A Case Study on Harmonic Analysis of Medium Transmission System Implemented with TCSC

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Abstract: ***In the recent scenario the power system network is facing the many power quality problems, out of which the voltage sag, Voltage swell, flickers, voltage unbalance and harmonics are more common problems which occurs. The Thyristor Controlled Series Capacitor is an effective FACTS controller to increase the power transfer capability. This paper represents the case study on harmonic analysis present in power signal without and with Thyristor Controlled Series Capacitor (TCSC) for 66kv, 115km and 33kv, 110km medium transmission line. In this paper modeling and simulation of medium transmission line is done and results are obtained for a transmission system implemented with and without TCSC. The simulation results demonstrate the performance of the system in improving the power profile. All simulations work is done in MATLAB/SIMULINK environment.***

Keywords: Power Quality, Harmonics, TCSC

1. Introduction

In Present scenario, increased use of transmission facilities owing to higher industrial demand and deregulation of the power supply industry has provided the necessity for finding new ways of maximizing the power transfers of existing transmission facilities which are maintaining acceptable levels of system reliability and stability [1]. In the past years, the power systems were simple and relatively non-remote. In the recent years the complexity of power system has been drastically increased with the rapid growth of power demand [2]. Now in the modern power systems, FACTS technology has been called "one of the three topics at the revolutionary forefront", especially in the recent years, many FACTS devices with various structures and properties are used in some actual projects of power systems in Europe and Japan. Flexible AC transmission system is an evolving technology to help electric utilities [3]. Its first concept was introduced by N.G Hingorani, in 1988. The solutions to improve the quality of supply in the electrical networks with go through the applications of the developments in semiconductor devices which is used to utilization of static power converters in electrical power system. The technological advances in power semiconductors are permitting the development of devices that react more like an ideal switch which is totally controllable and admitting high frequencies of commutation to major levels of tension and power [6]. In the whole world there are several sets of TCSC applied in transformer substations of 500Kv or above, have been in trial operation or under Construction [4]. One of the most important FACTS devices which is Connected to system in series is Thyristor Controlled Series Capacitor (TCSC) that is used to increase the overall capability of power transmission in a power long-haul transmission line. Its usage will improve the power transmission capability and Stability on system; it may. TCSC has some important advantages on the system. It can coordinate the power flow in the system and also it can regulate the voltage levels by changing the firing angle of thyristors that are controlling the amount of reactor which is in parallel with constant capacitors of the system. The thyristors are changing the reactance and when it is added to impedance of capacitors it can change the level of line compensation. In past papers on this subject, TCSC has been used only to improve the power transfer of the system, while it can also increase the voltage regulation and enhance the power quality factors including reduction in level of harmonics too[5].

2. Power Quality Issues

In the power quality improvement various FACTS devices are used to improve the power transfer capability and hence the voltage profile. In power quality issues there are lots of problem and which we will try to remove and get best result. The following problems arise in power system network:

Disturbances: Disturbance has been understood as a temporary deviation from the steady-state waveform, being in fact a short-term concept. This phenomenon is often used to refer to a no repetitive change in the amplitude of the system voltage at the fundamental frequency for a short period of time. This deviation can be a high-frequency phenomenon (impulsive, oscillatory and periodic transients) or a low frequency phenomenon (voltage dips, interruptions and swells). The main attributes for characterizing these kinds of disturbances are the change in the amplitude and duration of the occurrence. In some regulations permissible voltage deviations are defined dependently on a voltage level as voltage range for a time period: steady state, less than 1min, less than 10s and impulse voltage respectively. In practice, recorded parameters dependently on the needs can be averaged by a day, a week or a month.

A. Waveform Distortion: This area covers harmonics, interharmonics, harmonics phase-angle, harmonic symmetrical components and Notching. The most frequently used harmonic and interharmonics indices are:

- Harmonic Distortion (HD)
- Total Harmonic Distortion (THD)
- Total Interharmonics Distortion (TIHD)
- Total Demand Distortion (TDD)

And Distortion Band Factor (DBF) the THD, HD and TIHD indices are defined as the rms of the harmonics or interharmonics respectively expressed as a percentage of the fundamental or the Original distorted signal. The TDD is similar to the THD concept except that the distortion is expressed as a percentage of some rated or maximum load current magnitude rather than as a percentage of the fundamental current. Using the THD or HD indices, the lack of information about the value of respective harmonics may be observed. It is very important if detection of higher order harmonic is considered. The problem may be eliminated by estimation of waveform distortion caused by the frequency component of a respective frequency band.

