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Application of Fact Devices for Optimal Transmission Line Loading

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***Abstract*—The study involves identification of underutilized transmission lines in power system and with the help of FACT devices improve its loading characteristics (slightly below their thermal limit),and also study the possibility of using existing facil- ities in sub stations (shunt compensator) i.e. capacitors banks to be transformed to series compensators when needed ,by adopting proper switching methods and control. The simulation involves observing the behavior of simple double circuit transmission line having different line parameters in normal and compensated modes. The simulation is done in MATLAB.).**

Index Terms*—*Zero voltage switching (ZVS), Zero cur- rent switching, Fundamental Frequency Modulation, Thyristor Switched Series Capacitor(TSSC), Switching loss reduction, Re- active power compensation, Fast Fourier Transform (FFT).

I. INTRODUCTION

Power grids play vital role in nation development, as we are a developing nation the energy requirement always outnumber the energy availability. As energy requirement is a key factor for nations growth we can't avoid the need for expanding grid's power handling capabilities and circuit lengths to meet the rising demands across the length and breadth of the nation, as a result the grid become more and more complex often creating bottlenecks in power flow. These conditions may occur as result of simultaneous tripping of multiple numbers of transmission lines or due to change in normal grid connections to meet exigencies or due to maintenance work done in transmission lines. This results in partial power outage or in some case blackout. We can tackle this problem by expanding grids, but it is often very costly and is not preferred. During this kind of situations some transmission lines may get overloaded, some double circuit lines may undergo uneven load sharing all these factors affect the power transmission capability adversely. This study aims to find a solution to improve the line loading capability by using existing capacitor banks provided in substations and using these as TSSC when needed

The development of power electronics has led to many major advancements and breakthroughs in almost all areas of electrical engineering, and industry. FACT devices are one such advancement. Nowadays we are using FACT (flexible AC transmission) devices for many power transmission ap- plications, due its capability in solving many complicated issues in power systems such as [1] stability, harmonics, distributed generation, wind energy integration etc. Even though there are conventional methods for solving some of the issues

,these methods efficiency compared with FACT devices are very low. In this study we are considering a transmission line loading problem occurring due to variation in line pa- rameters over different circuit length .conventional methods to tackle this uneven loading problem is to vary the line parameter[2],introduce regulating transformers [3] etc. The transmission lines uneven loading is a serious issue, leading to power outage, excess thermal stress of existing lines in turn leading towards damage of conductors ,in severe cases partial blackout also occurs .our attempt is find a solution to this problem by using existing devices in substations along with static switches .after identifying the lines that are loaded unevenly at the feeding substation end we can introduce our FACT device and modify the power flow as required .as we know substations are equipped with capacitor banks for power factor correction and voltage profile improvement. We can utilize these capacitor strings as compensating device when needed. We are actually turning this capacitor s as TSSC (thyristor switched series capacitor) FACT device and using them as a series compensator.

II. APPLICATION OF FACT DEVICE FOR OPTIMAL TRANSMISSION LINE LOADING

By using TSSC(Thyristor switched series capacitor) we are actually offsetting lines inductive reactance thereby reduc- ing overall line impedance. The variation inline parameters is a function of conductor length. The line parameters are Resistance, Inductance and Capacitance. These variables have fixed value rated as resistance/inductance/capacitance per unit length for a particular conductor. Depending on the excitation voltage levels and power handling capability we choose our conductor. Once we choose the conductor the parameter are known and is a function of length. All these parameters are proportional to length.

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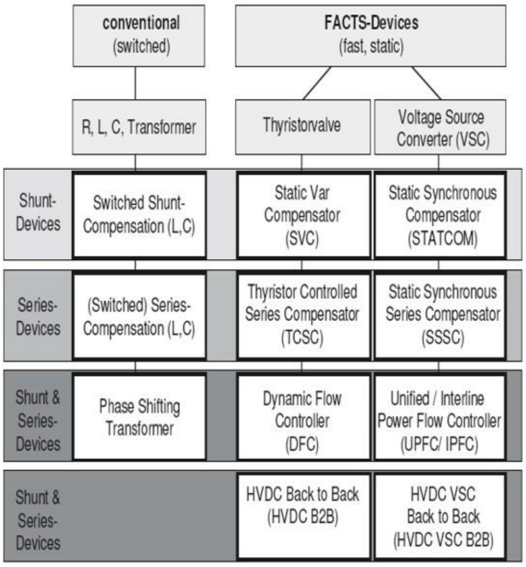

Fig. 1. Overview of major fact devices.

Usually power lines are double circuit lines, single circuit and multi circuit lines are also possible .here we are con- sidering a double circuit line with different circuit lengths and line is modelled as series lumped resistance and reactance .the shunt effect is neglected, so our line variables are inductance and resistance.

