POWER QUALITY ENHANCEMENT USING DYNAMIC VOLTAGE RESTORER

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Abstract: Improved and controlled power quality is an essential and fundamental requirement in any power-driven industry for optimum resource utilisation. However, critical power quality issues such as sags, swells, harmonic distortions, and other interruptions have been identified. These sags and swells are commonly found and have a severe impact on electrical devices or electrical machines, so they must be compensated as soon as possible to avoid any malfunction or failure. Custom power devices such as dynamic voltage restorers are used with space vector pulse width modulation technique (SVPWM) to solve these problems.

Keywords: Dynamic voltage restorer, FACTS, total harmonic distortion, sag, swell, harmonics etc.

1. INTRODUCTION

Power quality is related to the ability of resources to provide electricity without interruption. One of the biggest concerns in the electricity industry today is energy problems in critical loads. Power quality problems such as voltage sag, voltage swell, harmonic distortion, voltage imbalance may affect customer devices, causing inefficiency and power loss. The high costs associated with these disruptions explain the growing interest in energy efficiency strategies. Voltage sag is widely regarded as one of the most important power quality disturbances. Voltage sags can happen just as often as any other energy quality problem. Therefore, the losses caused by the customer sag voltage problem at the end of the load are large. Voltage sag temporary decrease in rms voltage magnitude in the range of 0.1 to 0.9 per unit [9], [10], [11]. It is usually caused by faults in the energy system and is reflected in its magnitude and duration. The voltage sag magnitude is defined as the net rms voltage within the voltage sag, which is usually per unit of low voltage level. The magnitude of the voltage sag depends on various factors such as the type of error, the location of the error and the impedance of the error. The duration of the power outage basically depends on how quickly the fault is erased by the protection device. In short, the voltage sag will remain until the error is cleared. Swell is defined as an increase of between 1.1p.u and 1.8p.u at rms voltage or current during a frequency of power from 0.5 to 1 minute [6], [7], [8].

Dynamic Voltage Restorer (DVR) is a power supply device used to inject a voltage of 3 phases in series and in conjunction with supply-supply voltages to compensate for power outages [4] and similarly react quickly for proper injection. part of the voltage (negative voltage magnitude) to compensate for the high voltage. In this operation, voltage degradation and inflammation are compensated using DVR based on the Space Vector Pulse Width Modulation technique (SVPWM). It has been found that DVR-based Space Vector PWM (SPWM) technology compensates for voltage sags and inflammation effectively compared to the Sinusoidal Pulse Width Modulation technique (PWM).

2. PROBLEM STATEMENT

Power electronics outfit similar as controlled cures, electric bow furnaces and welders, malleable speed drives, induction heating plates, particular computers and fluorescent lights represent major nonlinear loads proliferating among artificial and marketable guests. These bias beget high harmonious deformation and PQ problems. For illustration, variable frequency drive, which is used for motor speed control and furnishing smooth motor starting with its advantage for energy saving and enhancing system effectiveness, make losses in the form of heat dissipated in its element during the frequency conversion process which causes the harmonious deformation in the power system.

3. POWER QUALITY IMPROVEMENT ALTERNATIVE

DVR is considered an effective and efficient custom power tool to reduce the impact of power outages on critical load. In addition the DVR also has functions such as active power compensation and compliant compensation.

Active Power Filters (APF), unified power-quality conditioner (UPQC), Distribution Series Capacitors (DSC), Solid-State Transfer Switches (SSTS), Superconducting Magnetic Energy Systems (SMES), Uninterruptible Power Supply (UPS), Static Electronic Tap Changers (SETC), Solid State Current Limiter (SSFCL), Static VAR Compensator (SVC), and Thyristor Switched Capacitors (TSC), Distribution-STAT (DVR).

4. DYNAMIC VOLTAGE RESTORER (DVR)

A DVR (Dynamic Voltage Restorer) is a series connected to a solid device that incorporates fresh voltage into the system to control the voltage along the load into the convenient size and wave format indeed when the source voltage
isn't equal or distorted. In this process includes injection of active power from the DVR to the distribution system. With an infusion transformer, the DVR is connected between the voltage of the source or grid and the impressive loads. The difference between a voltage source and a crucial stack is compensated in DVR.

