Enhancement of Load Voltage Regulation by Series Reactance Emulation of SSSC

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Abstract:The Voltage source converter(VSC) based series voltage compensator can inject a voltage in series with the transmission line. The component of injected voltage which is in quadrature with the line current emulates reactance. In this paper it is shown that the voltage at the receiving end is maintained constant by connecting Static Synchronous Series Compensator(SSSC) in series with the transmission line. If the receiving end voltage rises beyond the set voltage, the SSSC acts in inductive region by injecting voltage to lead the line current by 90° and the receiving end voltage is brought back to the set voltage. Similarly if the receiving end voltage reduces due to overloading it is brought back to the nominal voltage by making the SSSC to act in capacitive region by injecting voltage which lags the line current by 90°.The simulation results show the effectiveness of reactance emulation of SSSC to regulate the receiving end voltage and thereby enhances the voltage regulation.

Keywords: FACTS, SSSC, VSC,voltage regulation.

I.   INTRODUCTION

Power system should supply power to various load centres as per the demand. The power flow is controlled in AC transmission to improve power transfer capacity, to reduce voltage drop caused by major disturbances. Voltage drop may be caused due to increase in the loading of the transmission line and/orshortage of reactive power. The problem of voltage regulation can be overcome by connecting series Flexible AC Transmission System(FACTS) device with the transmission line.

In this paper the voltage drop caused due to overloading causes variation in the voltage at the receiving end and can be maintained constant by connecting SSSC as compensator in series with the transmission line.

II.   FACTS TECHNOLOGY

Flexible AC Transmission System(FACTS) is defined as 'Alternating current transmission systems incorporating power electronic based and other static controller to enhance controllability and increase power transfer capability'. The FACTS controller is defined as ' a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters'. Facts controllers are classified as

- Shunt connected controllers
- Series connected controllers
- Combined series-series controllers
- Combined shunt-series controllers

In the present work SSSC is used as series connected FACTS controller to enhance the voltage regulation by varying the line compensation.

III.   WORKING OF SSSC

SSSC is a voltage source converter based series compensator. It is used for series compensation and was proposed by Gyugyi in 1989.

A. Operating principle of SSSC
The schematic representation of SSSC is shown in Fig 1.a.and the SSSC connected to the transmission system is shown in Fig 1.b. corresponding phasor diagram is shown in Fig 1.c.

By the phasor diagram we can see that at a given line current the injected voltage $V_q$forces the opposite polarity voltage across the series line reactance to increase by the magnitude of the injected voltage.

Series capacitive compensation means reducing the line impedance of the given physical line.

$$V_q = -jkXI \qquad (1)$$

$$K = X_{SSSC}/X \qquad (2)$$

where V_q is the injected voltage, I is the line current, X_{SSSC} is the reactance of the SSSC, X is the line reactance, k is the degree of series compensation and $j = \sqrt{-1}$.
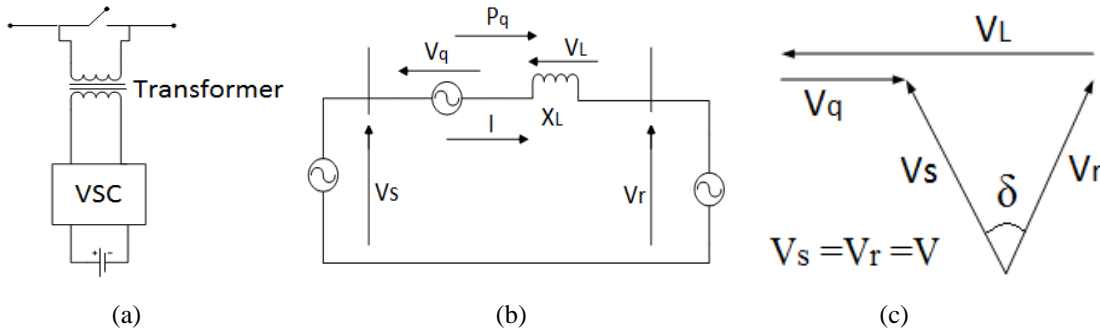

(a)   (b)   (c)

Fig 1.a. Schematic representation of SSSC   Fig 1.b. SSSC connected to the transmission line
Fig 1.c. Phasor diagram

