FAULT CURRENT LIMITER USING SOLID STATE DEVICES

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Abstract- The proposed transformer-based solid state fault current limiter(TBSSFCL) is capable of controlling the magnitude of fault current. In order to control the fault current, primary winding of an isolating transformer is connected in series with the line and the secondary side is connected to a reactor, paralleled with a bypass switch which is made of anti-parallel insulated gate bipolar transistors.By controlling the magnitude of ac reactor current, the fault current is reduced and voltage of the point of common coupling is kept at an acceptable level. Also, by this TBSSFCL, switching overvoltage is reduced significantly. The proposed TBSSFCL can improve the power quality factors and also, due to its simple structure, the cost is relatively low.

Keywords: *TBSSFCL, FCL, CB, DVR, VSIs.*

I. INTRODUCTION

Developing power system networks and their interconnections may increase the short-circuit levels beyond the capacity of circuit breakers (CBs). Shortcircuit fault can cause overvoltage transients, loss of synchronization, and isolation failure and may cause explosion of equipments containing insulating oil. There are solutions such as upgrading or replacing switchgears, which are expensive. Distribution network protection mainly relies on proven protection devices such as fuse.

This equipment is a self-triggering, cheap, small size, and reliable protective device which can interrupt fault currents without using sensors and actuators. But, it is a single-use device and needs manual replacement. Employing high impedance transformer to increase the fault circuit impedance is another solution, which causes additional network losses and needs redesign for maintaining the voltage profile. CB is also a protective device, which can be tripped and reset manually or automatically. However, CBs with high current interrupting capability are expensive electromechanical systems. Replacement of protective CBs is a costly solution to cope with rising fault current levels. In recent years, a novel scheme for limiting the magnitude of fault current, the so called “fault current limiter” (FCL), has been proposed and used as the best solution. This scheme can limit the fault current, dismissing the costly upgrade of switchgears. FCLs application in distribution networks not only suppresses the fault current and limits the inrush current, but also improves the transient stability, power quality, and reliability. Development of various types of FCLs has been conducted for many years by many research institutions around the world.

II. PROPOSED SYSTEM

The DVR is the most versatile and complex of the FACTS devices, combining the features of the STATCOM and SSSC. The main reasons behind the wide spreads of DVR are: its ability to pass the real power flow bi-directionally, maintaining well regulated DC voltage, workability in the wide range of operating conditions etc .The basic components of the DVR are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer.

The DC terminals of the two VSCs are coupled and this creates a path for active power exchange between the converters. Thus the active supplied to the line by the series converter can be supplied by the shunt converter as shown in figure 1 Therefore, a different range of control options is available compared to STATCOM or SSSC.

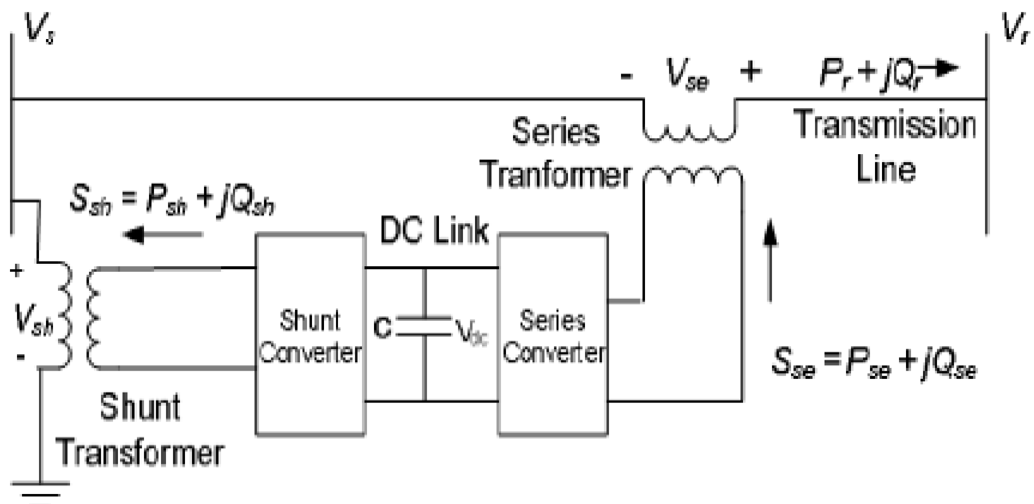

Figure 1. DVR schematic diagram

The DVR can be used to control the flow of active and reactive power through the transmission line and to control the amount of reactive power supplied to the transmission line at the point of installation. The series inverter is controlled to inject a symmetrical three phase voltage system of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals.

