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# Implementation Of Thyristor Controlled Series Capacitor (TCSC) In Transmission Line Model Using Arduino

Dr J.Sridevi
Professor, Dept of EEE, Gokaraju Rangaraju Institute of Engineering and Technology, Bachupally, Hyderabad, A.P, India

**ABSTRACT**
A grid of transmission lines operating at high or extra high voltages is required to transmit power from generating stations to load. In addition to transmission lines that carry power from source to load, modern power systems are highly interconnected for economic reasons. The large interconnected transmission networks are prone to faults due to the lightning discharges and reduce insulation strength. Changing of loads and atmosphere conditions are unpredictable factors. This may cause overloading of lines due to which voltage collapse takes place. These problems can be eased by providing sufficient margin of working parameters and power transfer, but it is not possible due to expansion of transmission network. Still the required margin is reduced by introduction of fast dynamic control over reactive and active power by high power electronic controllers. This paper describes about implementation of Thyristor Controlled Series Capacitor (TCSC) in transmission line model in order to enhance power flow at the receiving end. The triggering pulses to the thyristor are given using Arduino.
***Keywords -*** Thyristor Controlled Series Capacitor, Arduino, Compensation

## I. INTRODUCTION

The increasing Industrialization, urbanization of life style has lead to increasing dependency on the electrical energy. This has resulted into rapid growth of PSs [1]. This rapid growth has resulted into few uncertainties. Power disruptions and individual power outages are one of the major problems and affect the economy of any country. In contrast to the rapid changes in technologies and the power required by these technologies, transmission systems are being pushed to operate closer to their stability limits and at the same time reaching their thermal limits due to the fact that the delivery of power have been increasing. The major problems faced by power industries in establishing the match between supply and demand are Transmission & Distribution which supply the electric demand without exceeding the thermal limit. In large PS, stability problems causing power disruptions and blackouts leading to huge losses [2].These constraints affect the quality of power delivered. However, these constraints can be suppressed by enhancing the PS control.

One of the best methods for reducing these constraints is FACTS devices. With the rapid development of power electronics, FACTS devices have been proposed and implemented in PSs. FACTS devices can be utilized to control power flow and enhance system stability. Particularly with the deregulation of the electricity market, there is an increasing interest in using FACTS devices in the operation and control of PSs [3,4]. A better utilization of the existing PSs to increase their capacities and controllability by installing FACTS devices becomes imperative. FACTS devices are cost effective alternatives to new transmission line construction.

Due to the present situation, there are two main aspects that should be considered in using FACTS devices: The first aspect is the flexible power system operation according to the power flow control capability of FACTS devices. The other aspect is the improvement of transient and SSVS of PSs. FACTS devices are the right equipment to meet these challenges [5,6].

## II. THYRISTOR CONTROLLED SERIES CAPACITOR

A capacitive reactance compensator which consists of series capacitor bank shunted by a thyristor controlled reactor in order to provide a smoothly variable series capacitive reactance [7] as shown in Fig.1.

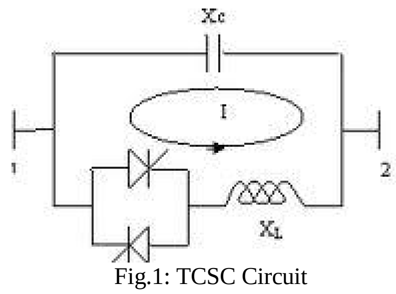


Fig.1: TCSC Circuit

Shunt compensation is ineffective in controlling the actual transmitted power, which at a defined transmission voltage, is ultimately determined by the series line impedance and the angle between the voltages of line

- It is always recognized that ac power transmission over long lines was primarily limited by the series reactive impedance of the line.
- Series Compensators are quite affective to Improve Voltage Stability, Transient Stability, and Power Oscillation Damping and also to Mitigate SSR and Power Quality Problems.

