Power Quality Problem Mitigation by using IDVR with SPWM (Sinusoidal Pulse Width Modulation) and SVPWM (Space Vector Pulse Width Modulation) Techniques

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Abstract— Voltage sag is a common and undesirable power quality phenomenon in the distribution systems which put sensitive loads under the risk. An effective solution to mitigate this phenomenon is to use dynamic voltage restorers and consequently, protect sensitive loads. Four basics compensation methods were proposed in the research community to eliminate the voltage sags and minimize the voltage disturbances at load side. This paper provides a review of those voltage compensation strategies with detailed discussions and comparisons to highlight their advantages and disadvantages. This paper describes the performance and efficiency of interline dynamic voltage restorer (IDVR) depends upon the control technique. Control technique plays a very important role in DVR. Space vector pulse width modulation (SVPWM) and sinusoidal pulse width modulation are two distinct control technique have been presented in this paper depending upon the performance and characteristics. Among these two techniques SVPWM finds the most effective technique because of easier digital realization and reduction of total harmonic distortion (THD) created by rapid switching inherent to these algorithm. The approach of this paper to the implementation of SVPWM and SPWM in IDVR and these methods investigated through the computer simulation by using MATLAB software.

Key words: Voltage restorer, SVPWM, SPWM

I. INTRODUCTION

Sensitive loads such as medical equipment, factory automations, semiconductor-device manufacturer, and paper manufacturer are vulnerable to power-supply disturbances [1]- [3]. Consequently, the demand for high power quality and voltage stability becomes a pressing issue. In the present power grids, voltage sags are recognized as a serious threat and a frequently occurring power-quality problem and have costly consequence such as sensitive loads tripping and production loss [4]-[7]. Both the "Canadian Power Quality Survey" conducted by the Canadian Electrical Associate (CEA) in 1991 over 550 customer sites and the "Distribution System Power Quality Survey" conducted by the Electric Power Research Institute (EPRI) on 222 utility distribution feeders between 1993 and 1995 have shown that voltage sags are the most frequent power quality events [8]. These disturbances occur due to, e.g., short circuits in upstream power transmission line or parallel power distribution line connected to the point of common coupling (PCC), inrush currents involved with the starting of large machines, sudden changes of load, energizing of transformers or switching operations in the grid [1]-[3], [9], [10]. According to the IEEE 1959-1995 standard, voltage sag is defined as a decrease of 0.1 to 0.9 p.u. in the rms voltage at system frequency and with the duration of half a cycle to 1 min

[11]. According to the definition and nature of voltage sag, it can be found that this kind of disturbance is a transient phenomenon whose causes are classified as low- or medium-frequency transient events [11]. Due to the above mentioned effects of voltage sags on sensitive loads, compensating voltage sags and minimizing their effects is necessary. Traditional methods of suppressing voltage variations include tap-changing transformers and uninterruptible power supplies (UPS).

However, tapchanging transformer is bulky, costly and not fast enough to eliminate the voltage sag effects at load side. On the other hand, UPS is bulky and expensive device whose power rating should be same as load power rating. Furthermore, there are custom power devices such as static synchronous compensator (STATCOM), distribution-STATCOM (DSTATCOM), unified power-quality conditioner (UPQC), and dynamic voltage restorer (DVR) as power electronics based solutions to minimize costly outcomes of voltage sags [12]. In comparison, DVR is more effective and direct solutions for "restoring" the quality of voltage at its load-side terminals when the quality of voltage at its source-side terminals is disturbed. DVRs compensate voltage sags by injecting the proper amount of voltages in series with the supply voltage, in order to maintain the load side voltage within the specification. Typically, a DVR consists of an energy storage device and an inverter which is coupled via a series transformer to the grid. The purpose of inverter is injecting the series voltage with a controlled magnitude and phase angle to restore the quality of load voltage and avoid load tripping [24]-[27]. The basic concept of DVR is depicted in Fig. 1. Moreover, there is a parallel switch to bypass and protect the DVR when the short circuit occurs in downstream power lines.
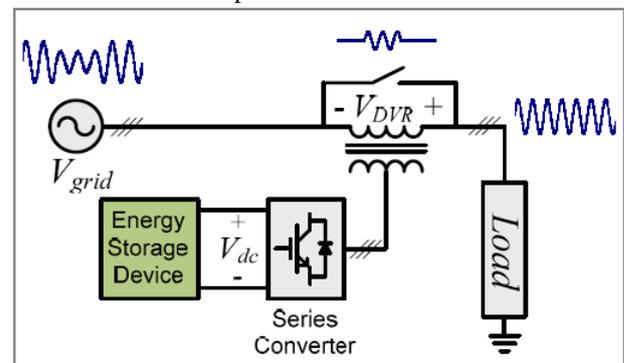