The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor constant. So, the net real power absorbed from the line by the DVR is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point. The two VSI's can work independently of each other by separating the dc side. So in that case, the shunt inverter is operating as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power flows on the transmission line.

The DVR can also provide simultaneous control of all basic power system parameters, viz., transmission voltage, impedance and phase angle. The DVR has many possible operating modes: Var control mode, automatic voltage control mode, direct voltage injection mode, phase angle shifter emulation mode, line impedance emulation mode and automatic power flow control mode.

Proposed System Block Diagram

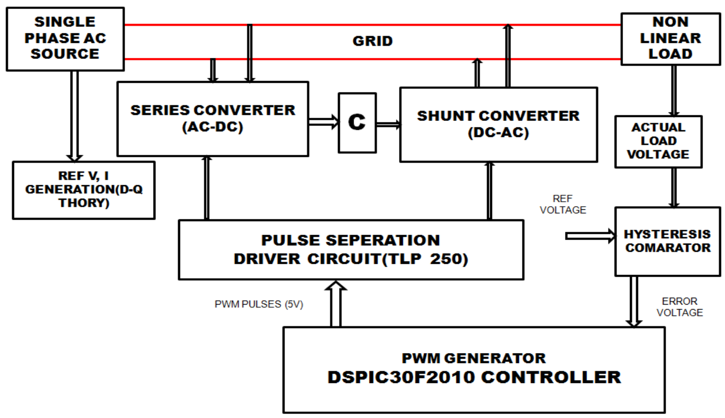

Figure 2 Proposed system block diagram

Proposed System Circuit Diagram

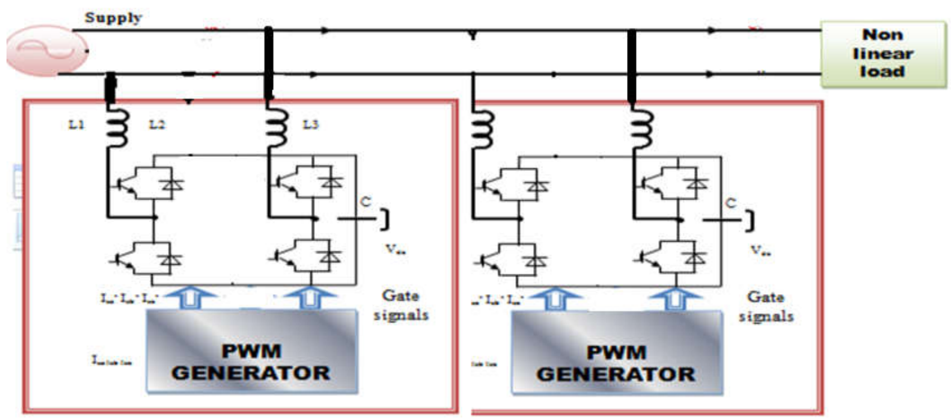

Figure 3 Proposed system circuit diagram

III. PROPOSED SYSTEM WORKING

A simplified schematic of a DVR is shown in Figure 1. The main features are, it has two inverters, one connected in series with the line through a series insertion transformer and another connected in shunt with the line through a shunt coupling transformer. Primarily, the series-connected inverter is used to inject a controlled voltage in series with the line and thereby to force the power flow to a desired value. In general, the series inverter may exchange both real and reactive power while performing this duty. A voltage sourced-inverter is able to generate the needed reactive power electronically at its ac terminals, but is incapable of handling real power exchange unless there is an appropriate power source connected to its dc terminals.

