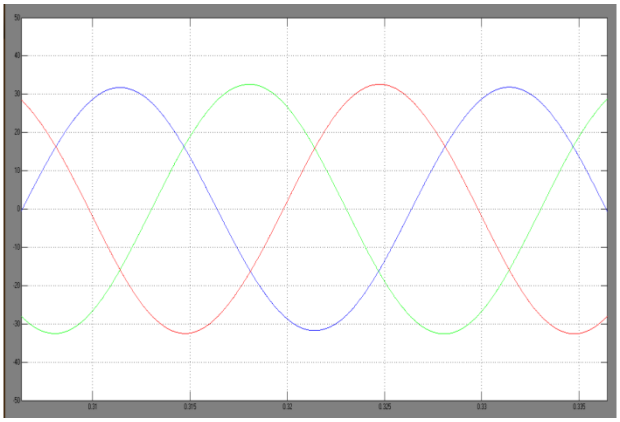

Fig.8 Stator current

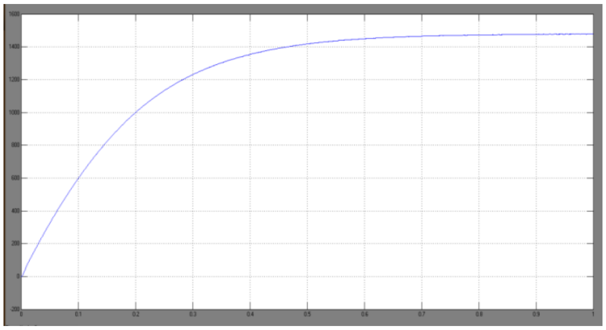

Fig.9 Induction motor Speed

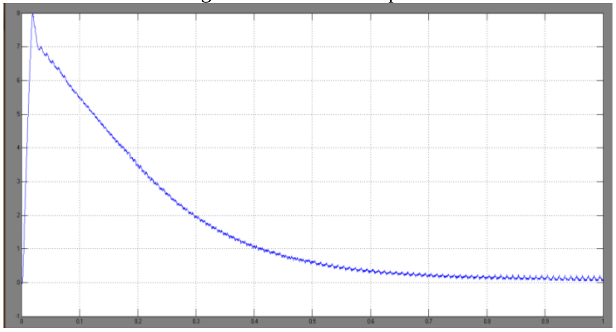

Fig.10 Induction motor Torque

V. CONCLUSION

In this paper Interline Dynamic Voltage Restorer (IDVR) is used to overcome the voltage sag and swell with the use of Cascaded H-Bridge multilevel inverter along with induction motor drive. This is proved by MATLAB simulation results. This paper proposes, not only improves the compensation capacity of the IDVR at high power factors, but also increases the performance of the compensator to mitigate deep sags at fairly moderate power factors. These advantages were achieved by decreasing the load power factor during sag condition. Finally, the simulation and practical results on the CHB based IDVR confirmed the effectiveness of the proposed configuration and control scheme.

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