Fig. 1: Principle operation of DVR

The control system of DVR has two main parts: detection and determining the reference signal. The first one is the voltage sag detection part in which the grid voltage are measured and analyzed and based on sag detection method, the voltage disturbance can be recognized. There are different detection methods such as peak measurement, rms

measurement, dq0 components measurement [1]-[5], decoupled positive- and negative-sequence dq0 components measurement and phasor parameters estimation using Kalman filter or complex Fourier Transformation as reported in articles. The second part of DVR control system is determining the reference signal of series injected voltage. The method to determine reference signal of series injected voltage is based on the type of energy storage device, its ability to support active power and sensitivity of load to voltage disturbances. There are four basic methods of voltage compensation including in-phase, pre-sag, energy minimized and hybrid compensation methods. This paper investigates the mentioned compensation methods with detailed discussions and the comparisons to highlight their advantages and disadvantages.

II. PROPOSED METHODOLOGY

A. Pulse Width Modulation and Technique

A Pulse Width Modulation (PWM) Signal is a method for generating an analog signal using a digital source. A PWM signal consists of two main components that define its behavior: a duty cycle and a frequency. The duty cycle describes the amount of time the signal is in a high (on) state as a percentage of the total time of it takes to complete one cycle. The frequency determines how fast the PWM completes a cycle. Inverter is a power electronic device which converts power from DC to AC. Now a days most of industrial application often needs a variable output power to compensate the voltage and to supply some which require variable voltage with frequency. This paper presents the two different techniques of PWM Sinusoidal pulse width modulation (SPWM) and space vector pulse width modulation (SVPWM).

B. Sinusoidal Pulse Width Modulation

The shift pulses for the 3 part electrical converter ar generated by comparison a curved reference signal with the high frequency triangular radio wave victimization curved PWM techniques. Modulation index is that the quantitative relation of peak magnitudes of the modulating wave form and also the carrier wave form. It relates the electrical converters dc-link voltage and also the magnitude of pole voltage output by the inverter. By variable the modulation index price will management the output voltage [5].
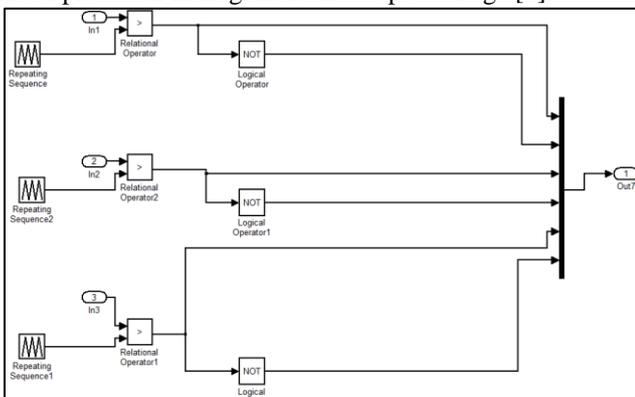

Fig. 2: SPWM generator for gating pulses

C. Space Vector Pulse Width Modulation

Space Vector PWM (SVPWM) refers to a special switch theme of six power switches of a 3- part VSI. It generates minimum harmonic distortion and additionally provides additional economical use of DC offer voltage as compared with the curving modulation technique. SVPWM treats the electrical converter as one unit. Specially the electrical converter are often driven to eight distinctive states. Modulation is accomplished by switch the state of electrical converter. Area vector pulse breadth modulation treats the curving voltage as a relentless amplitude vector rotating at constant frequency.

In 3 part electrical converter total eight vectors square measure attainable among those six square measure non-zero and 2 square measure zero vectors. Six non-zero vectors (V1-V6) form the axes of a horizontal as portrayed in Fig. 3 provides power to the load. The angle between any adjacent 2 non-zero vectors is sixty degrees. Meanwhile, 2 zero vectors (V0-V7) and square measure at the origin and apply zero voltage to the load. The eight vectors square measure referred to as the area vectors and square measure denoted by (V0, V1, V2, V3, V4, V5, V6, V7). Constant transformations are often applied to desired output voltage to urge the specified reference voltage vector, Vref within the d-q plane. The target of SVPWM technique is to approximate the reference voltage vector Vref exploitation the eight switch pattern.
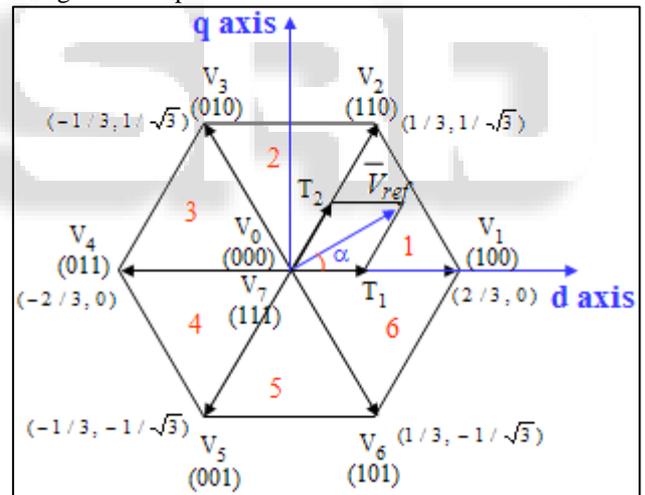