Consequently the series-connected inverter has its dc terminals connected to those of the shunt-connected inverter, which performs its primary function by delivering exactly the right amount of real power to meet the real power needs of series inverter. It obtains this real power from its connection to the ac bus. The shunt inverter can also perform a secondary function by electronically generating reactive power for regulation of the local ac bus voltage. The DVR thus offers the Power electronic systems have the capability of providing faster response compared to traditional mechanically based power system controls. Therefore to obtain the maximum capability out of the DVR, a control system with an equally faster response is required. It would be advantageous, if the time-varying equations can be transformed to a time invariant set. This would result in the simplification of the calculations both for steady and transient conditions especially when we are considering a huge power system. R.H.PARK introduced the d-q transformation. This paper presents operation of DVR using a control strategy which is based on d-q axis control theory. This d-q axis control system enables the DVR to follow the changes in reference values like AC voltage, DC link voltage, real and reactive powers through the line. By implementing a d-q axis controller it is possible to produce a relatively fast response and to reduce the interaction between real and reactive power flow.

In this control system, the transformation of a three phase system to d-q and d-q to 3-phase quantities is done according to Park's transformation, through which real and reactive power can be controlled individually, while also regulating the local bus voltage. Ooi et al., [3] suggested a control system for the DVR which is based on the principle that the real power is influenced by the phase angle whereas reactive power is dependent on the voltage magnitude. Therefore to control the real power flow in the transmission line the series DVR controller adjusts the angle of the series compensation voltage while to regulate the reactive power flow, the amplitude of the series voltage is controlled. As was presented in [3], the real and reactive power flows in the transmission line are influenced by both the amplitude and the phase angle of the series compensating voltage. Therefore, the real power controller can significantly affect the level of reactive power flow.

The reactive power controller then adjusts the series voltage magnitude to regulate the reactive power but in turn also changes the real power flow. Thus both controllers reacting to each others output. To improve the performance and to reduce the interaction between real and reactive power control system for a DVR based on d-q axis theory was presented by Yu et al., [4 and 5]. In [5], cross coupling controller using d-q axis theory is applied to the series converter of the DVR. In this paper, cross coupling controller using d-q axis theory is applied to the shunt controller of the DVR. Shunt inverter can be controlled in two different modes, viz. VAR control mode and Automatic voltage control mode. In var control mode, the shunt inverter control translates the var reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. In voltage control mode, the shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value. As in [5], the crossing gain of a power transmission line is much larger than its direct gain. The cross-coupling controller uses the q-axis voltage Vq, to control the d-axis current Id and the d-axis voltage Vd, to control the q-axis current Iq. This makes it possible to control both active and reactive powers independently.

In this simulation, the shunt inverter operates in voltage control mode. Figure-3 shows the DC voltage control circuit. DC link voltage is measured (Vdcm) and compared with the reference value (Vdcref), whose error is fed to PI controller and related quadrature axis voltage, Vq is developed. Id and Iq are obtained through Park's transformation of transmission line current. shunt coupling transformer is measured in p.u (Vpum) and compared with the AC voltage set point (here 1.0 p.u), whose error is fed to PI controller to generate the related direct axis voltage, The generated Vd and Vq signals are used to develop firing pulses for the six GTOs in the inverter, as shown in the Figure-5, in MATLAB environment.

A generalized sinusoidal pulse width modulation switching technique is used for pulse generation. H-L (high-low) logic in MATLAB is used to generate firing pulses. Two sets of signals, reference and triangular ones are needed, one set for turning-on and the other for turning-off the GTOs. Deblock option is available, which is made 0.1 seconds during this simulation. The series inverter controls the magnitude and angle of the voltage injected in series with the line. Main objective this voltage injection is to influence the power flow on the line. The actual value of the injected voltage can be obtained in several ways, viz. Direct voltage injection mode, phase angle shifter emulation mode, line impedance emulation mode and automatic powerflow control mode. In this simulation, the series inverter operates in the direct voltage injection mode. The series inverter simply injects voltage as per the theta order specified. By varying the theta order input to this controller power flow through the transmission line can be varied. Figure-6 shows the series inverter control circuit, which is an open loop phase angle controller, generates modulation index, mi and shift, as per the theta order specified.

