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Harmonics Reduction in Variable Speed Drives Through the Injection of Numerous Compensation Strategies

Qais Uddin Alvi[1], Ashish Bhargava[2]

[1]*Research scholar (M.Tech in Power System), Department of electrical engineering, Bhabha engineering research institute Bhopal (M.P.) 462026*

[2]*Head of the Department, Department of electrical engineering, Bhabha engineering research institute Bhopal (M.P.) 462026*

***Abstract* - In recent years, power quality has become the most prominent issue in the field of electrical engineering. A nonstandard voltage, current, or frequency is the result of a power quality problem. Various forms of outages affect utility distribution networks, sensitive industrial loads, and vital commercial operations, and service disruption can result in considerable financial losses. Voltage sag is one of the primary issues addressed here. Power quality issues can be mitigated thanks to rapid advancements in power electronics technology. This research focuses on issues such as voltage sag and other power quality issues. Many technologies, including STATCOM, tap changing transformers, UPFCs, and DVRs, are available to help with voltage sag issues. The dynamic voltage restorer, which injects both voltage and power into the system, is the most commercially viable method for mitigating voltage sag. The Dynamic Voltage Restorer is a power electronics-based device that can swiftly reduce voltage sag in the system and restore the load voltage to its pre-fault value. This article begins with an overview of important power quality issues for a DVR as well as voltage sag reduction using power electronics controllers. The functioning and components of DVR are then explained. Using the Sinusoidal Pulse Width Modulation (SPWM) method, this thesis proposes using the error signal to regulate the triggering of switches in an inverter. MATLAB SIMULINK was used to model and simulate the proposed DVR.**

INTRODUCTION

DVR (dynamic voltage restorer): A DVR is a voltage source converter that is linked in series with the supply through an injection transformer to recover voltage sag or swell. The DVR is the most technologically advanced and cost-effective technology for reducing voltage sag in distribution systems. The DVR's energy storage is in charge of delivering active power during voltage sag. If the energy comes from a neighboring feeder, the device is known as an interline dynamic voltage restorer. In certain circumstances, particularly in high-tech sectors like semiconductor factories, these disruptions can result in the full stoppage of an entire production line, resulting in significant economic implications for the afflicted company. The DVR is a power quality device that can safeguard these businesses from the majority of these disruptions, such as voltage sags and swells caused by distant system problems. If the supply grid is not completely disconnected due to breaker tripping, a DVR adjusts for these voltage excursions.

The power electrical core of new Custom Power devices like DVR is modern pulse-width modulated (PWM) inverters capable of creating accurate high-quality voltage waveforms. Because the quality of the applied control strategy has such a big impact on the entire control system's performance, a high-performance controller with quick transient response and strong steady-state characteristics is required. Sag detection, voltage reference generation, and transient and steady-state regulation of the injected voltage are the primary considerations for a DVR's control system. Voltage sags, voltage swells, interruptions, phase shifts, harmonics, and transients are all common power quality issues. Voltage sag is the most severe of the disruptions because sensitive loads are most vulnerable to transient voltage fluctuations

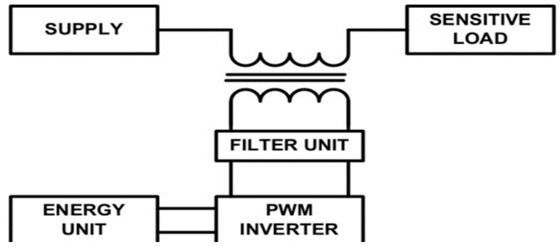

Fig. 1 Typical applications of DVR and its output

To reduce voltage sags and enhance power quality, a wide-area solution is needed. Using a digital video recorder (DVR) is a novel method. As illustrated in Fig.1, the fundamental functioning concept is to detect a voltage drop and inject the missing voltage in series to the bus. The use of DVR to safeguard sensitive loads from voltage sags has become a cost-effective option. The DVR is a quick, versatile, and cost-effective way to solve voltage sag issues. As illustrated in Fig.1, a DVR is made up of an energy storage unit, a PWM inverter, a filter, and an injection transformer.

1.1.1 Futures of DVR:

- Compared to the SMES device, DVR has a cheaper cost, smaller size, and a faster dynamic reaction to disturbances.
- DVR has the ability to manage active power flow.
- DVR also has a higher energy capacity and lower prices. It also requires less maintenance.
- UPS is not only expensive, but it also necessitates a high degree of maintenance because batteries leak and must be changed every five years or so.