B. Voltage unbalance: Unbalance describes a situation, in which either the voltages of a three-phase voltage source are not identical in magnitude or the phase differences between them are not 120 electrical degrees, or both. The degree of unbalance is usually defined by the proportion of negative and zero sequence components.

C. Voltage fluctuations and flicker: Voltage fluct-uations are described as the cyclical variations of the voltage envelope or a series of random voltage changes, the magnitude of which does not exceed the range of permissible operational voltage changes mentioned in IEC 38 (i.e. up to ±10%) . Fluctuations in the system voltage (concerning its rms value) can cause perceptible, low frequency light flicker depending on the magnitude and frequency of the variations. A common method of analyzing the severity of a flicker disturbance is to measure the fluctuation of light luminosity of an incandescent lamp. This assessment of flicker can be broadly divided into two parts: measurement of instantaneous flicker sensation as perceived by human eyes, and statistical evaluation of this severity level. The two severity indices short-term flicker severity and long term flicker severity have been proposed for flicker evaluation [7].

3. Series Compensation

When the line has high value of reactance to resistance ratio, the inductive reactance of the transmission line can be decreased by introducing series capacitors which results in low voltage drop. When a load with lagging power factor is connected at the end, voltage drop in the line is

$$VD = I\,(RCos\o + X_L Sin\o)\ volt \qquad (1)$$

If a capacitance 'C' with reactance Xc is connected in series with the line, then the reactance will be reduced to (XLXc) and hence the voltage drop is reduced. Further the reactive power taken by the line is also reduced [8].

3.1. Thyristor Controlled Series Capacitor

TCSC is a series FACTS device which allows rapid and continuous changes of the transmission line impedance. These devices have great application potential in accurately regulating the power flow on a transmission line, power oscillations in damping inter-area zone, mitigating sub synchronous resonance and improving transient stability [6]. A TCSC basically consists of a series capacitor bank shunted by a Thyristor-Controlled Reactor (TCR) which controls the equivalent TCSC series reactance [5]. Basic structure of TCSC is shown in Fig.1

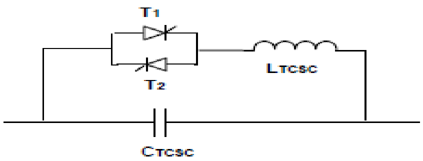

Figure.1: basic structure of TCSC

By using the TCSC in series with the line we can mitigate various voltage disturbance and harmonics. The survey reported that 68% of the power disturbances were voltage sags, and these types of disturbances were the only cause of production losses. Thyristor controlled series compensator FACTS device are the most important device and have been used for a number of years to improve voltage and power flow through the transmission line by resolving dynamic voltage issues. An SVC is shunt connected static generator. The utilities of SVC controller in transmission line are many: [1]

- Provides high performance in steady-state and transient voltage stability control.
- Dampen power swing.
- Reduce system loss.
- Control real and reactive power flow.

3.2. TCSC Operation

The basic operation of TCSC can be easily explained from circuit analysis. It consists of a series compensating capacitor shunted by a Thyristor controlled reactor (TCR). TCR is a variable inductive reactor XL (fig.2) controlled by firing angle α. Here variation of XL with respect to α is given by [9].

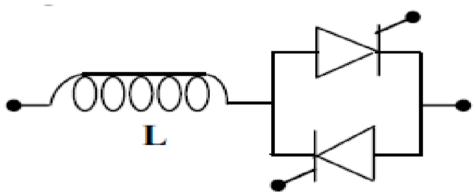

Figure.2: Equivalent circuit of TCR

Figure.3: Varies from XL to infinity

$$X_L(\alpha) = Xc\,\frac{\Pi}{\Pi - 2\alpha - Sin2\alpha} \qquad (2)$$

For the range of 0 to 90 of α, $X_L(\alpha)$ start vary from actual reactance X_L to infinity. This controlled reactor is connected across the series capacitor, so that the variable capacitive reactance (fig.4) is possible across the TCSC to modify the transmission line impedance. Effective TCSC reactance XTCSC with respect to alpha (α) is,

$$X_{TCSC} = X_C + C_1 \{2(\Pi-\alpha)\} + Sin\{2(\Pi-\alpha)\} - C_2 cos^2 (\Pi\alpha)\, [Wtan\{w(\Pi-\alpha)\}]-tan(\Pi-\alpha) \qquad (3)$$

