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SIMULATION AND HARDWARE IMPLEMENTATION OF STATCOM-DYNAMICVOLTAGERESTORER (S-D) DEVICE

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ABSTRACT

Power quality has become an important factor in power systems, for consumer and household appliances with proliferation of various electric and electronic equipment and computer systems. The main causes of a poor power quality are harmonic currents, poor power factor, supply-voltage variations, etc. A technique of achieving both active current distortion compensation, power factor correction and also mitigating the supply-voltage variation at the load side is compensated by unique devices S-D (STATCOM and DVR) in this paper. The proposed S-D system can improve the power quality at the point of common coupling on power distribution systems under unbalanced and distorted load conditions. The STATCOM is connected across the load to compensate for current–related problems such as reactive power compensation. The series component of the S-D device is Dynamic Voltage Restorer which inserts a voltage so as to maintain the voltage at the load terminals balanced and free of distortion.

Keywords: power quality, STATCOM, DVR, newton raphson algorithm.

INTRODUCTION

A power system is a large interconnected network with components converting nonelectrical energy into the electrical form to meet the demanded high quality power supply to the end users. [1]

The term power quality control refers to maintain nearer sinusoidal waveform of voltage and current at the load terminal. [2]

Generally, transformers transport electric power between different voltage levels of a power system. It may also use to control the phase displacement between the input voltage and current phase by an angle adjusted by means of a tap changer. Such special transformers are termed as Phase Shifting Transformer (PST). [3]

Basic functionality of HVDC system is to convert electrical current from AC to DC terminal at the transmitting end and from DC to AC terminal at the receiving end. [4]

The Flexible AC Transmission System (FACTS) is a new technology based on power electronic devices which offers an opportunity to enhance controllability, stability and power transfer capability of AC Transmission Systems [5]

SVC is the first device in the first generation of FACTS controller introduced to provide fast-acting reactive power compensation in the transmission network. [6]

TCSC is designed based on the thyristor based FACTS technology that has the ability to control the line impedance with a thyristor-controlled capacitor placed in series with the transmission line. [10]

Synchronous Series Compensator is based on solid-state voltage source converter designed to generate the desired voltage magnitude independent of line current. [11]

STATCOM is designed based on Voltage source converter (VSC) electronic device with Gate turn off thyristor and dc capacitor coupled with a step down transformer tied to a transmission line. [12]

UPQC is designed by combining the series compensator (SSSC) and shunt compensator (STATCOM) coupled with a common DC capacitor. It provides the ability to simultaneously control all the transmission parameters of power systems. [13]

IPFC consists of two series connected converters with two transmission lines. It is a device that provides a comprehensive power quality control for a multi-line transmission system and consists of multiple number of DC to AC converters, each providing series compensation for a different transmission line. [14]

The STATCOM is connected across the load to compensate for current–related problems such as reactive power compensation. [15]

The series component of the S-D device is Dynamic Voltage Restorer which inserts a voltage so as to maintain the voltage at the load terminals balanced and free of distortion. [16]

Newton Raphson power quality algorithm is used to solve for the power quality problem in a transmission line with S-D Controller as shown in the quality. [17]

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STATCOM-DVR (S-D) Controller

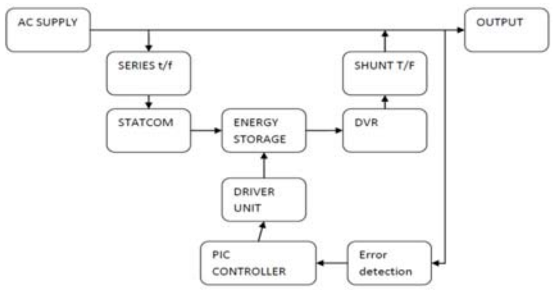

Figure-1. Block diagram of S-D controller.

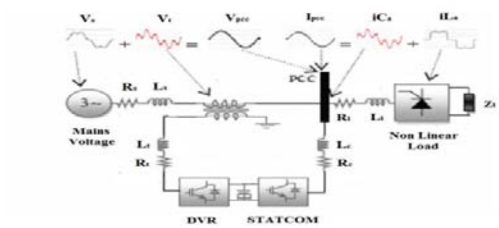

Figure-2. S-D device system.

A technique of achieving both current compensation and also meeting the supply voltage variation on load side is compensated by S-D device method. It uses a STATCOM (Static Synchronous Compensator) and a Dynamic Voltage Restorer (DVR) to compensate power quality problems. The STATCOM is connected across the load to compensate for current–related problems such as reactive power compensation and the DVR is connected in series with the line through series transformers. It acts as controlled voltage source and compensates voltage related problems.