A TCSC is a series-controlled capacitive reactance that can provide continuous control of power on the ac line over a wide range [8]. From the system viewpoint, the principle of variable-series compensation is simply to increase the fundamental-frequency voltage across an fixed capacitor (FC) in a series compensated line through appropriate variation of the firing angle, α. A simple understanding of TCSC functioning can be obtained by analyzing the behaviour of a variable inductor connected in parallel with an FC. The equivalent impedance, Zeq, of this *LC* combination is expressed as

- The impedance of the FC alone, however, is given by $-j(1/\omega C)$.
- If $\omega C - (1/\omega L) > 0$ or, in other words, $\omega L > (1/\omega C)$, the reactance of the FC is less than that of the parallel-connected variable reactor and that this combination provides a variable-capacitive reactance are both implied.
- If $\omega C - (1/\omega L) = 0$, a resonance develops that results in an infinite-capacitive impedance-an obviously unacceptable condition.
- If, however, $\omega C - (1/\omega L) < 0$, the *LC* combination provides inductance above the value of the fixed inductor.

This situation corresponds to the inductive- mode of the TCSC operation. In the variable-capacitance mode of the TCSC, as the inductive reactance of the variable inductor is increased, the equivalent-capacitive reactance is gradually decreased. The minimum equivalent-capacitive reactance is obtained for extremely large inductive reactance or when the variable inductor is open-cir-cuited, in which the value is equal to the reactance of the FC itself.

Providing fixed-series compensation on the parallel path to augment power-transfer capability appears to be a feasible solution, but it may increase the total system losses. Therefore, it is advantageous to install a TCSC in transmission paths, which can adapt its series-compensation level to the instantaneous system requirements and provide a lower loss alternative to fixed-series compensation. The series compensation provided by the TCSC can be adjusted rapidly ensure specified magnitudes of power flow along designated transmission line. This condition is evident from the TCSC's effectively, that is, ability to change its power-flow as a function of its capacitive-reactance setting:

$$P = V_1 V_2 \sin\delta / X \quad (1)$$

Where $P$ = the power flow from bus 1 to bus 2.
$V_1$, $V_2$ = the voltage magnitudes of buses 1 and 2, respectively
$X_L$= the line-inductive reactance,
$X_C$= the controlled TCSC reactance combined with fixed-series capacitor reactance.
$\delta$= the difference in the voltage angles of buses 1, 2.

This change in transmitted power is further accomplished with minimal influence on the voltage of interconnecting buses, as it introduces voltage in quadrature. The freedom to locate a TCSC almost anywhere in line is a significant advantage. Power-flow control does not necessitate the high-speed operation of power flow control devices. Hence discrete control through a TSSC may also be adequate in certain situations. However, the TCSC cannot reverse the power flow in a line, unlike HVDC controllers and phase shifters.

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## III. DESIGN CRITERION OF TCSC

Consider the Line reactance of the transmission line in per unit system. For 50% compensation, the value of the capacitor in the TCSC will be 50% of the line reactance. Now for capacitive compensation, the value of inductive reactance must be greater than capacitive reactance, that is,

$$X_L > X_C$$

$$X_{TCSC} = (X_L * X_C) / (X_L - X_C) \quad (2)$$

Total reactance of the line with TCSC is

$$X = X_L - X_{TCSC} \quad (3)$$

The design criterion for the present case to find the value of capacitance and inductance of a TCSC controller is based on the net reactance of the transmission line and power flow control through it. SMTB Test System is developed with a transmission line model of 0.2p.u reactance. The design of TCSC is based on line reactance value, in the present case the compensation is limited to 50%. Hence take the fixed capacitive reactance value equal to 0.1p.u, Take the value of $X_C$ as 0.1p.u
Line reactance is 61.1Ω
Actual
$X_C$ = % of compensation * line reactance

$X_C = 0.8*15.7 = 12.56\Omega$
$X_C = 1/2\pi fC = 1/2\pi$
$C = 1/2\pi*50*12.56$
$C = 220\ \mu F$
In Fig.1, $X_C$ is in parallel with $X_L$
$Q_C = 109^2/12.56 = 945.94$ VAR
Here, $X_L > X_C$
Therefore, L = 100mH
$X_L = 2\pi f*L = 31.4\Omega$
**Practical Design:**
L = 100mH; C=220 µF.

