

Enhancement of Power Quality in Distribution System Using Custom Power Device

Bharathi.R , Paranjothi.G

PG Scholar, Department of Power System Engineering, The Kavery Engineering College, India

Assistant Professor, Department of Power System Engineering,, The Kavery Engineering College, India

ABSTRACT: The most noticeable topic for electrical engineering is power quality in recent year. Utility distribution networks, sensitive industrial load and critical commercial operation suffer from various types of outages and service interruption can cost significant financial losses. One of the major problems dealt here is the voltage sag. With the fast development in power electronics technology have made it possible to mitigate power quality problems. This work concentrates on the power quality problem such as voltage sag ,swell and to kept unity power factor. Many of the devices such as DSTATCOM, tap changing transformer, and DVR are available to mitigate voltage sag problems. Among these, dynamic voltage restorer and DSTATCOM can provide the most commercial solution to mitigate voltage sag by injecting voltage as well as power in to the system. Dynamic Voltage Restorer(DVR) is a series connected power electronics based device that can quickly mitigate the voltage sag in the system and restore the load voltage. The PI Controller is used to generate triggering pulse. Simulation results carried out by MATLAB/SIMULINK verify the proposed method.

KEYWORDS: Distribution Static Compensator (DSTATCOM), Dynamic Voltage Restorer(DVR), Proportional Integral(PI) Controller, Voltage sag,swell.

1. INTRODUCTION

“Reliability” is a key word for utilities and their customers in general, and it is crucial to companies operating in a highly competitive business environment, because it affects profitability, which definitely is a driving force in the industry. Although electrical transmission and distribution systems have reached a very high level of reliability, disturbances cannot be totally avoided. Any disturbances to voltage waveform can cause problems related with the operation of electrical and electronic devices. Users need constant sine wave shape, constant frequency and symmetrical voltage with a constant rms value to continue the production. This increasing interest to improve efficiency and eliminate variations in the industry has resulted more complex instruments sensitive to voltage disturbances such as voltage sag, voltage swell, interruption, phase shift and harmonic. Voltage sag is considered the most severe since the sensitive loads are very susceptible to temporary changes in the voltage. In some cases, these disturbances can lead to a complete shutdown of an entire production line, in particular at high tech industries like semiconductor plants, with severe economic consequences to the affected enterprise.

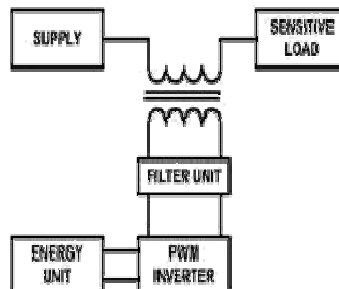
II. OVERVIEW OF POWER QUALITY PROBLEMS

- A. Power Quality Problem: There exist numerous types of PQ problems which effect the performance of electrical equipment or sometime lead to its damage. However, the ubiquitous among them .
- B. Voltage Sag: Is defined as reduction of rms voltage from 0.1 to 0.9 per unit, for a period of 0.5 cycle to 1 minute mainly resulted from fault or switching large inductive loads.
- C. Voltage Swell: Is defined as increase of rms voltage from 1.1 to 1.8 p.u for a period of 0.5 to 1 minute mostly caused by energizing capacitor or removal of large inductive loads.

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- D. Voltage Harmonics: Are sinusoidal currents and voltages having frequencies that are integer multiple of the supply frequency mainly caused by non-linear loads or rectifiers. - Interruptions: Are the reduction of rms voltage by at least 0.9 p.u within a period of less than a minute mostly caused by undue overloading or line damage due to accidents. –
- E. Voltage Unbalance: Is variation in voltage magnitude or phase angle in one of the phases of a 3-phase system, mainly caused by incorrect distribution of single-phase loads.

III. CUSTOM POWER DEVICE

Custom power device is used to mitigating numerous power quality problems. Basic functions are fast switching and current or voltage injection for correcting anomalies in supply voltage or load current by injecting or absorbing reactive and active power. The power electronic controllers that are used in the custom power solution can be a network compensating type. The compensating device either compensate a load ,i.e. its power factor, unbalance conditions or improve the power

quality of supplied voltage ,etc.

