A User Friendly Simulink Model for FC-TCR to Investigate Power System Issues

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Abstract--- In this paper discussion and demonstration of performance analysis of Static Var Compensator (SVC) FC-TCR type which is applied to control dynamic behavior of transmission systems is made. Dynamic behavior in the sense voltage control issues of transmission system using reactive power compensation is analyzed and performed. Experimental model of medium transmission line at my college has been simulated in MATLAB software to show the importance of reactive power compensation. With the help of simulation the dependence of firing angle of TCR in the reactive power exchange of SVC as well on the THD (total harmonic distortion) level has been shown. Simulations have been shown to determine the importance of co-ordination between fixed capacitor (FC) and thyristor controlled reactor (TCR) in order to provide proper compensation. Four different conditions have been simulated.

I. INTRODUCTION

The demand of electrical energy is increasing continuously. To fulfill this demand the generation has to be increased which is limited by constraints like environmental, financial, time, availability of resources etc. Flexible AC transmission system (FACTS) is a generic term representing the application of power electronics based solutions to AC power system. These systems can provide compensation in series or shunt or a combination of both series and shunt. The FACTS can attempt the compensation by modifying impedance, voltage or phase angle. FACTS devices can be connected to a transmission line in various ways, such as in series with the power system (series compensation), in shunt with the power system (shunt compensation), or both in series and shunt [2]

A. Series Facts Devices

The series Compensator could be variable impedance, such as capacitor, reactor, etc. or a power electronics based variable source of main frequency to serve the desired need. Various Series connected FACTS devices are;

- Static Synchronous Series Compensator (SSSC)
- Thyristor Controlled Series Capacitor (TCSC)
- Thyristor Switched Series Capacitor (TSSC)
- Thyristor Controlled Series Reactor (TCSR)
- Thyristor Switched Series Reactor (TSSR)

B. Shunt Facts devices

Shunt Controllers may be variable impedance, variable source, or a combination of these. In principle, all shunt Controllers inject current into the system at the point of connection. Various shunt connected controllers are;

- Static Synchronous Series Compensator (STATCOM)
- Static VAR Compensator (SVC)
- Thyristor Controlled Reactor (TCR)
- Thyristor Switched Capacitor (TCS)

C. Combined Shunt-Series Facts Devices

This may be a combination of separate shunt and series controllers, which are controlled in a coordinated manner or a Unified Power Flow Controller with series and shunt elements. In principle, combined shunt and series controllers inject current into the system with shunt part of controller and voltage with the series part of controller. Various combined series shunt Controllers are: Various combined series shunt Controllers are;

- Unified Power Flow Controller
- Thyristor Controlled Phase Shifter

II. FC-TCR TYPE SVC

Static var compensator (SVC) is a shunt connected device to exchange the reactive power for providing a dynamic control over voltages. Fixed capacitor-thyristor controlled reactor is one type of SVC to be focused in this paper. It consists of parallel connection of fixed capacitors and reactor connected in series with anti-parallel thyristors and the whole assembly is connected in parallel with the transmission system or with the load.

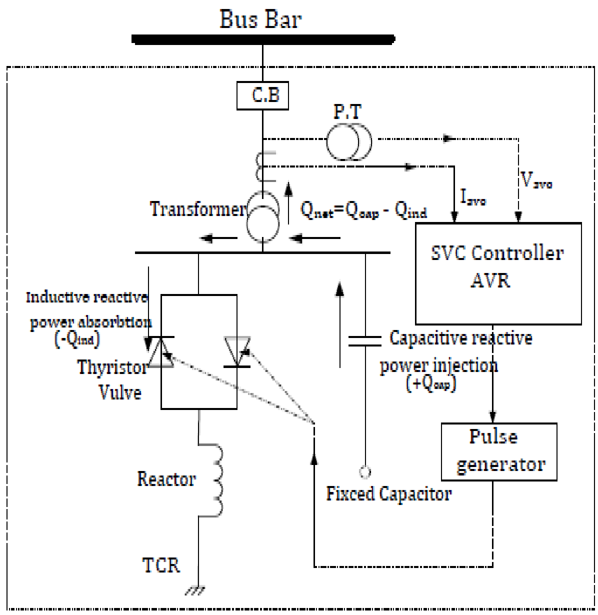

Fig. 1: Schematic diagram of FC-TCR

As shown in figure 1, step down transformer is provided to isolate the SVC from high voltages. With the variation of firing angle to thyristors we can vary the Qtcr and ultimately we can vary the Qsvc. Whenever there is a condition of light loading or no-loading we have to trigger the thyristors such that net reactive power of SVC is inductive. Similarly in case of heavy loading conditions the net reactive power of SVC should be capacitive.