Fig. 3: Vector representation of switching gate

III. SIMULATION RESULTS

Simulation has made for two independent feeders with two independent sources. When one of the feeder experience voltage sag controller sense it and error signal send it to the controller. The basic function of controller in IDVR is to detect a voltage difference in the system and generation trigger pulses for the both sinusoidal PWM and space vector PWM based DC-AC inverter and execution of the trigger pulses when the disturbance has overcome. The three phase DC-AC inverter can also be used as AC-DC converter to replenish the DC link in balanced normal condition.
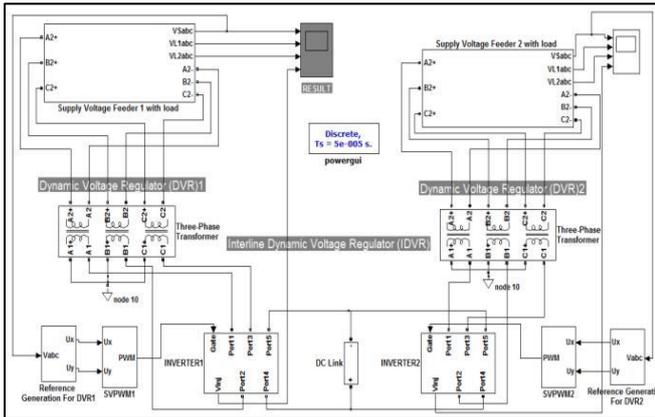
Fig. 4: Complete interline dynamic voltage restorer system
MATLAB simulation model of interline dynamic voltage restorer is shown in figure 4

A. Simulation Results of Space Vector Pulse Width Modulation

Simulation results presented in this paper work are for the 3 phase voltage sag of 30% which appears in the load bus on feeder one (3.3Kv) for a duration 0.3ms to 0.7ms. The DVR 1 is operated in active control mode and mitigates the sag above with optimum energy.
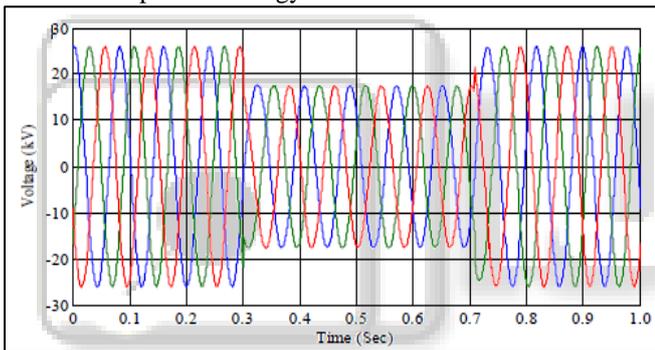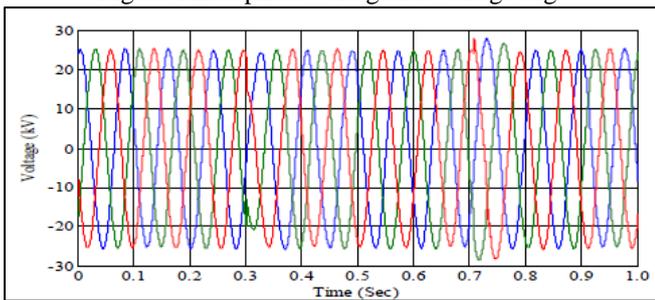