## IV. RESULTS AND DISCUSSIONS

The model of transmission line of Pi section with lumped parameters for a length of 136 KM is simulated in MATLAB software without series capacitor with induction motor as load. The simulation diagram is shown in Fig.2. The active and reactive power waveforms are shown in Fig.3.

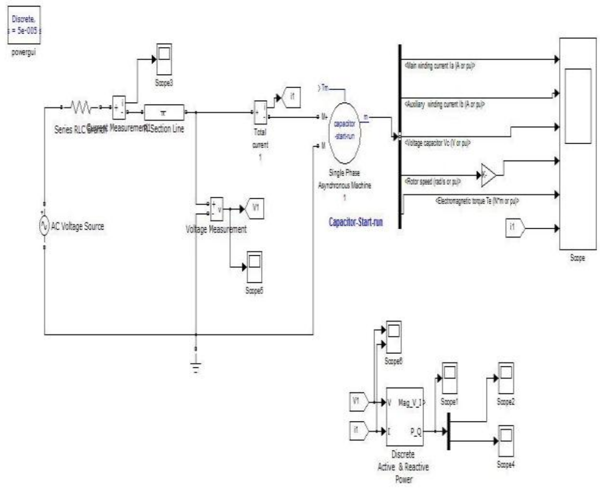

Fig.2: MATLAB Simulation of transmission line without series capacitor

Fig.3: Active and Reactive power waveforms

The model of transmission line of Pi section with lumped parameters for a length of 136 KM is simulated in MATLAB software with series capacitor with induction motor as load. The simulation diagram is shown in Fig.4.

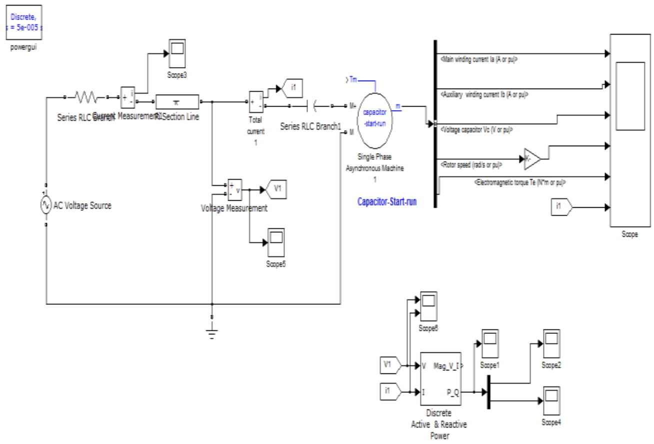

Fig.4: MATLAB Simulation of transmission line with series capacitor

The transmission line model has been implemented in hardware as shown in Fig.5, and shown in the following figures.

**Parameters:**
Resistance =100 ohms
Inductance =50 mH
Capacitance =220 µF
According to the current carrying capacity the transmission line wire gauge has been taken as 4 AWG. Ceiling fan (Induction motor) is taken as load to the transmission line.

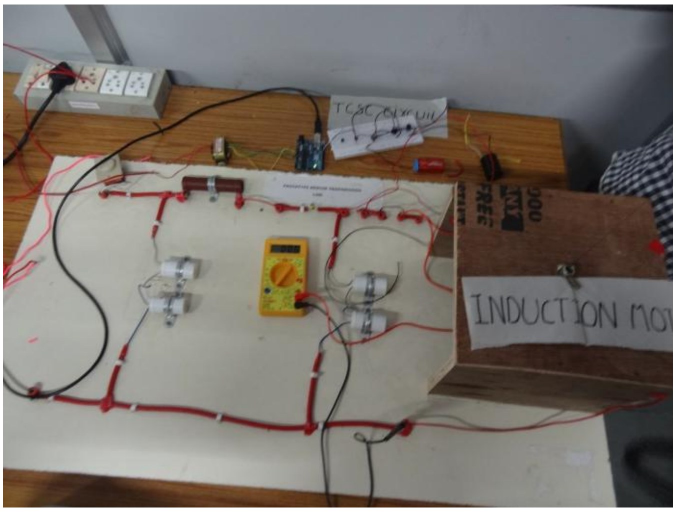


Fig 5 Voltage at the receiving end without using TCSC

TCSC is placed in the transmission line and thyristors are triggered using aurdino program as shown in Fig. 6.