Firing angle of thyristors vary from 90^0 to 180^0 if angle is measured from positive zero crossing of voltage and it varies from 0^0 to 90^0 if it is measured from voltage peak. At zero VAR output of FC-TCR the firing angle should be set such that capacitive and inductive reactive power cancels each other.

III. MATHEMATICAL MODELLING OF FC-TCR

When the gating of SCR is delayed with respect to positive zero crossing of voltage, the voltage across inductor can be expressed as:-

$$Vc = \sqrt{2}Vc\sin(\omega t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .1$$

$Vc =$ Instantaneous capacitor voltage

Instantaneous TCR current is given by:-

$$i = \frac{\sqrt{2}Vc}{\omega L}\int_{\alpha}^{t} \sin(\omega t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. 2$$

$$= \frac{\sqrt{2}Vc}{\omega L}(-\cos(\omega t) - \cos(\alpha)) \ldots\ldots\ldots\ldots\ldots 3$$

Amplitude of fundamental component for even function is given is:-

$$a = \frac{4}{\pi}\int_0^{\pi} f(t).\cos(\omega t).d(\omega t) \ldots\ldots\ldots\ldots\ldots ..4$$

$$= \frac{4}{\pi}\frac{\sqrt{2}Vc}{\omega L}\int_0^{\pi}(-\cos(\omega t) - \cos(\alpha)) \ldots\ldots\ldots ..5$$

Hence the R.M.S value of fundamental component is :-

$$I = \frac{Vc}{\omega L}(2\pi - 2\alpha + \sin(2\alpha)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

Hence the susceptance of TCR from above equation is given by:-

$$Btcr = \frac{1}{\omega L}\left(\frac{(2\pi - 2\alpha + \sin(2\alpha))}{\pi}\right) \ldots\ldots\ldots\ldots .7$$

Total susceptance of SVC in terms of firing angle is given by:-

$$Bsvc = Btcr + Bc \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .8$$

$$= Bl\left(\frac{(2\pi - 2\alpha + \sin(2\alpha))}{\pi}\right) + Bc \ldots\ldots\ldots\ldots .9$$

Hence by the variation of firing angle of TCR, we can vary the SVC susceptance and thus the reactive power exchanged by SVC, which is given by

$$Qsvc = V^2 \cdot Bsvc \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

IV. EXPERIMENTAL MODEL

Consider the experimental model at my college. Experiment and simulation has been carried out to show the importance of reactive power in maintaining voltage profiles.

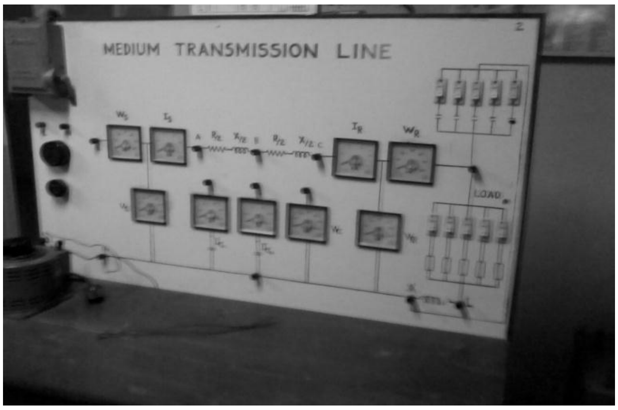

Fig. 2: Medium transmission line experimental model

SOURCE					LOAD			
P	Q	V	I	LOAD	P	Q	V	I
38.47	6.573	220	0.177	1450	38.3	7.9	219	0.17
67.0	14.8	220	0.13	850	66.5	27.76	216.5	0.333
83.13	40.4	220	0.40210	650	82.21	51.42	213.9	0.4532
89.28	64.12	220	0.5	550	87.92	73.38	211.6	0.5417
89.49	83.78	220	0.5571	290	87.84	91.59	209.8	0.6097

Table 1: Simulated data of model

SOURCE				LOAD		
P	V	I	LOAD	P	V	I
45	220	0.2	1450	30	220	0.2
80	220	0.35	850	75	218	0.38
83	220	0.55	650	81	210	0.52
89	220	0.7	550	84	209	0.7
92	220	0.84	490	88	205	0.82

Table 2: Experimental data of the model

From the above tables we can note that with the increase in R-L loading, voltage drop down and also we can see the similarity between experimental data and simulated data.