1.5 Working of DVR:

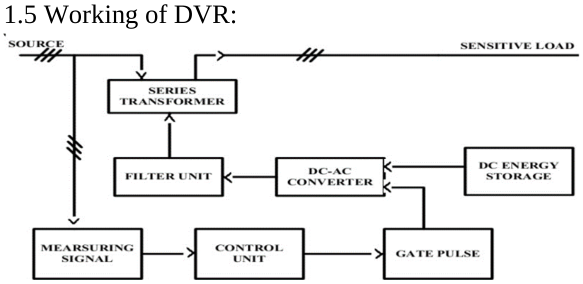

Figure 2 Function blocks of designed DVR

Voltage sags are the most severe of the voltage transients (sags, swells, harmonics, etc.). To minimise the amount of voltage sags, users might enhance end-use devices or employ protective devices. However, a Dynamic Voltage Restorer is a good overall solution for reducing voltage sags and restoring load voltage to pre-fault levels (DVR). It's a solid-state DC to AC switching power electronic converter that connects the feeder and the sensitive load with three single-phase AC voltages in series. Using a DVR is a more dependable and quick way to ensure that clients have a steady supply of energy. The primary disadvantages of DVR include standby losses, equipment expenses, and the need for extensive design research. By analysing the control unit signals, the PWM inverter unit generates the needed missing voltage, which is then injected into the system through injection transformers.

1.6 Control strategy of DVR

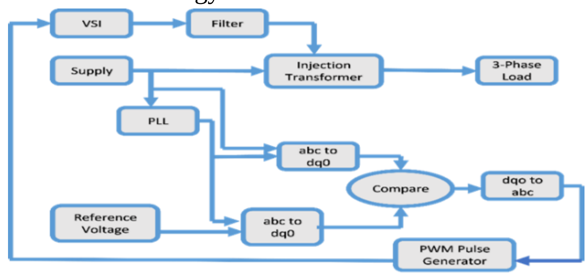

Figure-3 Flowchart of feed forward control technique for DVR based on dqo transformation**.**

The basic functions of a controller in a DVR are to detect voltage sag/swell events in the system, compute the correcting voltage, generate trigger pulses to the Sinusoidal PWM based DC-AC inverter, correct any anomalies in the series voltage injection, and terminate the trigger pulses once the event has passed. In the absence of voltage sags/swells, the controller may be utilized to move the DC-AC inverter into rectifier mode, which will charge the capacitors in the DC energy link. DVR is controlled via the dqo or Park's transformation. The dqo method returns the sag depth and phase shift, as well as start and finish timings. The instantaneous space vectors are used to express the Quantities. To begin, transform the voltage from the abc to the dq0 reference frame. Zero phase sequence components are disregarded for the sake of simplicity. The feed forward dq0 transformation for voltage sags/swells detection is depicted in Figure-3.10 as a flow chart. Each of the three stages includes a detecting procedure. The control is based on a voltage reference being compared to the observed terminal voltage (Va,Vb,V c). When the supply voltage falls below 90% of the reference value, voltage sags are recognized, whereas voltage swells are identified when the supply voltage rises to 25% of the reference value. The error signal is modulated to provide a commutation pattern for the voltage source converter's power switches (IGBTs). The commutation pattern is created using the sinusoidal pulse width modulation (SPWM) method, which also controls voltages.

Figure-3 is a block schematic of a phase locked loop (PLL). The PLL circuit generates a unit sinusoidal wave that is phased with the mains voltage.

$$\begin{bmatrix} Vd \\ Vq \\ Vo \end{bmatrix} = \begin{bmatrix} \cos\theta & \cos(\theta - 2\pi/3) & 1 \\ -\sin\theta & -\sin(\theta - 2\pi/3) & 1 \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \quad (1)$$

Equation defines the transformation from three phase system abc to dqo stationary frame. In this transformation, phase A is aligned to the d -axis that is in quadrature with the q-axis. The theta (θ) is defined by the angle between phase A to the d-axis.

SIMULATION AND RESULTS

Simulation for Sag and Swell without DVR

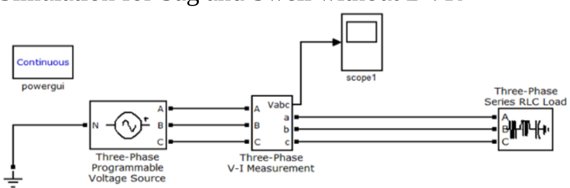

Fig. 4 Simulation circuit for voltage sag and swell without DVR

The system consists of voltage of 1 pu, 50 Hz source with 10kw 3-phase RLC load shown in fig 5.1. voltage sag is occurred at 0.5 sec to 1 sec of .5 pu and voltage swell occurred of 0.5 pu for 0.2 sec to .25 sec. Fig: 5.2 shows three phase voltage waveform under fault condition without DVR. As shown fig 5.1, sag occurs at 0.1 sec to 0.15 sec. Now the function of DVR would be to inject acompensating voltage, which would result in fairly constant voltage across the load terminal. With the use of the fast acting power electronics converters, DVR is capable to inject voltage for such a small duration of few cycles. The simulation parameters are given in following table