The DVR is a power quality device, which can protect these industries against the bulk of these disturbances, i.e. voltage sags and swells related to remote system faults. A DVR compensates for these voltage excursions, provided that the supply grid does not get disconnected entirely through breaker trips. Modern pulse-width modulated (PWM) inverters capable of generating accurate high quality voltage waveforms form the power electronic heart of the new Custom Power devices like DVR. Because the performance of the overall control system largely depends on the quality of the applied control strategy, a high performance controller with fast transient response and good steady state characteristics is required. The main considerations for the control system of a DVR include: sag detection, voltage reference generation and transient and steady-state control of the injected voltage. The typical power quality disturbances are voltage sags, voltage swells, interruptions, phase shifts, harmonics and transients. Among the disturbances, voltage sag is considered the most severe since the sensitive loads are very susceptible to temporary changes in the voltage.

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The wide area solution is required to mitigate voltage sags and improve power quality. One new approach is using a DVR. The basic operation principle is detecting the voltage sag and injecting the missing voltage in series to the bus as shown in Fig.4.1. DVR has become a cost effective solution for the protection of sensitive loads from voltage sags. The DVR is fast, flexible and efficient solution to voltage sag problems. DVR consists of energy storage unit, PWM inverter, and filter and injection transformer. The DVR injects a voltage, VDVR in series with the AC mains via the reactance of the coupling transformer

$$V_{DVR} = V_L + Z_L I_L - V_S$$

$$\text{and } I_L = \frac{P+jQ}{V_L^*}$$

$$S_{DVR} = V_{DVR} I_L^*$$

A. Distribution Static Compensator (DSTATCOM)

The primary aims of DSTATCOM are:

- Power factor correction
- Current harmonics filtering
- DC Load offset cancellation
- Load balancing

It can be used for voltage regulation at the distribution bus, being an active filtering device. It is connected in parallel with the PCC. The DSTATCOM is often referred as a shunt active power filter. It consists of a voltage source PWM converter equipped with a DC capacitor and an interface inductor. The advantages of the voltage source PWM converter are higher efficiency, lower cost and smaller physical size. The current-source PWM inverter cannot be used in multilevel or multi-step mode configurations to allow compensation in higher power ratings. The limitation of this system is that it provides only current harmonic compensation D-STATCOM is a VSC based control, shunt power electronics device capable of maintaining system voltage level through exchanging real and reactive power with the AC system with aid of a DC energy storage (DES), a coupling transformer and a controller. It is generally connected amid the distribution supply bus and the load to be protected, at Point of Common Coupling (PCC). Fig shows its basic building block.

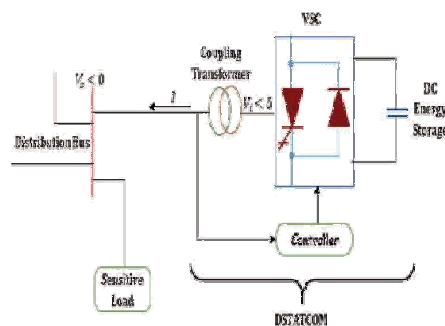


Figure no.1.DSTATCOM Configuration

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Arbitrarily, the exchange of real (P) and reactive (Q) power taking place between the system and the DSTATCOM can be attuned by altering the magnitude and phase of the DSTATCOM's output voltage and the supply bus AC voltage as depicted in equation and summarized in Table 1.

$$\text{Real Power: } P = \frac{V_{vsc} V_{bus}}{X_L} \sin \delta$$

$$\text{Reactive Power: } Q = \frac{V_{bus}^2}{X_L} - \frac{V_{vsc} V_{bus}}{X_L} \cos \delta$$

The co inverted AC voltages (VSC output) are then coupled to the network through the reactance of the coupling transformer. Due these real and reactive power exchanges, it can be operated in both inductive and capacitive mode.

Voltage Relation	DSTATCOM ↔ AC SYSTEM		Mode / Function
$ V_{vsc} > V_{bus} $	Q	→	Capacitive
$ V_{vsc} < V_{bus} $		←	Inductive
$\delta < 0$	P	→	P-absorption
$\delta > 0$		←	P-discharge

Table 1. .voltage regulation and its function

Shunt connected VSC offers the D-STATCOM multifunctional configuration that can be optimized for:

- Reactive power compensation. Reduction of harmonics level.
- Voltage stability and pf correction

In this regard, it is employed to control load voltage ast PCC.

B. Dynamic Voltage Restorer (DVR)

DVR, also referred as Static Series Synchronous Compensator (SSSC), is a solid state device that injects voltage into the AC system in order to maintain the sensitive load voltage at certain level. It is connected in series unlike D-STATCOM. DVR has similar configuration and control as DSTATCOM with its transformer coupled in series with the AC supply.

Through the conversion of the DC voltage in the DES with aid of the VSC, the supply bus voltage, Vs and the D-STATCOM output voltage, Vi have the following instantaneous values. Where VD, n and ma are the DC voltage across the capacitor, coupling transformer turns ratio and PWM amplitude modulation ratio respectively. The frequency of the 3-phase output voltage of the VSC together with its phase angle solely depends on the switching pattern of the semi-conductor switch used.