The injected voltage lags the line current by 90° for normal capacitive compensation. The injected voltage can be reversed by making the injected voltage to lead or lag by 90°. For inductive compensation the injected voltage leads the line current by 90°.
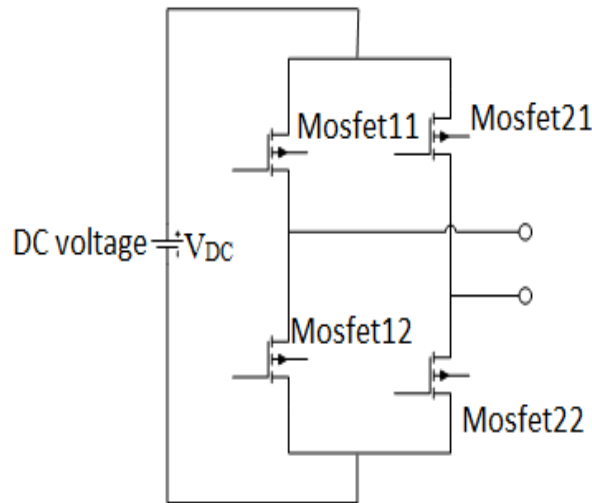
B. Unipolar SPWM Voltage source converter

Fig 2. Voltage source converter.

Inverter converts dc voltage to ac voltage. The VSC used here is Unipolar Sinusoidal Pulse Width Modulation(SPWM). The Single phase voltage source converter is as shown in Fig 2. It consists of four Mosfets as switching devices, each leg contains two mosfets.

In unipolar switching, the triangular carrier wave is compared with two sinusoidal signals which are positive and negative. The output voltage switches between 0 and V_{dc} in unipolar switching. The switching event is halved in unipolar case. Unipolar switching is more significant than bipolar because it reduces harmonics.

In VSC, if one of the two diagonal pair of Mosfets conduct each time that is (Mosfet11 and Mosfet22) or (Mosfet12 and Mosfet21), the output voltage will have two levels $+V_{dc}$ and $-V_{dc}$.

IV. STUDIED SYSTEM

Fig 3. Represents the studied system, in which SSSC is connected to the transmission line. The parameters considered in this system are

AC voltage source = 230V

Line resistance R_1 = 1Ω for 10km

Line impedance X_1 = 3.83Ω for 10km

Load resistance R_L= 59.75Ω

Load impedance X_L = 5.47Ω

Frequency of repeating sequence = 20KHz

DC voltage = 70V

Filter:
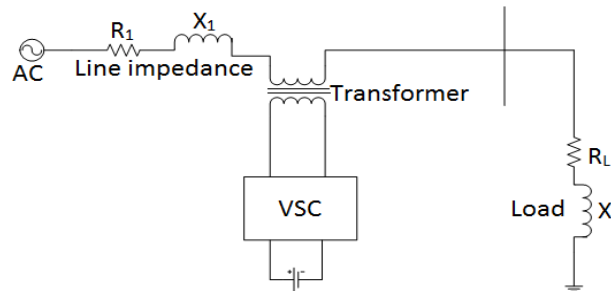
Inductor=1mH

Capacitor= 2.6mF

Resistor= 0.1Ω

VSC :

Fig 3.Schematic representation of studied system

If the receiving end voltage is greater than the set voltage, the SSSC is made to operate in inductive region and if it is below the set voltage it is made to operate in capacitive region. When the overloading occurs the receiving end voltage decreases and the SSSC is made to operate is capacitive region and the voltage is regulated. Similarly if the receiving end voltage rises above the set value, the SSSC acts in inductive region and the voltage is maintained constant.

V.   SIMULATION

In SSSC the injected voltage and the line current are in quadrature. If the injected voltage leads line current by 90° then its inductive mode of operation and emulates inductive reactance and if the injected voltage lags the line current by 90° its capacitive mode of operation and emulates capacitive reactance. Fig 4.showscapacitive and inductive mode of operation.
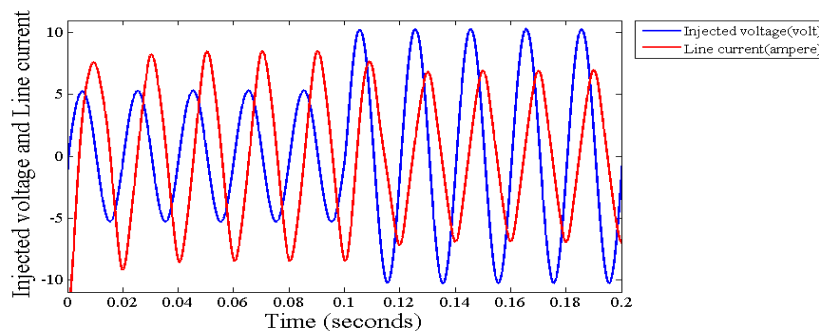

Fig 4.Waveform of injected voltage and line current showing inductive and capacitive mode of operation.