![Fig. 1: Block Diagram of DVR](image)

The inverter assures that the infusion transformer receives a volatile or line voltage. This device is built on a PWM power source converter that can provide sinusoidal voltage at any point size, frequency, or stage. The DVR framework consists of two main components: the control region and the control unit. The DVR power circuit basically includes a power source converter, an infusion-related transformer setting, a separate inverter output channel, and a live power gadget connected to a dc connect as it happens afterwards:
- Series Voltage Injection / Booster Transformers
- Voltage Source Inverter (VSI)
- Control and protection

Standard DVR configurations include a power circuit and a control circuit.

![Fig. 2: DVR Equivalent Circuit](image)

A. Maintaining the Integrity of the Specifications
VSI is used to convert the DC voltage supplied by a power storage device to an AC voltage. This voltage is amplified by a transformer injection into a large system. The VSI rate is usually low voltage and high current due to the use of step up injection transformers.

B. Voltage Injection Transformer
Its main job is to boost the VSI's low ac voltage to the desired level. Single-phase injection transformers are utilised in three-phase DVR applications. The inverter and injection transformer ratio determine the amount of low-voltage power that the DVR can compensate.
The passive low pass filter consists of an inductor and a capacitor. It can be installed on the high voltage side or on the inverter side of the injection transformer. It's used to filter the harmonic components that change from injected voltage. By placing the filter on the side of the inverter, the high-order harmonics are averted from entering the motor, thereby reducing the voltage stress on the injection transformer. When the filter is placed on the high voltage side, as harmonics can enter the high power side of the transformer, a high voltage transformer is needed.

Merit of DVR over other Custom Power Devices:
- Dynamic voltage restores is smaller in size and lower in price compared to Distribution Static Compensator (DSTATCOM) and other custom electronic devices.
• Dynamic voltage restorers have more capacity as compared to Uninterrupted Power Supply (UPS) and Solid State Transfer Switch (SMES). Dynamic voltage restorers have many advantages over Uninterrupted Power, such as low cost, high volume, low loss, injecting only the non-voltage supply part and small adjustment.

• The economic comparisons of Solid State Transfer Switch (SMES) and Dynamic voltage restorers have been investigated and revealed that Solid State Transfer Switch offers a better solution with expected savings, solution costs per KVA, annual operating costs and maximum profit / cost ratio if, uninterrupted or independent feed feeds are otherwise available. Dynamic voltage restorers is considered the least expensive solution, because Solid State Transfer Switch do not control voltage and do not produce / absorb active power. Its sole purpose is to deactivate the faulty feed in order to operate healthy.

5. OPERATING PRINCIPLE OF DVR

Compensation based on a series of electronic converter power that can protect loads from all interruptions outside the supply without switching off is called Dynamic Voltage Restorer (DVR). This device uses IGBT solid-state power switches in a pulse-width modulated (PWM) inverter structure. The DVR is capable of producing or absorbing \ authentically controlled and active power in its ac output terminal. The DVR is made with solid state state dc to ac switching power converter that injects a set of three acres of ac voltages into the series and adapts to the supply voltage voltages. The amplitude and phase angle of the injected voltage varies thus allowing for real and effective power exchange control between the DVR and the distribution system. DVR dc input terminal is connected to a power source or power supply device of the appropriate capacity. The active power exchanges between the DVR and the distribution system is generated internally by the DVR without the ac passive reactive components. The actual power converted to output DVR terminals is provided by the DVR input dc terminal with an external power source or power storage system. It is connected to a series with a distribution service that provides critical load. In order to remove an error or change in the A-line of the incoming server or an error in the distribution-1 server, the voltage at feeder-2 will decrease. During solid state operation, the DVR can compensate for inductive drop in line by applying voltage to the quadrature and current feeder.

Figure 3. DVR Connection for voltage sag correction of sensitive loads

6. SPACE VECTOR PULSE WIDTH MODULATION

The Space vector pulse modulation method is an advanced, calculated PWM method among all PWM modes for flexible drive applications. Due to its advanced features and easy implementation with digital signal processors, it has been gaining widespread use in recent years. Space vector switching is the most effective way to produce the six PWM pulses required in a two-phase power inverter phase. A regional model of a standard third-party PWM source converter is shown in Figure 4. The S1 to S6 are six outgoing power switches, controlled by the variables a, a , b, b , c and c . When the top transistor is turned on, that is, when a, b or c is 1, the corresponding lower transistor is turned off, i.e., a , b or the corresponding c is 0. Therefore, the opening and closing circuits of the transistors S1, S3 and S5 can be used to determine the output voltage.

Figure 4. Three-Phase Voltage Source PWM Inverter.