In most applications, the DC Energy Storage (DES), is reinforced with a fuel cell or photovoltaic solar system just like in inverters [9-11]. There exist some configuration in such a way that the DC link tap power from the main AC source, thereby disregarding the need of the DC link source

IV. VOLTAGE SOURCE INVERTER

DC to AC converters produce an AC output waveform from a DC source. Applications include adjustable speed drives (ASD), uninterruptable power supplies (UPS), active filters, Flexible AC transmission systems (FACTS), voltage compensators, and photovoltaic generators. Topologies for these converters can be separated into two

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distinct categories: voltage source inverters and current source inverters. Voltage source inverters (VSIs) are named so because the independently controlled output is a voltage waveform. Similarly, current source inverters (CSIs) are distinct in that the controlled AC output is a current waveform.

DVR is the result of power switching devices, which are commonly fully controllable semiconductor power switches. The output waveforms are therefore made up of discrete values, producing fast transitions rather than smooth ones. The ability to produce near sinusoidal waveforms around the fundamental frequency is dictated by the modulation technique controlling when, and for how long, the power valves are on and off. Common modulation techniques include the carrier-based technique, or pulse width modulation, space-vector technique, and the selective-harmonic technique

Voltage source inverters have practical uses in both single and three-phase applications. Single-phase VSIs utilize half-bridge and full-bridge configurations, and elaborate high-power topologies when used in multicell configurations. Three-phase VSIs are used in applications that require sinusoidal voltage waveforms, such as UPSs, and some types of FACTS devices.

Current source inverters are used to produce an AC output current from a DC current supply. This type of inverter is practical for three-phase applications in which high-quality voltage waveforms are required.

A relatively new class of inverters, called multilevel inverters, has gained widespread interest. Normal operation of CSIs and VSIs can be classified as two-level inverters, due to the fact that power switches connect to either the positive or to the negative DC bus. If more than two voltage levels were available to the inverter output terminals, the AC output could better approximate a sine wave. It is for this reason that multilevel inverters, although more complex and costly, offer higher performance.

Each inverter type differs in the DC links used, and in whether or not they require freewheeling diodes. Either can be made to operate in square-wave or pulse-width modulation (PWM) mode, depending on its intended usage. Square-wave mode offers simplicity, while PWM can be implemented several different ways and produces higher quality waveforms.

V. TEST SYSTEM AND SIMULATION ANALYSIS

This section presents the tests carried out on the D-STATCOM and DVR together with the results. In each case, the system is simulated before and after connecting the devices to determine their effectiveness and robustness of the controllers.

A. DSTATCOM

For DSTATCOM, getting 230kV from the grid is applied to VI measurement. The VI measurement unit calculates the voltage and current of the grid system. The point of common coupling will connect DSTATCOM and grid system. RL filter is used to mitigate the harmonics. The ratio of voltage and current is 1:1 is taken from distribution transformer. When fault occurs in the grid line before and after VI measured every time via VI measurement. Circuit breaker is placed between backup and grid system. It automatically disconnects when fault occurs. Z source rises the power factor and while peak hour backup supply is used. The error calculation is performed by controller circuit. When inverter receives gate pulse from controller its start operation. IGBT device is used for high power applications

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B.DVR

DVR and DSTATCOM are both performs to mitigate the voltage sag and swell.It consist of the same components of DSTATCOM.Here also the same process will be performed but difference is DVR and boost up or isolation transformer is used to connect between grid and backup supply.it is used to eliminate transient and also be improved the system stability.This test is performed with DVR and simulation result is carried out by MATLAB.

SIMULATION DIAGRAM:

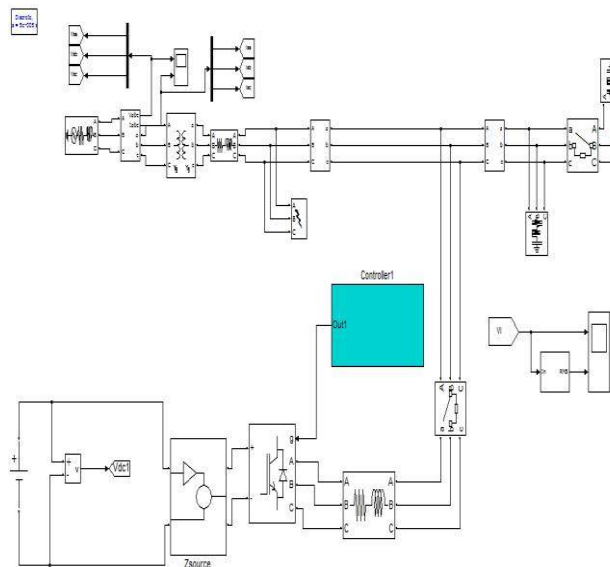


Figure no.2.DSTATCOM simulation diagram

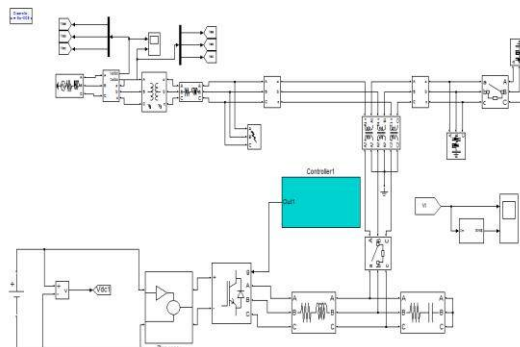


Figure no.3 DVR simulation diagram

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PI CONTROLLER

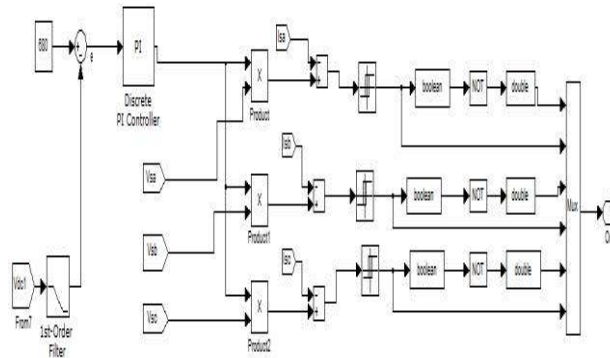


Figure no.4 PI subcontroller system

The PI controller is mostly used in industrial applications, due to low cost, simple structure and easy design. PI controller will eliminate forced oscillation and used in on and off operation. Boolean is used to convert analog to logic and double converts logic to analog. In between of them NOT gate is performed. The controller is used to measure the phase angle deviation, real and reactive power. The effectiveness of proposed PI control is built using the MATLAB software program. The simulation result is performed by Simulink.

SIMULATION RESULT

The figure 6 shows the output of DSTATCOM, figure 7 shows DVR output. The simulation is carried out with DVR and DSTATCOM by using Simulink. The graph shows the voltage and current waveform.

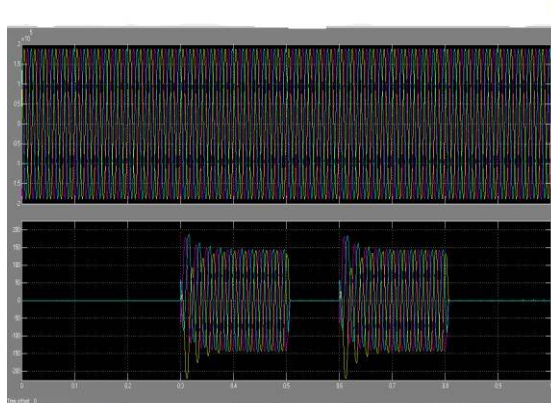


Figure 5. voltage and current waveform-DSTATCOM

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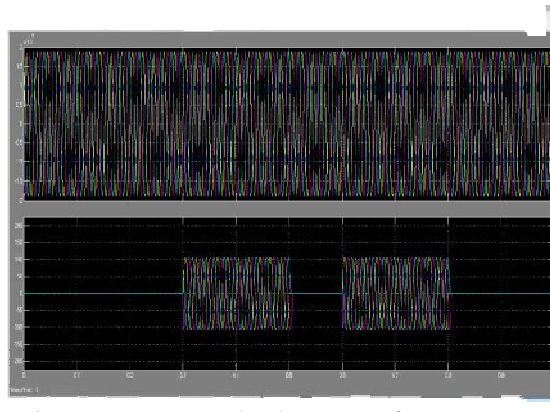


Figure 6. current and voltage waveform-DVR

VI. CONCLUSION AND DISCUSSION

Various operating conditions are analyzed and tested. The devices presented have shown great performance in mitigating the disturbances and improve the power factor is unity and also enhance the power quality . It can be deduced from the results obtained that DVR clears the voltage instability and restores system voltage much better than D-STATCOM. Exchange of reactive power between these devices while compensating and mitigating the voltage sags and swells forced the DC link voltage to vary continuously. The coupling transformer gives the improved system stability .

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