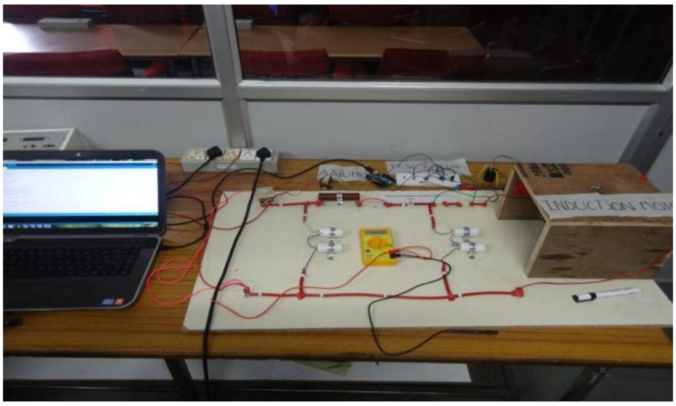

Fig 6: Single phase transmission line model involving TCSC using Arduino

**Arduino Program:**

```
int sensorPin1= A3;
int sensorPin2= A4 ;
int output= 12;
int sensorValue1=0;
int sensorValue2=0;
void setup()
{
pinMode(12,OUTPUT);
Serial.begin(9600);
}
void loop()
{
sensorValue1= analogRead (sensorPin1);
Serial.println(sensorValue1);
sensorValue2= analogRead (sensorPin2);
Serial.println (sensorValue2);
if(sensorValue1<=298 || sensorValue2<=298 )
{
digitalWrite(output, LOW);
}
if (sensorValue1>298 || sensorValue2>298 )
{
digitalWrite(output, HIGH); }}
```

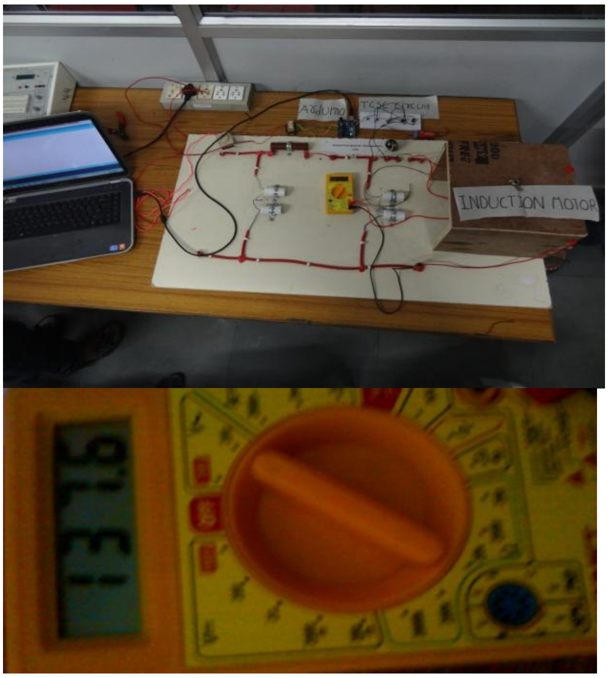


Fig 7: Voltage at the receiving end with TCSC

## V. CONCLUSION

Thyristor controlled series capacitor (TCSC) using Arduino has been implemented to a Transmission line model and we have observed that there has been an improvement in the receiving end power and voltage for the same sending end voltage with TCSC. Also there is an improvement in the efficiency and voltage regulation of transmission line. Receiving end voltage and active power can be improved where ever necessary in transmission line according to our requirements, by varying the firing angle of anti-parallel Thyristors .

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