Operation of S-D Controller

S-D ideally works as an ideal ac to dc power converter in which real power can freely quality in either direction between ac terminals of the two converters and each converter can independently generate or absorb reactive power at its own AC output terminal. The main functionality of S-D provided by shunt converter by injecting an AC voltage considered as a synchronous ac voltage source with controllable phase angle and magnitude in series with the line. The transmission line current quality through this voltage source results in real and reactive power exchange between it and the AC transmission system. The inverter converts the real power exchanged at ac terminals into dc power which appears at the dc link as positive or negative real power demand.

Series Converter Operation: In the series converter, the voltage injected can be determined in different modes of operation: direct voltage injection mode, phase angle shift emulation mode, Line impedance emulation mode and automatic power quality control mode. Although there are different operating modes to obtain the voltage, usually the series converter operates in automatic power quality control mode where the reference input values of P and Q maintain on the transmission line despite the system changes.

Shunt Converter Operation: The shunt converter operated in such a way to demand the dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. Shunt converter operates in two modes: VAR Control mode and Automatic Voltage Control mode. Typically, Shunt converter in S-D operates in Automatic voltage control mode

Newton Raphson Algorithm and Quality Chart

In this paper Newton Raphson power quality algorithm is used to solve for the power quality problem in a transmission line with S-D Controller as shown in the quality chart in Figure-3.

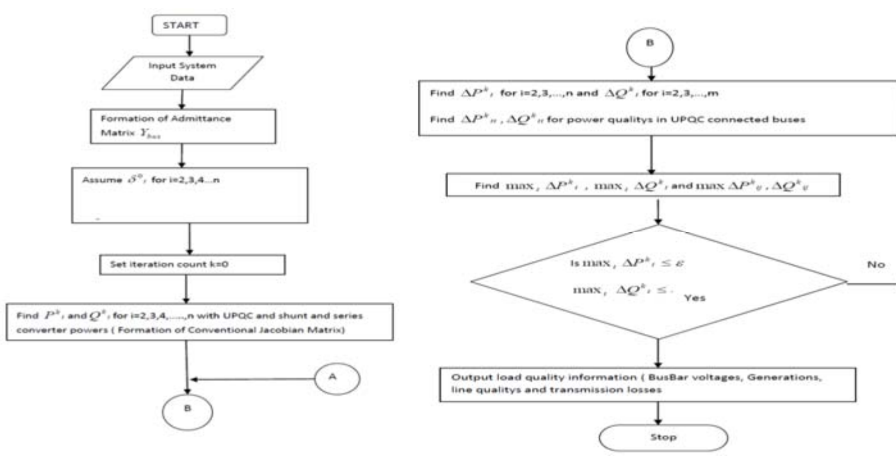

Figure-3. Quality chart for load quality by Newton Raphson with S-D device.

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CASE STUDY OF A NETWORK WITH S-D CONTROLLER

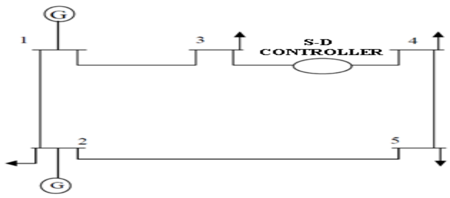

Figure-4. A standard 5-Bus network with S-D controller.

In this paper, we have considered an IEEE standard - bus network with S-D controller to study the power quality control of a power system. For the analysis as shown in Figure-4, bus 1 considered as slack bus, buses 2 and 3 as voltage control buses and buses 4, 5 as load buses. To include a S-D controller an additional bus 6 placed in between buses 3 and 4 in the network. It maintains the active and reactive powers leaving the S-D controller towards the bus 4. The S-D controller shunt converter is set to regulate bus 3 nodal voltage magnitude at 1 pu.

MATLAB programming with Newton Raphson algorithm is used to find out the method to solve the control setting of the 5-bus network with S-D Controller.

In large-scale power quality studies the Newton-Raphson method has proved out to be the most successful algorithm with its strong convergence characteristics. In order to apply Newton-Raphson method to the power quality problem the relevant equations expressed in the form of unknown nodal voltage magnitudes and phase angles.

SIMULATION RESULTS

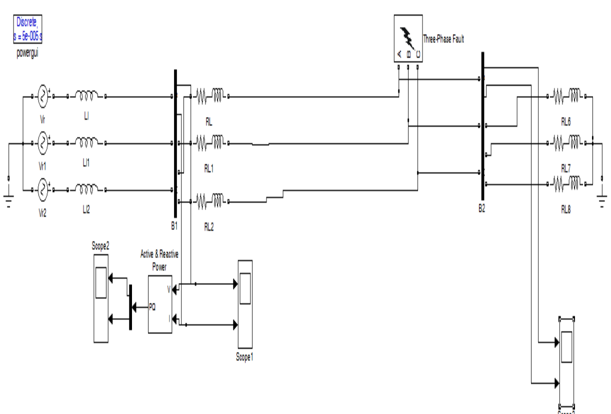

Figure-5. Power system without compensation.