$$Where,\ C1 = \frac{XC+XL}{\Pi}$$

$$C2 = \frac{4XL^2C}{XL\Pi}$$

$$\omega = \sqrt{XC/XL}$$

$$X_{LC} = \frac{XCXL}{XC-XL}$$

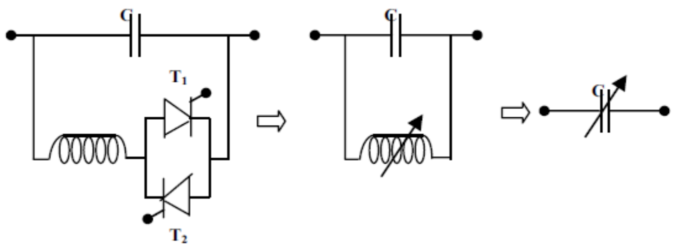

Figure.4: Equivalent circuit of TCSC

4. Simulation Model

Fig.5. Shows a simulation model for power flow and its Harmonic analysis. Analysis is done for 33kv and 66kv medium transmission system. In simulation we will check the harmonic present in the power signal with & without TCSC with the help of FFT tool in MATLAB simulink.

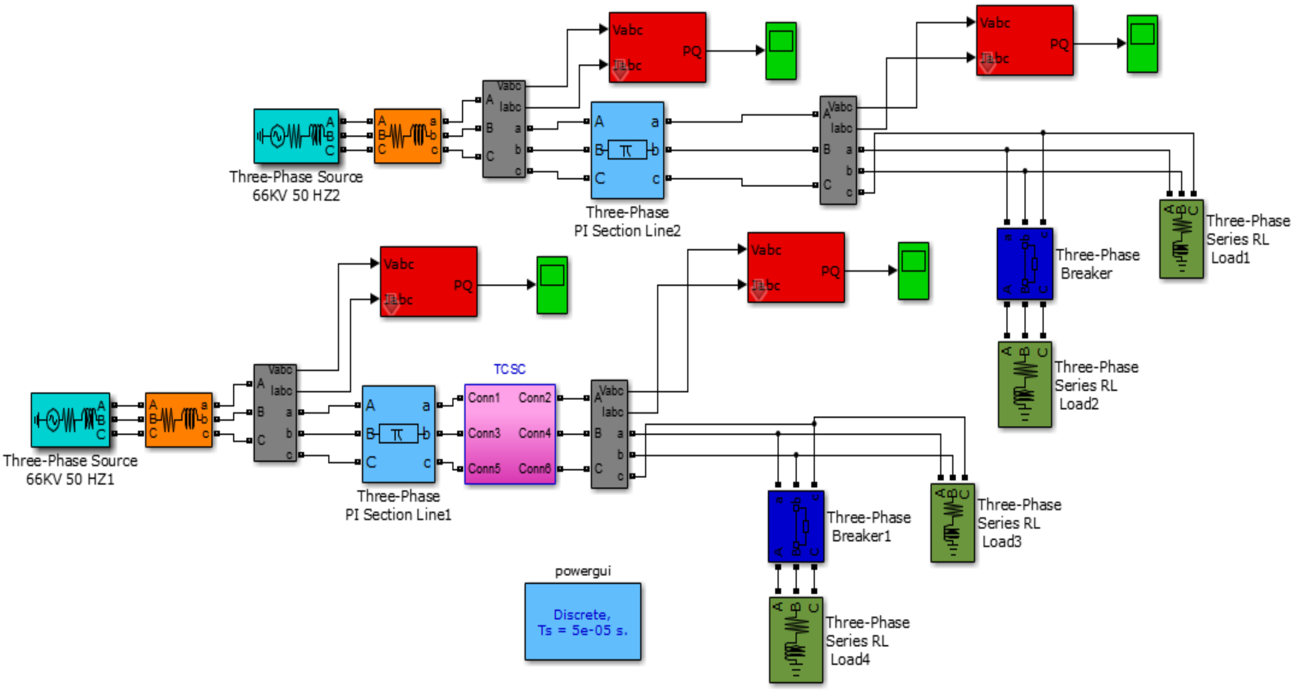

Figure.5: Simulation model without a series compensator & with series compensator (TCSC)

5. Results of Simulation

I] Fig.6 shows a Power Vs Time waveform for a 66kv medium transmission line. Pink line indicates the real power and yellow line indicates the reactive power.

