Power Flow Enhancement by using Thyristor Controlled Series Capacitor (TCSC)

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Abstract – *The power transfer capability of long high voltage transmission line is often limited by the inductive reactance of the transmission line. Series compensation is in some instance employed to lower the inductive reactance of the transmission line, which increases the transmission line power transfer capability. Numerous techniques have been employed to provide series compensation of a transmission line. One such technique is to use a Thyristor controlled series capacitor (TCSC).*

A thyristor controlled series capacitor (TCSC) belongs to the flexible alternating current transmission system (FACTS) family of devices. It is a variable capacitive and inductive device the can be used to provide series compensation in high voltage transmission lines. One of the significant advantages that TCSC has over other series compensation devices is that its reactance can be instantaneously and continuously variable. This means that the TSCS can be used not only to provide series compensation but can also be used to enhance the stability of the power system.

Key Words: **Arduino, Capacitor Filter, Regulator, Rectifier and TCSC.**

1. INTRODUCTION

Flexible alternating current transmission system (FACTS) is a recent technological development in electrical power systems that open the gate way to new opportunities for controlling power flow, satisfying voltage security constraints, power loss reduction, increasing system efficiency and security, flexibility and improving system response in the urgent circumstances. There can be series as well as shunt compensation techniques for the transmission line using these FACTS devices. In series compensation, line impedance is modified, i.e. the reactance of the transmission line is reduced. This will improve the voltage profile at the receiving end voltage and the active power flow capability in a transmission line will be increased. For shunt compensation technique, reactive power is injected into the line to regulate the voltage at the point of connection. Since there are various losses occurring in a long transmission line such a heat loss (i.e. I^2R losses), Corona losses, Skin effect, radiation losses etc. Due to these reasons the voltage regulation increases, so the actual sending end power is not being efficiently received at the receiving end. And the power system becomes unstable.

To overcome these problems, we use compensation techniques that are using compensating devices like Thyristor Controlled Series Capacitor (TCSC) device. This device is connected to the transmission line so that the reactance of the line is decreased and power flow is boosted into the transmission lines.

1.1 LITERATURE SURVEY

Power Grid Corporation of India Ltd (PGCIL) installed two Thyristor Controlled Series Capacitors (TCSC). The banks were installed on the Rourkela-Raipur double circuit 400 KV power transmissions interconnect between the Eastern and the Western region of the grid. The main purpose of the major AC interconnection is to enable the export of surplus energy from the Eastern regions to the Western regions of India during normal operation conditions, and also during contingencies. The TCSC's are located the Raipur end of the lines. TCSC enables damping of inter area power oscillations between the two regions, which would otherwise have constituted a limitation on power transfer over the interconnector. Dynamic simulations were performed during the design stages and subsequently confirmed at the commissioning and testing stages have proved the effectiveness of the Raipur TCSC as power oscillation dampers.

1.2 SYSTEM METHODOLOGY

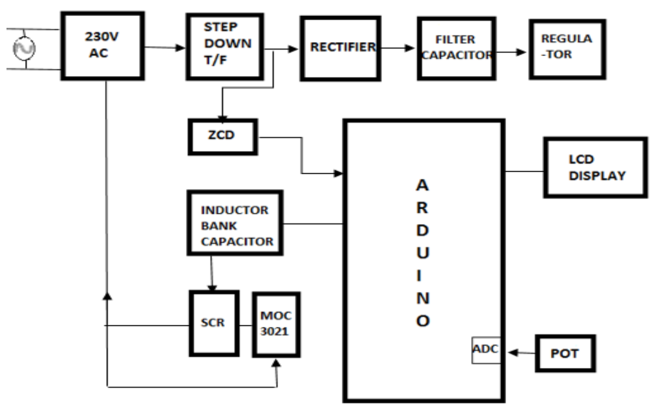


Figure 1:

1.2. HARDWARE SPECIFICATION

A) STEPDOWN TRANSFORMER

Figure2:

Transformer is a static device which transfers electrical energy from one circuit to another. It operates on the principle of electromagnetic induction between two windings of transformers which are isolated electrically. The frequency and power remain constant throughout the process. This reduces the voltage from 230 Volts to device operating voltage.