A. Simulink model

Fig 5.a, 5.b, 5.c represents the Simulink model of SSSC connected to the transmission line and the Simulink model to generate reference signal for SPWM and Voltage source converter respectively.

The PLL tracks the line current and it is summed with ±π/2 according to the condition given to the switch. The condition given to the switch is the RMS value of receiving end voltage,it is set to 228V. If the receiving end voltage rises above the set limit, the output of the switch will be +π/2. If it is below the set limit the output of the switch will be −π/2.The output of the summer is given to the sine trigonometric function. This sine wave is used as reference signal to the SPWM.

In unipolar SPWM, the sine wave is compared with the repeating sequence and the pulse obtained is given to the MOSFETS as firing pulses. Theswitching frequency of MOSFETS is 20KHz. The dc bus source voltage of VSC is maintained at 70V. The dynamics of DC bus voltage is regulated. The output voltage of full H-bridge is filtered using RLC filter and is injected using transformer to the line.
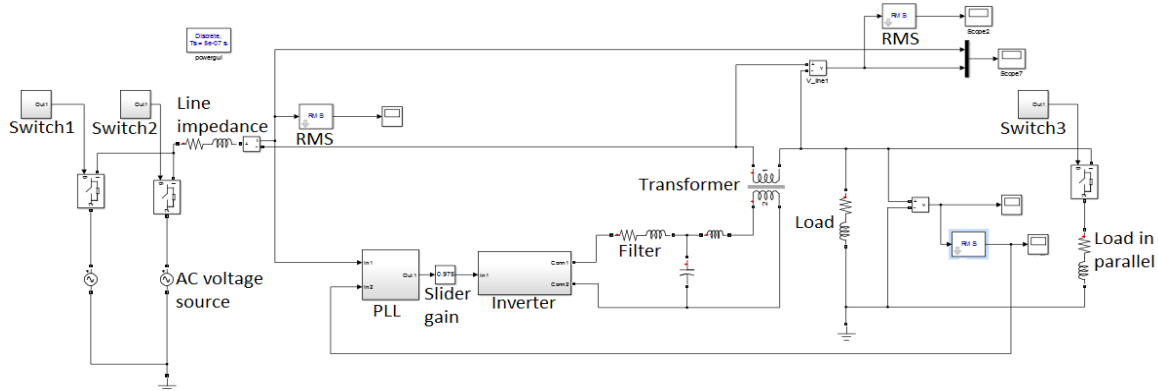
Fig 5.a. Simulink model of SSSC connected to the transmission line.
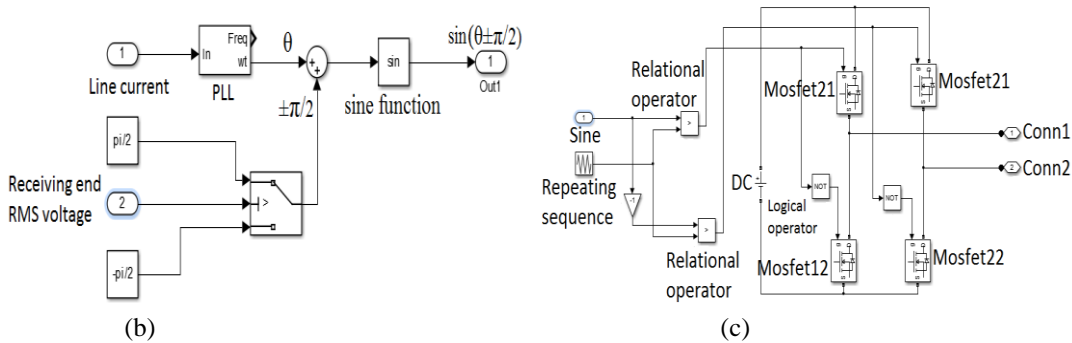

(b)   (c)

Fig 5.b. Simulink model to generate Fig 5.c. Simulink model of Voltage source converter.
reference signal to SPWM

B. Waveform

Fig 6 represents the waveform of the injected voltage and line current,Fig 7 represents the waveform of receiving end voltage.