V. DEPENDENCE OF FIRING ANGLE ON HARMONICS LEVEL

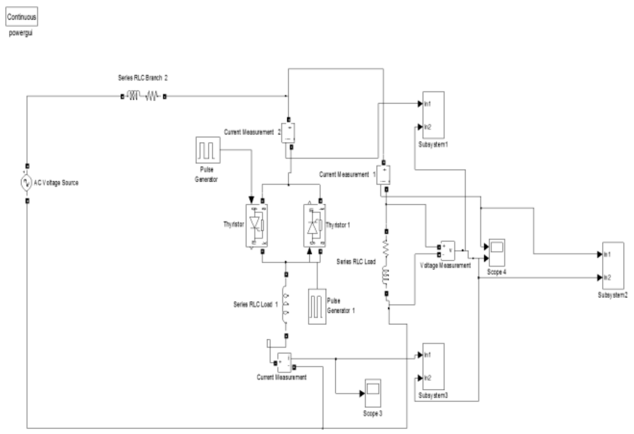

Fig. 2: MATLAB circuit to show effect of firing Angle

With the increase in firing angle of TCR, harmonics generated increases.FFT analysis has been carried out in the

MATLAB software to show this phenomenon. Consider the circuit as shown in above figure

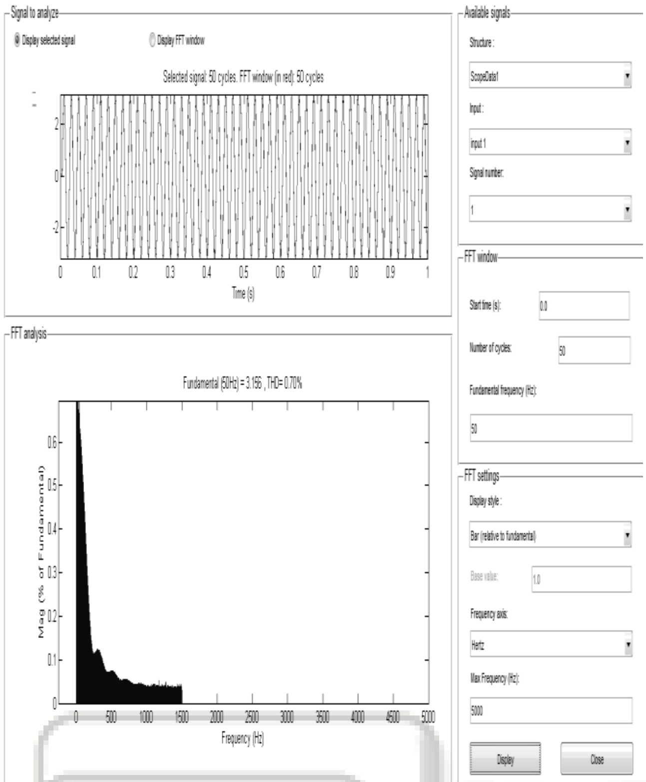

Fig. 3: FFT analysis of current waveform at α=90^0

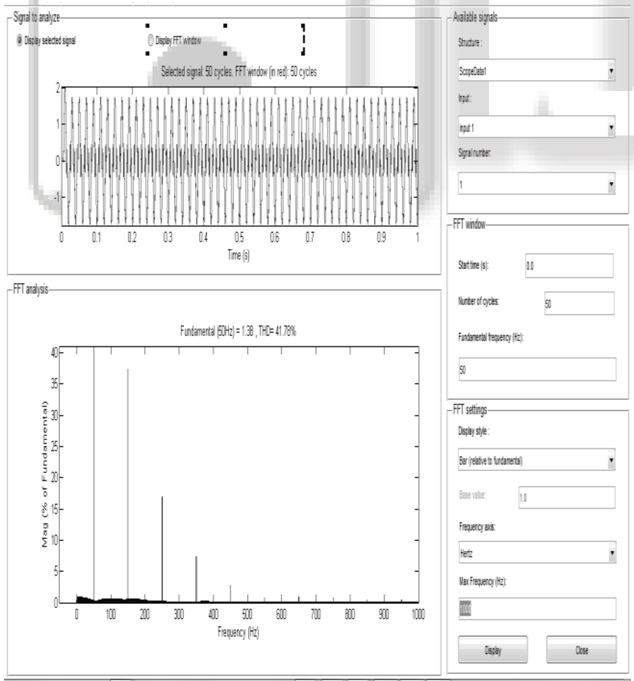

Fig. 4: FFT analysis of current waveform at α=110^0

Firing angle in degrees	Reactive power absorbed by TCR	Total harmonic distortion(THD)	Current in TCR
90	883.2	0.70	2.248
110	338	41.78	0.8971
140	72.51	132.63	0.3019
160	13.72	267.7	0.09871
180	0	0.09	0