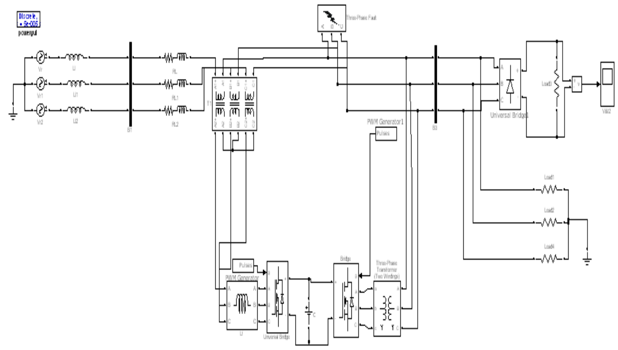

Figure-6. Power system with compensation.

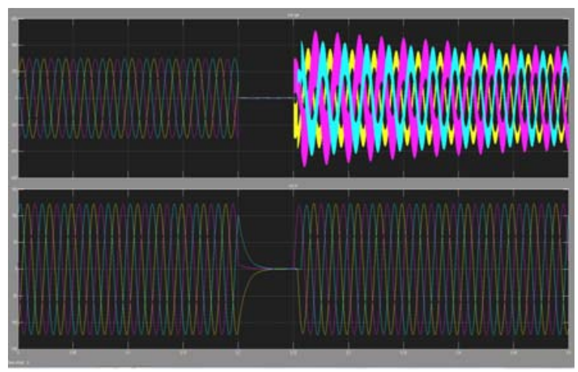

Figure-7. Three phase voltage and current.

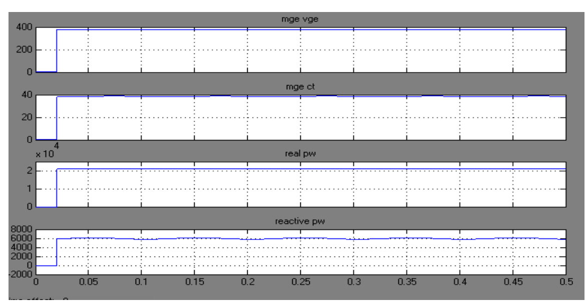

Figure-8. Reactive power injections waveforms before compensation.

Figure-9. Three phase voltage and current waveforms after compensation using S-D device.

HARDWARE IMPLEMENTATION

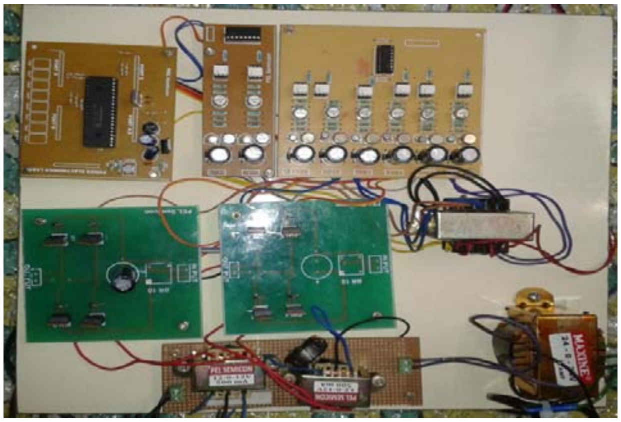

Figure-10. Photograph of hardware.

HARDWARE DESCRIPTION

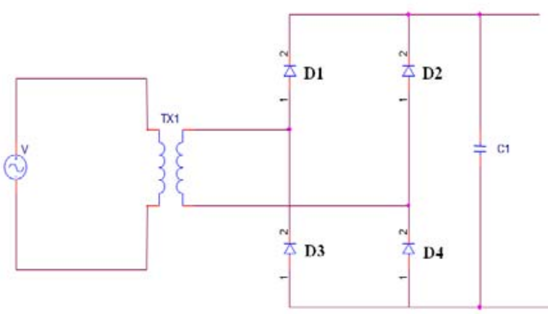

Figure-11. Rectifier circuit.

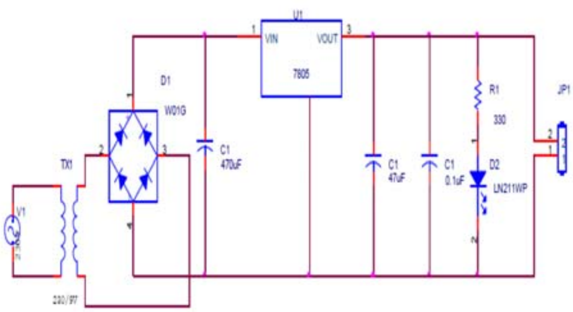

Figure-12. Power Circuit for microcontroller.