IV. HARDWARE OUTPUT

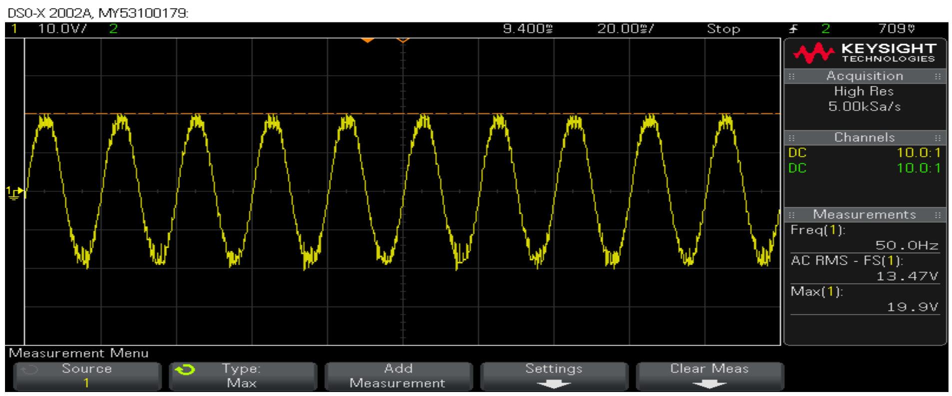

Figure 4 Input AC source voltage

The figure 4 shows the input AC voltage is given to the proposed DVR system. The topology will reduce the source current harmonics. This will increase the power factor of the system. The results indicate digital waveform of source voltage.

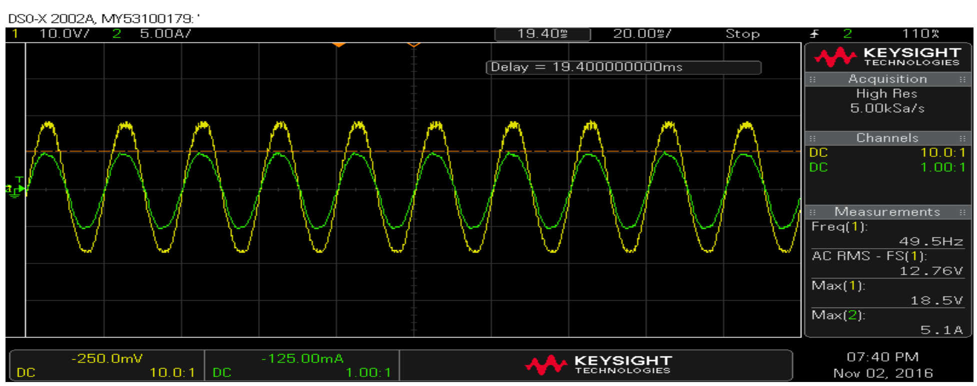

Figure 5 Input AC source voltage & current after using DVR..

The figure 5 shows the hardware results of both input voltage and current. Both are inphase. This is lead to unity power factor operation.

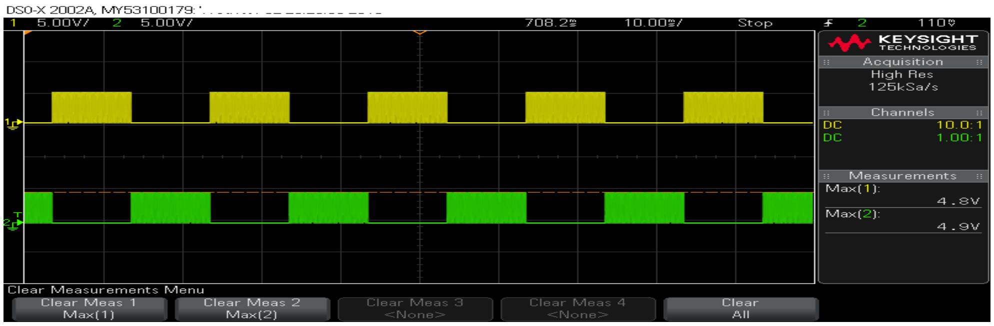

Figure 6 PWM pulse to the converter

The figure 6 shows the PWM pulses to the converter, the first pulse is given to the not gate, and it is fed to the second switch. The pulses are produced using fuzzy logic control technique. The PWM pulses are having 10KHz switching frequency.