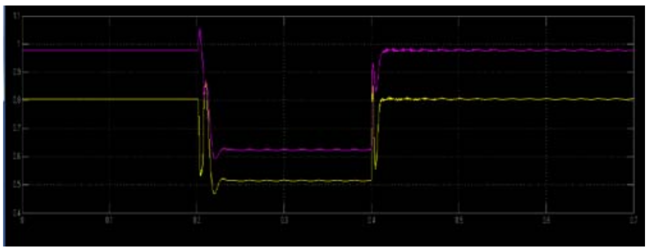

Figure.6: Power Vs Time waveform for 66kv medium line

II] Fig.7 shows a Power Vs Time waveform for a 66kv medium transmission line with series compensator TCSC.

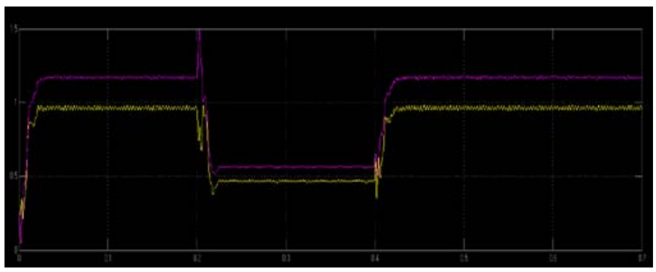

Figure.7: Power Vs Time waveform for 66kv medium line with TCSC

III] Fig.8 shows Total harmonic distortion present in the power signal for a 66kv medium transmission line.

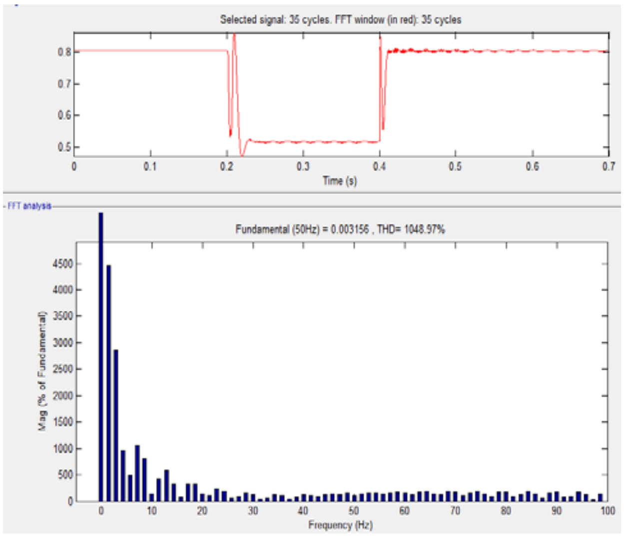

Figure.8: Total harmonic distortion present in power signal for a 66kv line

IV] Fig.9 shows a Total harmonic distortion waveform for a 66kv medium transmission line with series compensator TCSC.

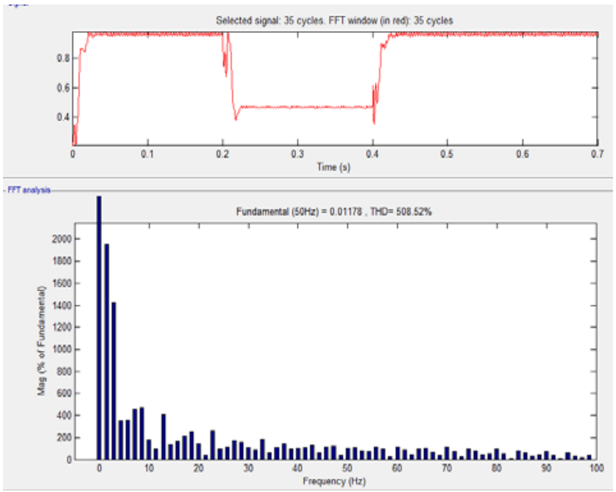

Figure.9: Total harmonic distortion present in 66kv medium line with TCSC

V] Fig.10 shows a Power Vs Time waveform for a 33kv medium transmission line

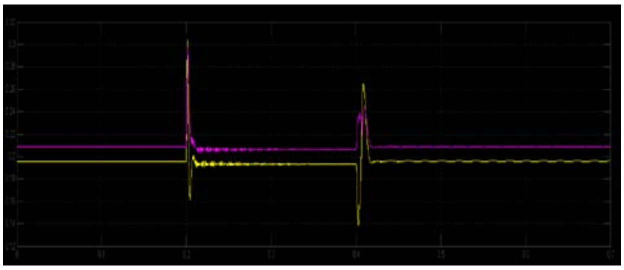

Figure.10: Power Vs Time waveform for 33kv medium line

VI] Fig.11 shows a Power Vs Time waveform for a 33kv medium transmission line with a series compensator TCSC