The first building block in the dc power supply is the full wave rectifier. The purpose of the full wave rectifier (FWR) is to create a rectified ac output from a sinusoidal ac input signal. It does this by using the nonlinear conductivity characteristics of diodes to direct the path of the current.

The operation of power supply circuits built using filters, rectifiers, and then voltage regulators. Starting with an AC voltage, a steady DC voltage is obtained by rectifying the AC voltage, then filtering to a DC level, and finally, regulating to obtain a desired fixed DC voltage. The regulation is usually obtained from an IC voltage regulator Unit, which takes a DC voltage and provides a somewhat lower DC voltage, which remains the same even if the input DC voltage varies, or the output Load connected to the DC voltage changes.

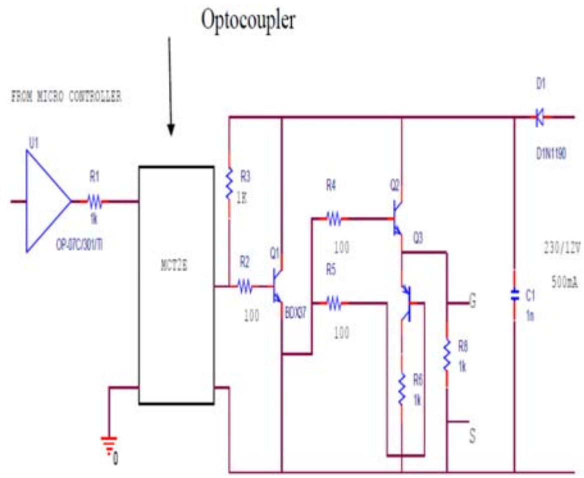

Figure-13. Driver circuit.

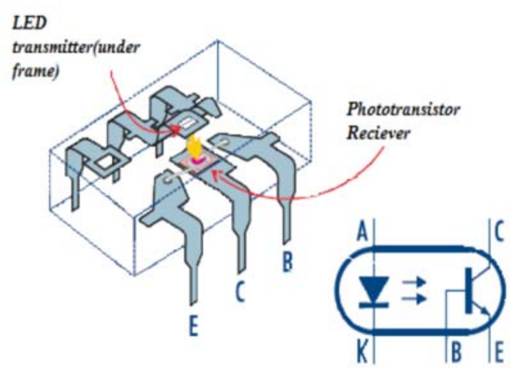

Figure-14. Construction of optocoupler.

There are many situations where signals and data need to be transferred from one subsystem to another within a piece of electronics equipment, or from one piece of equipment to another, without making a direct ohmic electrical connection. Often this is because the source and destination are (or may be at times) at very different voltage levels, like a microprocessor, which is operating from 5V DC but being used to control a triac that is switching 240V AC. In such situations the link between the two must be an isolated one, to protect the microprocessor from over voltage damage.

Optocoupler typically come in a small 6-pin or 8-pin IC package, but are essentially a combination of two distinct devices: an optical transmitter, typically a gallium arsenide LED (light-emitting diode) and an optical receiver such as a phototransistor or light-triggered diac. The two are separated by a transparent barrier which blocks any electrical current flow between the two, but does allow the passage of light. The basic idea is shown, along with the usual circuit symbol for an optocoupler. Usually the electrical connections to the LED section are brought out to the pins on one side of the package and those for the phototransistor or diac to the other side, to physically separate them as much as possible. This usually allows optocouplers to withstand voltages of anywhere between 500V and 7500V between input and output. Optocouplers are essentially, digital or switching devices, so they're best for transferring either on-off control signals or digital data. Analog signals can be transferred by means of frequency or pulse-width modulation.

CONCLUSIONS

The proposed control strategy use only minimum measurement like loads and mains voltage measurements for S-D device. The instantaneous reactive power theory is used by measuring mains voltage, current and capacitor voltage. But the conventional methods require measurements of the load, source and filter voltages and currents.

The simulation results show that, when unbalanced and Nonlinear load current or unbalanced and distorted mains voltage conditions, the above control algorithms eliminate the impact of distortion and unbalance of load current on the power line, making the power factor unity.

This paper deals with the case study of power quality control with the STATCOM-DVR Controller (SDC) that is used to maintain and improve power system operation and stability.

This paper presents the power quality operation of power systems and its limitations, different devices to control the power quality with the existing transmission lines, types of FACTS controllers used in the power system, basic characteristics and operation of SDC, Newton Raphson quality chart and algorithm with SDC and a case study of power quality control with SDC.

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