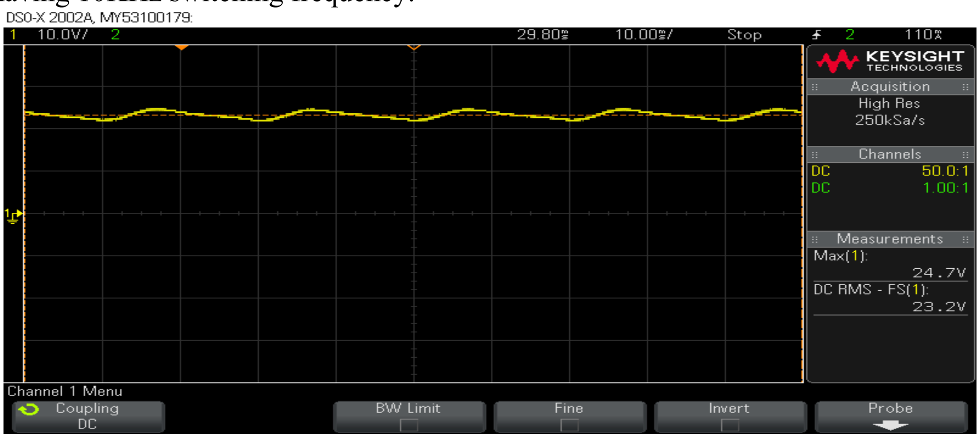

Figure 7 Output voltage of the series converter

The figure 7 shows the hardware output voltage of series converter. The PI control technique is used to get constant voltage.

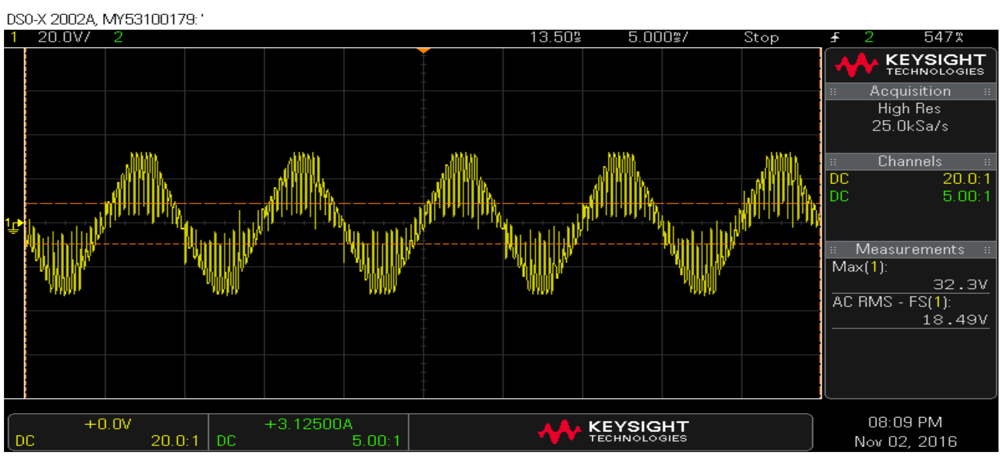

Figure 8 Output voltage of the shunt converter

Figure 8 shows the output voltage of the shunt converter, the inverter will produce square wave output voltage, this will reduce the primary fault current.

V. CONCLUSION

In this project, a control algorithm has been proposed for the generation of reference load voltage for a voltage-controlled DVR. The performance of the proposed scheme is compared with the traditional voltage-controlled DVR. The proposed method provides the following advantages: 1) at nominal load, the compensator injects reactive and harmonic components of load currents, resulting in UPF; 2) nearly UPF is maintained for a load change; 3) fast voltage regulation has been achieved during voltage disturbances; and 4) losses in the VSI and feeder are reduced considerably, and have higher sag supporting capability with the same VSI rating compared to the traditional scheme. The simulation and results show that the proposed scheme provides DVR, a capability to improve several PQ problems (related to voltage and current).

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