Table 3: Relation between THD and firing angle of TCR

From the above table we can say that with the increase in firing angle, harmonics generated will increase

VI. IMPORTANCE OF CO-ORDINATION BETWEEN FC AND TCR

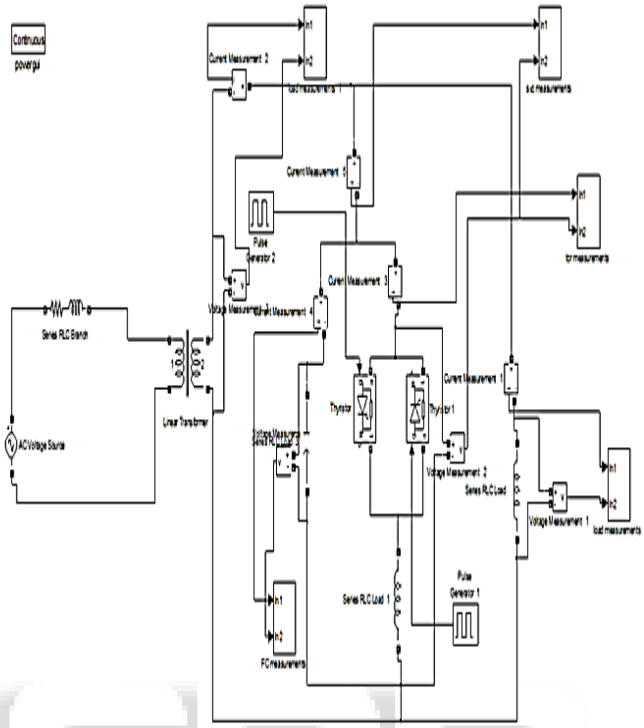

Fig. 5: MATLAB circuit of FC-TCR

The above MATLAB circuit consists of FC-TCR alongwith the inductive to simulate four different conditions.

A. Condition 1

When no compensation is available we shall see the measurements made by subsystem across the loading.

SOURCE		LOAD	
V	VAR	V	VAR
386.6	696.5	386.6	696.5

Table 4: Condition of no compensation

B. Condition 2

When compensation is available (FC-TCR),we can see that less VAR is absorbed by the source which improves the power factor.

SOURCE		LOAD		SVC		FC		TCR	
V	VAR	V	VAR	V	VAR	V	VAR	V	VAR
440.4	225	440.4	13.08	440.4	602	440.4	1023	440.4	422.7

Table 5: Condition of proper compensation

C. Condition 3

When line is lightly loaded excessive reactive power demand is set by the capacitors which increase voltage.

SOURCE		LOAD		SVC		FC		TCR	
V	VAR	V	VAR	V	VAR	V	VAR	V	VAR
529	1603	529	13.08	529	982.31	529	1023	529	40.69

Table 6: Condition of overvoltage

D. Condition 4

In this condition the overvoltage resulted from excessive leading reactive power demand is compensated by triggering thyristor of inductor at proper at proper firing angle.

SOURCE		LOAD		FC		TCR		SVC	
V	VAR	V	VAR	V	VAR	V	VAR	V	VAR
439.6	130.1	439.6	8.744	123.1	1061	1158	1158	439.6	123.1

Table 7: Condition of proper triggering of TCR

Hence from the above four conditions we summarize that voltage distortions prevail in case of no compensation. Also if the compensation is provided it it necessary to have proper co-ordination between fixed capacitor(FC) and thyristor controlled reactor(TCR).

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VII. CONCLUSION

In this research paper we have addressed and analysed some of the power system issues.A detailed analysis using Simulink model in MATLAB has been attempted to understand VAR control in transmission system. MATLAB simulation of medium transmission line model has been carried out. Fast fourier transform (FFT) analysis has been carried in MALTAB software to conclude that THD level in current waveform increases with increase in TCR firing angle. Also four different conditions have been studied to understand the importance of co-ordination between FC and TCR in operation of this SVC

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