The purpose of the PWM space vector method is to measure reference voltage vector Vref using eight switching patterns. One simple way to measure is to produce the output of the inverter in a short time, T is the same as Vref.
Figure 5. Vector Representations of the Switching Gates.

A. Determination of $V_d$, $V_q$, $V_{ref}$, And Angle ($\alpha$)

\[
V_d = V_{an} - \frac{1}{2}V_{bn} - \frac{1}{2}V_{cn}
\]

\[
V_q = V_{an} + \frac{\sqrt{3}}{2}V_{bn} - \frac{\sqrt{3}}{2}V_{cn}
\]

\[
\alpha = \tan^{-1}\left(\frac{V_d}{V_q}\right)
\]

\[
V = \sqrt{V_d^2 + V_q^2}
\]

Figure 6. Voltage Space Vector and its Components in ($\alpha$, $\beta$).

B. Determination of Time Durations $T_1$, $T_2$, $T_0$

\[
T_1 = \frac{\sqrt{3}}{V_{dc}} T_s |V_{ref}| \left(\sin \frac{\pi}{3} \cos \theta - \cos \frac{\pi}{3} \sin \theta\right)
\]

\[
T_2 = \frac{\sqrt{3}}{V_{dc}} T_s |V_{ref}| \left(\sin \theta \cos \frac{(n-1)\pi}{3} - \cos \theta \sin \frac{(n-1)\pi}{3}\right)
\]

\[
T_0 = T_2 - (T_1 + T_2)
\]

\[
T_s = \frac{1}{f_s}
\]

Where $n=1$ through 6, i.e. sector 1 to 6 and $0 \leq \theta \leq 60^\circ$

7. SIMULINK MODEL OF DVR WITH PI CONTROLLER SVPWM MODEL DESIGN

Figure 7 shows the configuration of the proposed DVR design using MATLAB/SIMULINK, where the outputs of a three phase inverter are connected with series transformer. When a voltage disturbance occurs, with the help of dqo transformation based control scheme, the output of inverter are often steered in phase with the incoming ac source. As for the filtering scheme of this method, output of inverter is installed with capacitors and inductors.

The general functions of a controller in a DVR are the identity of voltage sag/swell events in the system computation of the correcting voltage, generation of trigger pulses to the space vector pulse width modulation SVPWM based inverter, correction of anomalies in the series voltage injection and termination of the trigger pulses when the event has passed. The controller can also be wont to shift the inverter into rectifier mode to charge the capacitors within the DC energy link within the absence of voltage sags/swells.
The dqo conversion or Park conversion is used to control the DVR. The dqo method provides information about the depth and phase shift of the dip, representing the start and end times. A quantity is expressed as an instantaneous space vector. First, we convert the voltage in the abc coordinate system to the reference value dqo. For simplicity, phase 0 sequence components are ignored. The control is predicated on the comparison of a voltage reference and therefore the measured terminal voltage (Va, Vb, Vc). The voltage sags is detected when the availability drops below 90% of the reference value whereas voltage swells is detected when supply voltage increases up to 25% of the reference value. The error signal is employed as a modulation signal that permits generating a commutation pattern for the facility switches (IGBT’s) constituting the voltage source converter. The commutation pattern is generated by means of the space vector pulse width modulation SVPWM voltages are controlled through the modulation.

Figure 7. Simulink Model of DVR with PI SVPWM

8. THD ANALYSIS OF PI CONTROLLER BASED DVR

A DVR is connected to the system through a series transformer with a capability to insert a maximum voltage of 50% of the phase to ground system voltage. Apart from this, a series filter is also used to remove any high frequency components of power. The load considered in the study is a 5 KVA capacity with lagging power factor.

Fig. 8.(a)

The three-phase voltage sag is simulated, and figure-3(a) shows a 50% three-phase voltage sag occurring at the utility grid. It shows a 50% voltage sag that begins at 0.2s and lasts until 0.5s, for a total voltage sag duration of 0.3s.

Fig. 8.(b)

In figure 3(b) and 3(c) shows the voltage injected by the DVR and the corresponding load voltage with compensation. The load voltage is maintained at 1 pu as a result of DVR.
9. CONCLUSION

This paper presents a control technique for Dynamic Voltage Restorer (DVR) using Space Vector Pulse Width Modulation technique for instant mitigation of voltage sag or swells from the system. The modeling and simulation of a DVR using MATLAB/SIMULINK has been presented. A control technique follows the scaled error of the between source side of the DVR and its reference for sags/swell correction has been presented. The simulation shows that the DVR performance is satisfactory in mitigating voltage sags/swells.

REFERENCES