Fig. 5: Three phase voltage for voltage sag

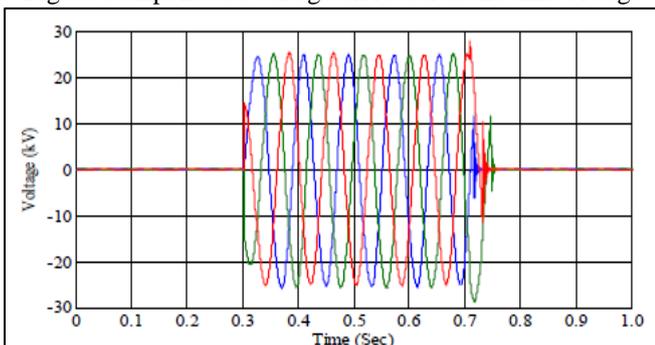Fig. 6: Compensated voltage on feeder at the time of sag

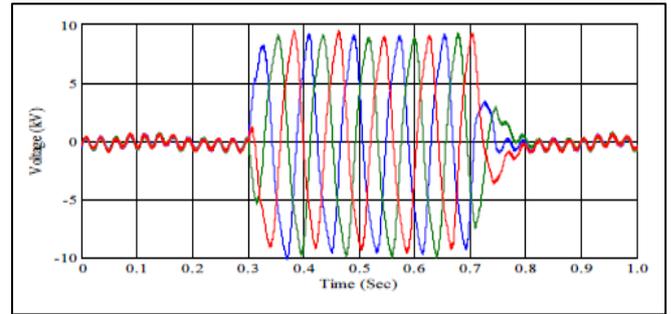Fig. 7: Three phase voltage across load

Fig. 8: Injected voltage waveform

B. SVPWM Total Harmonic Distortions Results

Space vector pulse width modulation technique is more superior to sinusoidal pulse width modulation in terms of total harmonic distortion (THD) and switching losses [8].
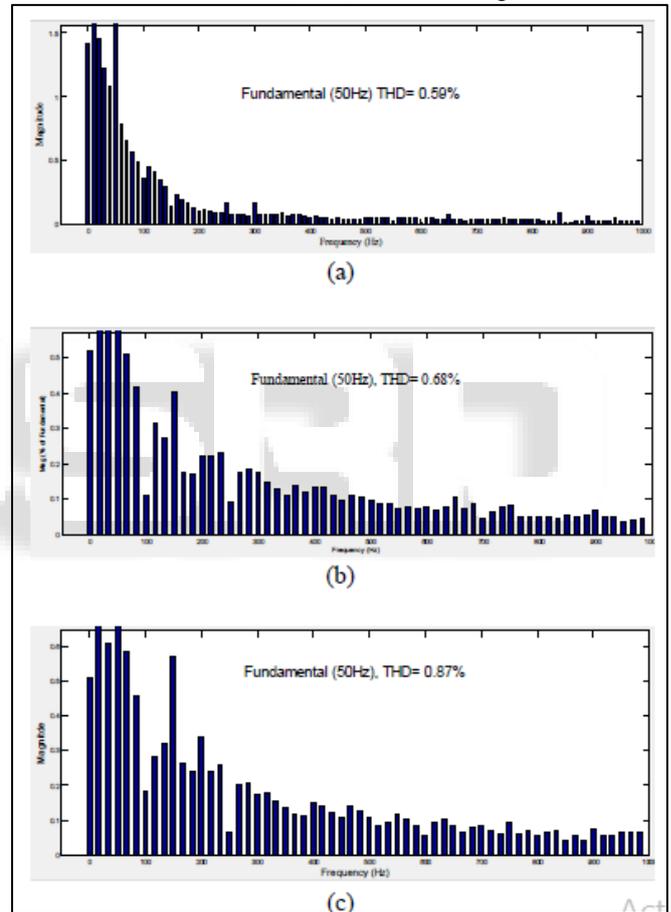

Fig. 9: total harmonic distortion by SVPWM technique (a) THD 0.59% at 20% sag. (b) THD 0.68% at 25% sag (c) THD at 0.87% at 30%

IV. CONCLUSION

Voltage sag is one of the major and frequently occurring problems in present power grids. Voltage sags are not acceptable for sensitive loads because they cause power loss for sensitive loads, which is a costly problem. Recently due to the increased integration of sensitive loads into power grid, providing high quality power is an important requirement. To suppress the problem of voltage sag, DVRs are suitable devices to compensate these voltage sags,

protect sensitive loads and restore their voltage during voltage sag. One of the important topics in DVR is the procedure and method of voltage compensation. There are few basic compensation methods including in-phase, pre-sag, energy minimized and hybrid compensation methods while each one has some processes and conclusions. This paper has reviewed and discussed in details the mentioned compensation methods and provided a comparison.

Simulation of interline Dynamic voltage restorer by using MATLAB has been presented. This paper work proposed a new control technique space vector pulse width modulation and sinusoidal pulse width modulation shows that SVPWM technique is more superior to SPWM technique in terms of total harmonic distortion.

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