Supply Source	3-Φ, 1 puV, 50 Hz
Load	10kW, 100Var
Filter	L=20mH, C=30μF
DC Voltage Source	600V

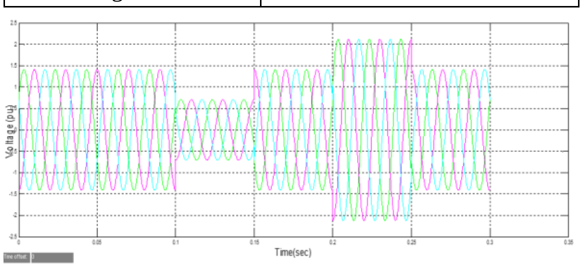

Fig. 5 simulation result for voltage sag and swell without DVR

Simulation for system with PLL circuit and abc to dq0 Block

Fig 6 shows the simulation of system with abc to dq0 transformation block which convert voltage waveform into dq0 form as shown in fig 7

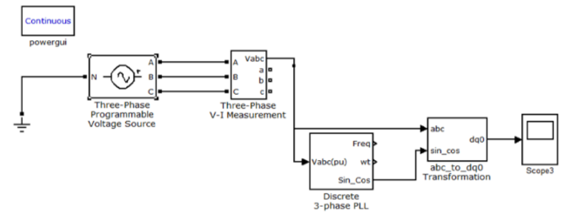

Fig. 6 Simulation for system with PLL circuit and abc to dq0 Block

5.4 Simulation for system with error signal generated

Fig 5.9 shows the simulation of comparison of reference voltage and supply voltage fig 5.10 shows the supply voltage and reference voltage in steady state condition.

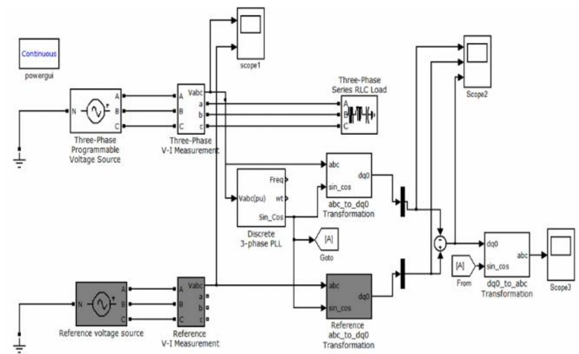

Fig. 7 Simulation for system with error signal generated

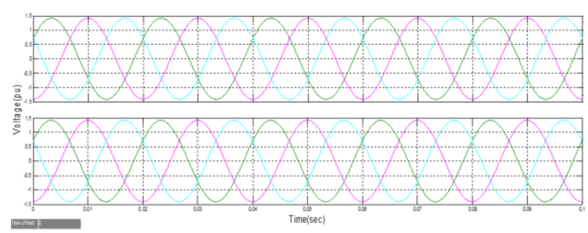

Fig. 8 Simulation result of supply voltage and reference voltage

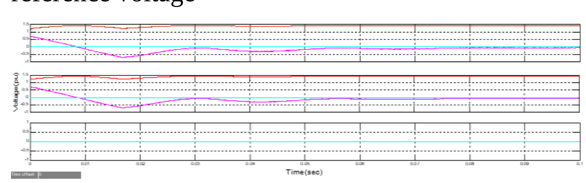

Fig. 9 Simulation result of supply voltage and reference voltage and error signal in dq0

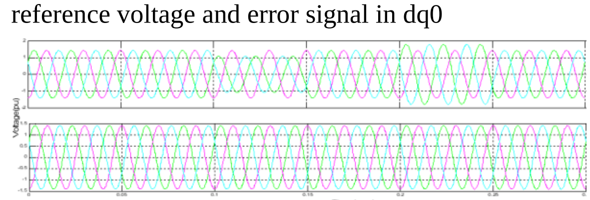

Fig. 10 Simulation result of supply voltage and reference voltage in the event of sag and swell in one phase