Referring Fig 6 and Fig 7. InitiallySSSC acts in capacitive region. At t_1=0.1sec load is connected in parallel and there is decrease in receiving end voltage (Fig 7). At t_2=0.2sec receiving end voltage is maintained constant by increasing the injected voltage by varying modulation index (Fig 6) and simultaneously the voltage is maintained constant(Fig7).

At t_3=0.3sec, when source voltage is increased the receiving end voltage increases beyond the set value(Fig 7), therefore the SSSC acts in inductive region. At t_4=0.4sec the injected voltage is increased by varying the modulation index(Fig 6) and at t_6=0.6sec the voltage is maintained constant(Fig 7).

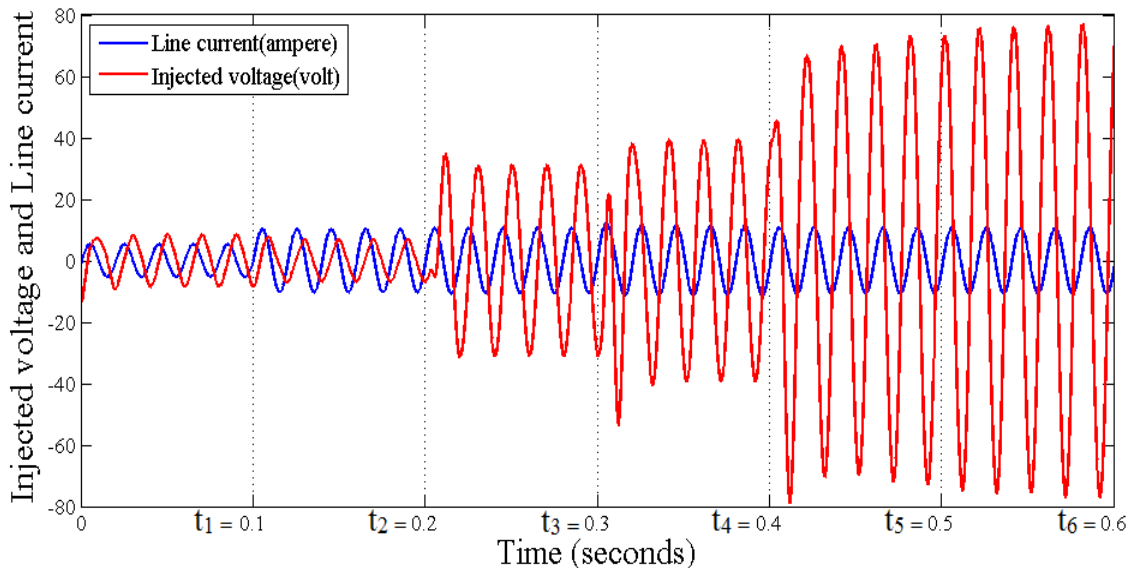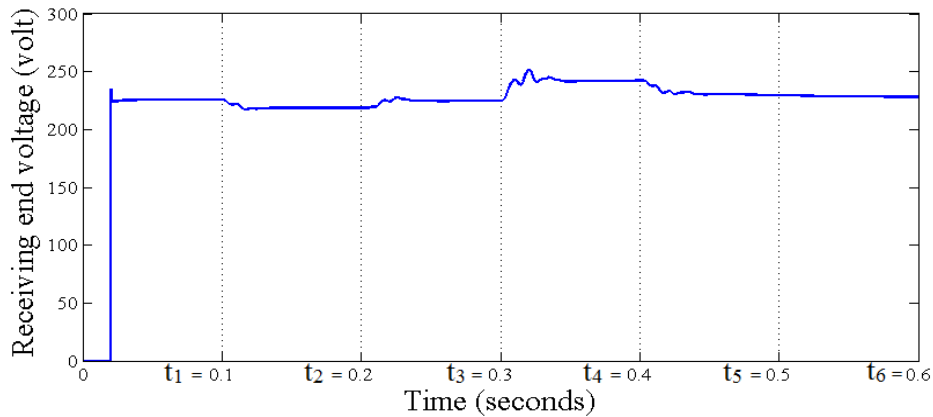Fig 6.Waveform of Injected voltage and Line current.

Fig 7.Waveform of receiving end voltage.

VI.   CONCLUSION

The performance of SSSC connected to the transmission line is analyzed. SSSC injects voltage in series with line. By the simulation results its shown that the voltage is regulated by capacitive and inductive reactance emulation by series connected SSSC to the line. Hence voltage is maintained constantby injecting voltage in quadrature with the line current.

ACKNOWLEDGEMENT

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