B) RECTIFIER

A rectifier is a device composed of one or more diodes that rectifies the alternating voltage (AC) to a direct current (DC) voltage.

C) FILTER CAPACITOR

Filter capacitor are used to filter off undesirable frequencies. A filter capacitor is a device that consists of a capacitor in certain orientation that functions as low pass filter or a high pass filter. Usually capacitor filters out low frequency signals. These are signals that are very close to 0Hz (hertz) known as DC signals.

D) VOLTAGE REGULATOR

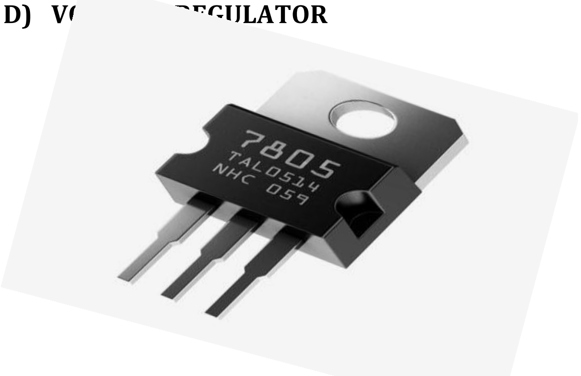


Figure 3:

Voltage regulator is used to regulate the power supply or it is used to maintain the constant voltage level. In this project we use IC 7805 it means that integrated circuit 78 series and 05 indicates the voltage level. This voltage regulator is used primary side in PCB circuit. It generates a fixed output voltage that remains constant for any changes in input voltage or load conditions. It acts as a buffer for protecting components from damage.

E) ZERO CROSS DETECTOR

It is essential to synchronize the firing thyristor pulse with line current and voltage. An OP-AMP base voltage digitizer circuit is used for generating a square pulse synchronized with the input voltage. Output of zero cross detector is fed to the first pin of micro controller. This rising edge will occur after every ten millisecond for a line frequency of 50Hz. In this way α is generated by delaying the trigger pulse to thyristor firing pulse. Here firing pulse of the power semiconductor device are synchronized with the line voltage because such procedure reduced the harmonic content present in the signal.

F) INDUCTOR BANK CAPACITOR

These are inductor and capacitor bank; the capacitance is fixed and the inductance is varied. Inductance of the inductor is 3.05mH and capacitance of the capacitor is 3.33μF.

G) SCR/ TRIAC

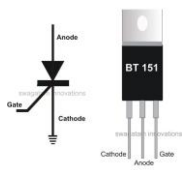


Figure 4:

Silicon controlled rectifier is a semiconductor device the functions as an electrically controlled switch. The basic purpose of an SCR is to turn on and off as and when biased properly.

TRIAC (triode for AC) is a semiconductor device widely used in power control and switching operations.

H) ARDUINO AT MEGA 328-P

Figure 5:

Arduino is an open–source electronic platform based on easy to use hardware and software. Arduino boards are able to read input- light on sensor, a finger on a button, or a twitter message and turn it into an output, activating the motor, turning on the LED, displaying something online.

Here we are employing Arduino to control various devices like LCD display, inductor capacitor bank, etc.

I) MOC 3021

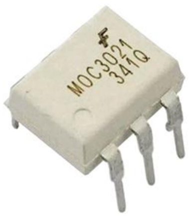


Figure 6:

The MOC3021 was designed to interface between electronic and high power TRIAC to control loads for AC voltage operation.

J) LCD DISPLAY (16X2)

Figure 7:

A liquid crystal display is a flat panel display or other electronically modulated optical device that uses the light modulating properties of liquid crystals combined with polarizer. It doesn't display light directly, instead using a backlight or reflector to produce image in color or monochrome.

LCD display displays the data we wish to display.