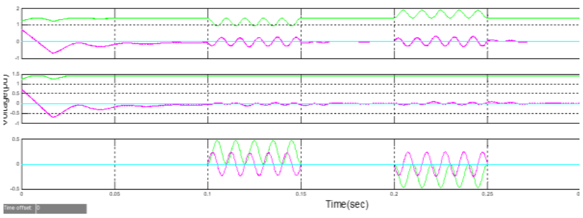

Fig. 11 Simulation result of supply voltage and reference voltage and error signal in dq0 in the event of sag and swell in one phase

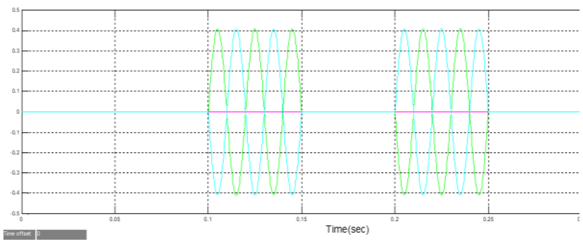

Fig. 12 Simulation result of error signal in abc in the event of sag and swell in one phase

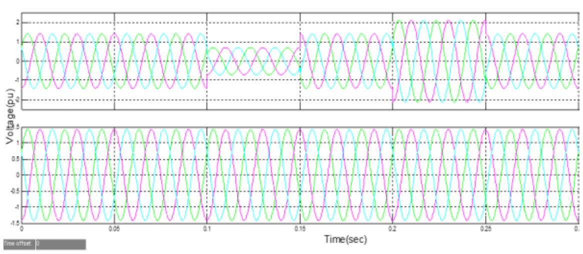

Fig. 13 Simulation result of supply voltage and reference voltage in the event of sag and swell in all phases

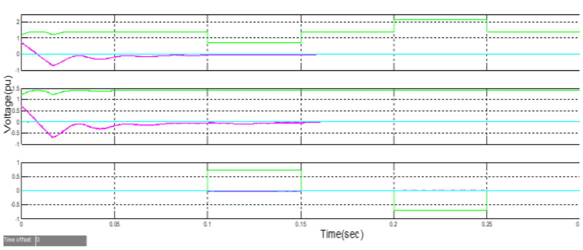

Fig. 14 Simulation result of supply voltage and reference voltage and error signal in dq0 in the event of symmetrical sag and swell

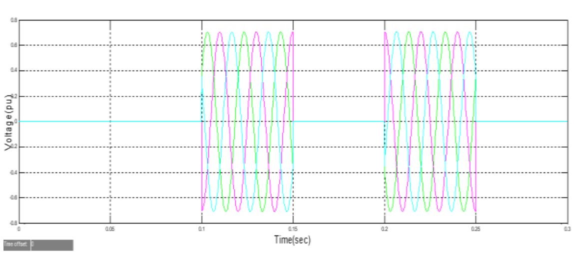

Fig. 15 Simulation result of error signal in abc in the event of symmetrical sag and swell

Fig. 8 to fig. 15. shows the output of voltage, Simulation result of supply voltage and reference voltage and error signal in dq0 in the event of symmetrical sag and swell, Simulation result of error signal in abc in the event of symmetrical sag and swell respectively.

Simulation of SPWM based inverter

Generation of Gate pulse

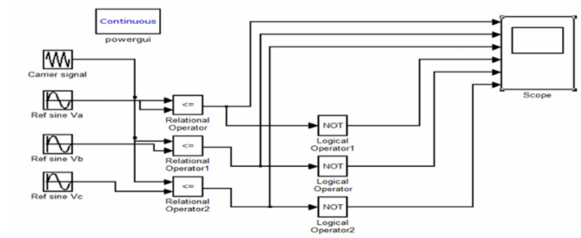

Fig. 16 shows the pulse generation circuit in which reference wave is compared with carrier wave.