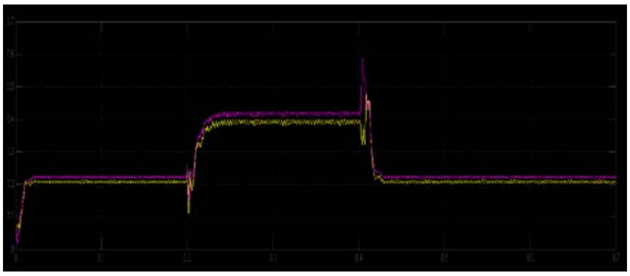

Figure.11: Power Vs Time waveform for 33kv medium line

VII] Fig.12 shows Total harmonic distortion present in the power signal for a 33kv medium transmission line.

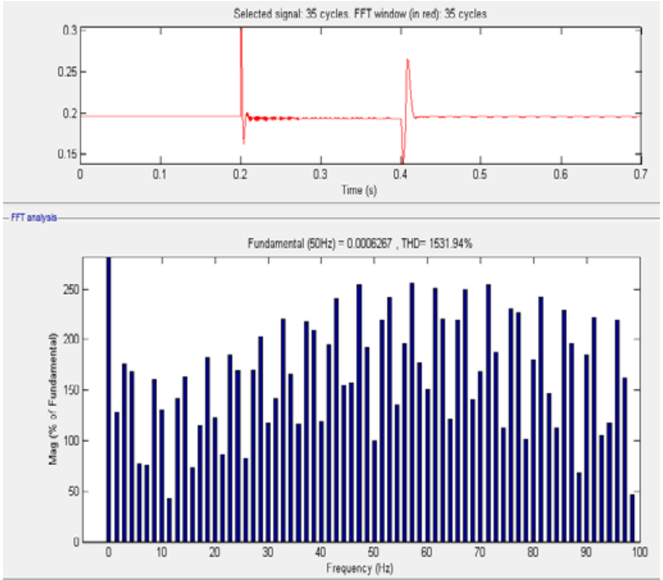

Figure.12: Total harmonic distortion present in power signal for a 33kv line

VIII] Fig.13 shows Total harmonic distortion present in the power signal for a 33kv medium transmission line with a series compensator TCSC.

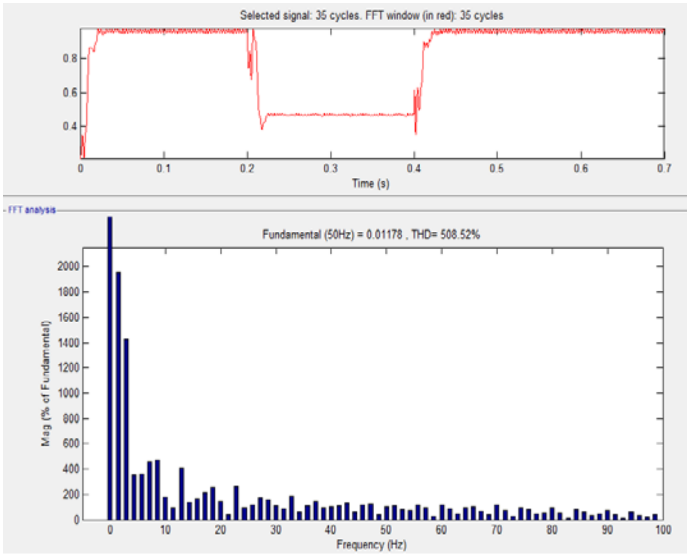

Figure.13: Total harmonic distortion present in power signal for a 33kv medium line with a series compensator TCSC

6. Conclusion

Simulation has been done for 66kv and 33kv medium transmission line for the analysis of harmonics present in the power signal. We have seen the performance of transmission line without the series compensator and with the series compensator. In the result section the power flow through the transmission line and its Harmonic analysis has been shown.

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