2. WORKING

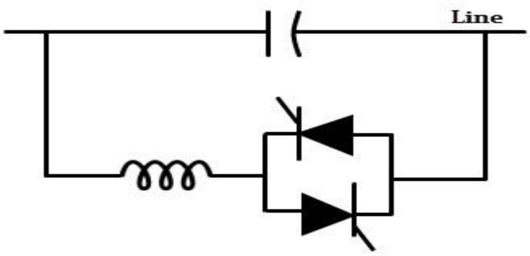


Figure 8:

TCSC is a device that consists of two anti parallel thyristor in series with one inductor L. These two combinations in parallel with one capacitor C. The combination of inductor in series with two anti parallel thyristor.

TCR is variable inductive reactor [$X_L(\alpha)$] turned at firing angle α.

$$X_L(\alpha) = X_L \frac{\pi}{\pi - 2\alpha - \sin 2\alpha}$$

$X_L = 2\pi fL$ and $XC = 1/2\pi fC$

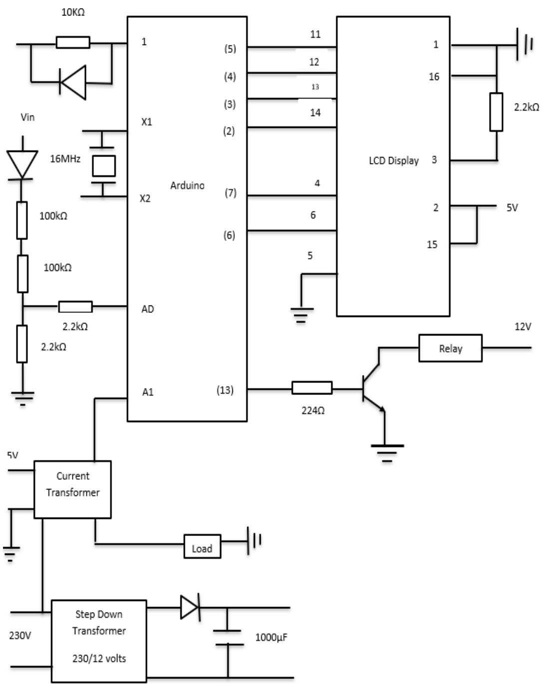
For the variation of α from 0^0 to 90^0, the inductive reactance X_L (α) varies from actual reactance (X_L) to ∞. These thyristor control reactor in connected in parallel with the series capacitor so the variable capacitive reactance is possible across the TCSC which modifies the transmission line impedance.

CHARACTERISTICS OF OPERATING REGION OF TCSC

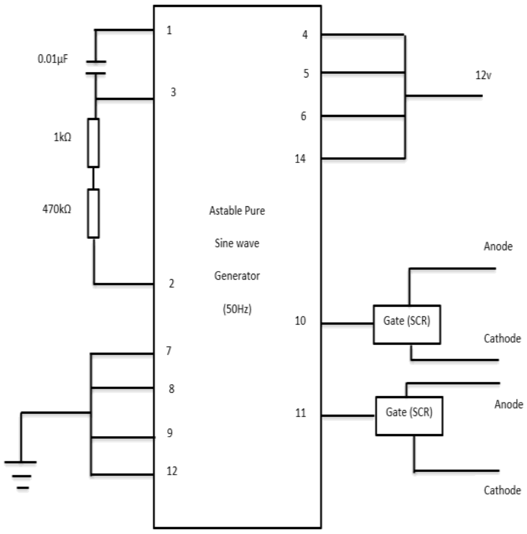
Range of firing angle α^0	Operating Region
$90^0 \le \alpha \le \alpha_L$	Inductive region
$\alpha_L \le \alpha \le \alpha_C$	Resonance region
$\alpha_C \le \alpha \le 180^0$	Capacitive region

Table 1:

2.1 CIRCUIT DIAGRAM



Circuit diagram 1: TCSS



Circuit diagram 2: Arduino to LCD circuit

3. OUTPUT

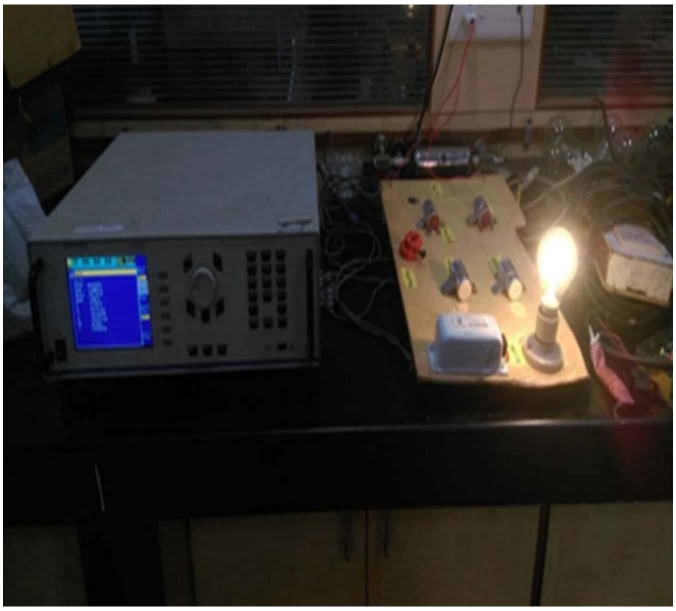


Figure 9: Circuit without TCSC

Figure 9 shows the power flow from AC mains to the load through a modeled transmission line without compensating the voltage at load end. That is without TCS.

Serial Number	Measured parameter of transmission line without TCSC	Measured values
1	Voltage at sending end	235.17 Volts
2	Current at sending end	0.47 Amp
3	Voltage at receiving end	227.05 Volts
4	Current at receiving end	0.53 Amp
5	Power factor at sending end	0.642
6	Power factor at receiving end	0.51
7	Active power at sending end	70.96 Watts
8	Active power at receiving end	61.37 Watts

Table2:

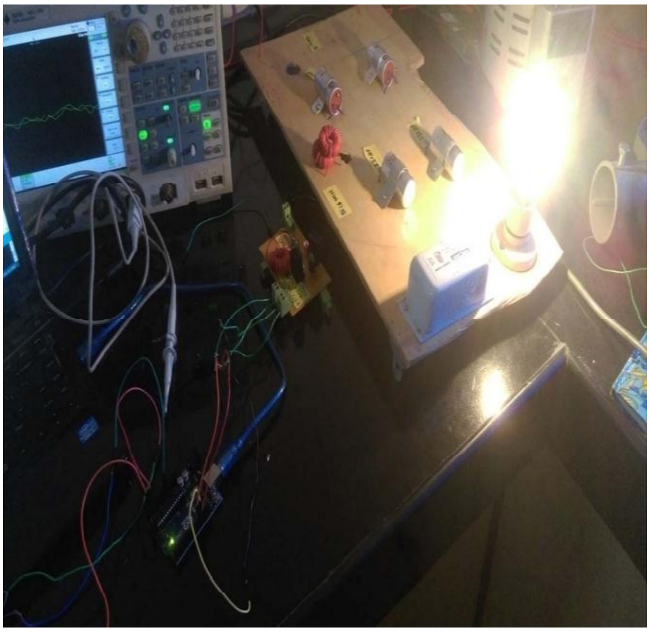


Figure 10: Circuit with TCSC

Figure 10 shows power flow from AC mains to load through a modeled transmission line with compensating the voltage at the load end. That is with TSCS.

Serial Number	Measured parameter of transmission line with TCSC	Measured Values
1	Voltage at sending end	235.17 Volts
2	Current at sending end	0.46 Amp
3	Voltage at receiving end	235.02 Volts
4	Current at receiving end	0.45 Amp
5	Power factor at sending end	0.65
6	Power factor at receiving end	0.64
7	Active power at sending end	70.31 Watts
8	Active power at receiving end	69.18 Watts

Table 3:

3. CONCLUSIONS

From this project we conclude that we were actually able to improve the power flow efficiency in a transmission line by using compensating device like TCSC. Also we reduced the transmission line losses thus improving the voltage profile at the receiving end and improving the system stability.

3.1 FUTURE SCOPE

Transmission systems will be more reliable as the transmission losses will be somewhat reduced. Power factor will be improved as well as reactive power will be reduced. So voltage profile at the receiving end will be maintained within proper regulation.

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