Fig. 16 Generation of Gate Pulse

Generation of Gate pulse

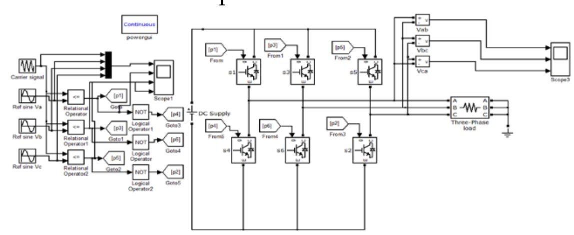

Fig. 17 SPWM based inverter Without Filter Circuit

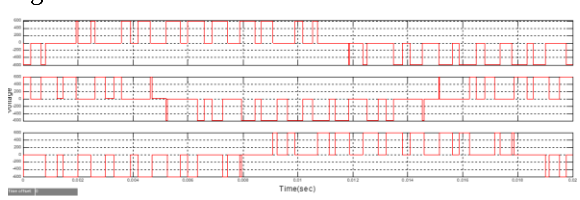

Fig. 18 SPWM based inverter Voltage waveforms Without Filter Circuit

Simulation of SPWM inverter with filter circuit

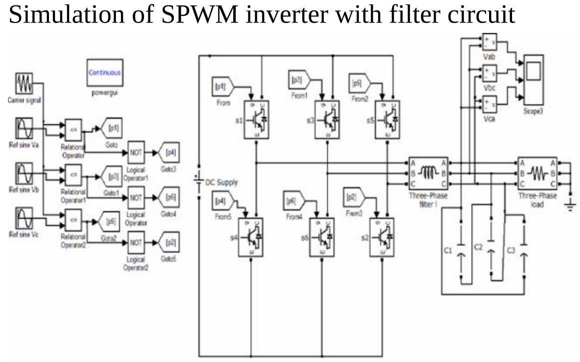

Fig. 19 SPWM based inverter With Filter Circuit

Fig 19 shows the simulation of SPWM inverter with Filter circuit so that the output voltage is purely sinusoidal as shown in fig, 20.

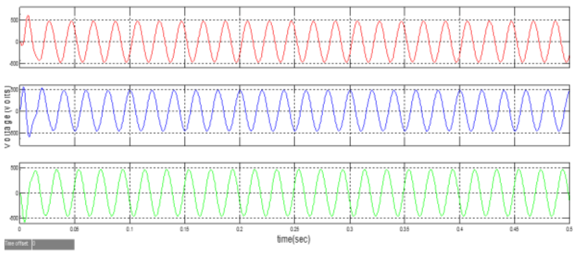

Fig. 20 SPWM based inverter Voltage waveforms With Filter Circuit

CONCLUSION

Voltage sags and current harmonics are the most important power quality problems in commercial and industrial utility of customers. These power quality problems can cause tripping of sensitive electronic equipments, abnormal operations of facilities and tremendous economic losses. Custom Power devices have now been of interest for more than a decade that are able to improve the reliability and the quality of power delivered to electric power customers. UPQC consisting of two voltage source inverters with a common DC link is a custom power device and can simultaneously perform the tasks of APF and DVR. However, UPQC does not provide different levels of power for their customers since UPQC solves only end user power quality concerns. In this thesis, a novel control strategy for the case of three phase four wire UPQC based on the concepts of (1) Instantaneous active and reactive Power theory, (2) Instantaneous symmetrical component theory and (3)Fuzzy hysteresis band controller are presented. The main objective of this research was to develop the UPQC control algorithms for enhanced performance. Instantaneous symmetrical component theory is easy to implement and it has reasonable dynamic response. The control strategy generates reference compensating currents of shunt active filter and reference compensating voltages of series active filter in such a manner that the source side currents and load side voltages become sinusoidal and balanced in various power quality conditions. The neutral current that may flow to forward the transformer neutral point is effectively compensated such that the transformer neutral point is always at virtual zero potential. Based on instantaneous active and reactive Power theory, a suitable mathematical model of the UPQC has been developed. The UPQC controller was designed using the instantaneous power method based on 0 transform and fundamental positive sequence detection. Using this control strategy, harmonic detection, reactive power compensation have been simulated and the results are analyzed. In situations where the UPQC is connected to a weak supply point and a fuzzy logic hysteresis band controller is used to control the shunt and series inverter, due to the switching frequencies in the supply current, the load side voltage can become unacceptably distorted. APF eliminates the load current harmonics and keeps the supply current at the PCC almost sinusoidal. Dynamic response is very critical for DVR since many industrial loads are very sensitive to voltage sags. When voltage sag occurs on the supply voltage, DVR quickly starts to inject the missing voltage to the system and keeps the load voltage magnitude nearly at 1 pu. APF continues the current harmonic elimination. An adaptive dc link voltage controller has been proposed for obtaining a better performance system both in steady state and during the transients. We have analyzed the operation of a UPQC that combines the operations of a DSTATCOM and DVR. The series component of the UPQC inserts voltage so as to maintain the voltage at the PCC balanced and free of distortion. Simultaneously, the shunt component of the UPQC injects current in the a.c. system such that the currents entering the bus to which the UPQC is connected are balanced sinusoids. Both these objectives must be met irrespective of unbalance or distortion in either source or load sides. The effectiveness of the proposed control strategies has been proved through Simulations. Based on the simulation studies and THD level, it can be recommended that control strategy based on Fuzzy hysteresis band controller is suitable for all the power quality issues with very good transient and steady state operations.

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