A. FACT DEVICES OVERVIEW

The development of FACTS-devices has started with the growing capabilities of power electronic components. Devices for high power levels have been made available in converters for high and even highest voltage levels. The overall starting points are network elements influencing the reactive power or the impedance of a part of the power system. For the FACTS side the taxonomy in terms of 'dynamic' and 'static' needs some explanation [4]. The term 'dynamic' is used to express the fast controllability of FACTS-devices provided by the power electronics. This is one of the main differentiation factors from the conventional devices. The term 'static' means that the devices have no moving parts like mechanical switches to perform the dynamic controllability. Therefore most of the FACTS-devices can equally be static and dynamic. The left column in Figure contains the conventional devices build out affixed or mechanically switchable components like resis- tance, inductance or capacitance together with transformers. The FACTS-devices contain these elements as well but use additional power electronic valves or converters to switch the elements in smaller steps or with switching patterns within a cycle of the alternating current. The left column of FACTS- devices uses thyristor valves or converters. These valves or converters are well known since several years.

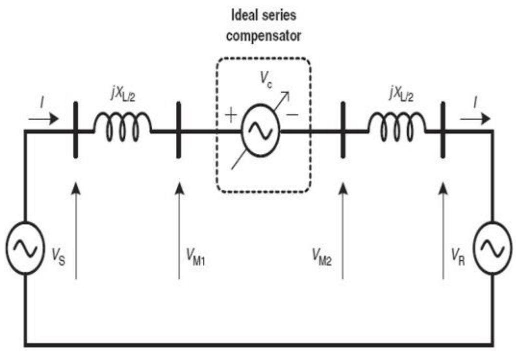

Fig. 2. Ideal series compensator connected in the middle of transmission line

B. APPLICATIONS OF FACT DEVICES AND COMPENSA- TION METHODS

Flexible AC Transmission Systems, called FACTS, got in the recent years a well known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice. Even more concepts of configurations of FACTS-devices are discussed in research and literature. In most of the applications the controllability [5] is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines. FACTS-devices provide a better adaptation to varying operational conditions and improve the usage of existing installations.

The basic applications of FACTS-devices are: Power flow control, Increase of transmission capability, Voltage control, Reactive power compensation, Stability improvement, Power quality improvement, Power conditioning, Flicker mitigation, Interconnection of renewable and distributed generation and storages.

In all applications the practical requirements, needs and benefits have to be considered carefully to justify the invest- ment into a complex new device. The usage of lines for active power transmission should be ideally up to the thermal limits. Voltage and stability limits shall be shifted with the means of the several different FACTS devices. It can be seen that with growing line length, the opportunity for FACTS devices gets more and more important. The influence of FACTS-devices is achieved through switched or controlled shunt compensation, series compensation or phase shift control. The devices work electrically as fast current, voltage or impedance controllers. The power electronic allows very short reaction times down to far below one second.

The ideal series compensator [6] is modeled by a voltage source for which the phasor is VC, connected in the middle of a lossless transmission line .The current flowing through the transmission line is given by: $I = (V_S R - V_C)/j\, X_L$

$V_S R = V_S R - V_R$.

If the ideal series compensator voltage is generated in

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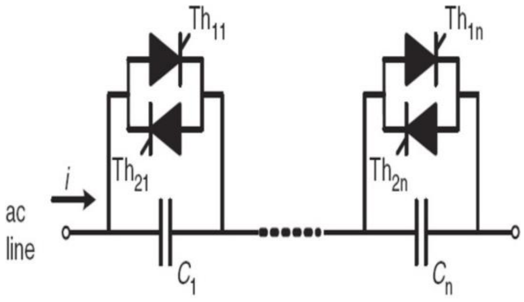

Fig. 3. TSSC Implementation and Performance analysis.

such a way that its phasor V_C is in quadrature with line current I, this series compensator does not supply neither absorb active power. As previously discussed, power at the series source is only reactive and the voltage source may, in this particular case, be replaced by capacitive or inductive equivalent impedance. The equivalent impedance would then given by

$X_{eq} = X_L(1 + s)$

where, s = X_Comp/X_L (0≤ s≤1)

is the compensation factor and XComp is the series equivalent compensation reactance, negative if capacitive and posi- tive if inductive. In this case the compensation voltage is given by $V_C = I_L$Xeq

And the transmitted power is equal to Ps = $V^2/X_L(1\text{-}s)\sin\delta$

Equation shows that the transmitted power can be considerably increased by series compensation, choosing a proper compensation factor s. The reactive power at the series source is given by

$Q_{cs} = 2v^2/X_1\ [s/(1\text{-}s)2(1\text{-}\cos\delta)]$

C. TSSC IMPLEMENTATION AND PERFORMANCE ANAL- YSIS

Figure 3 shows the thyristor-switched series capacitor (TSSC). In this device, the thyristors should be kept Untriggered so as to connect the capacitors in series with the transmission line [7]. If the thyristors are turned-on, the capacitor is bypassed. Thyristors turn-on must be at a zero-voltage condition (ZVS), as it occurs in the case of the TSC, to avoid current spikes in the switches. An example of an application based on this concept is presented in. This compensation system has the advantage of being very simple. However, it does not allow continuous control. If the connection/disconnection of the capacitors is to be made at sporadic switching, no harmonic problem occurs. Depending on the frequency the thyristors are switched, harmonic or sub harmonics may appear. In this arrangement, it is interesting to choose the value of the capacitors in such a way that many different combinations can be achieved [8].

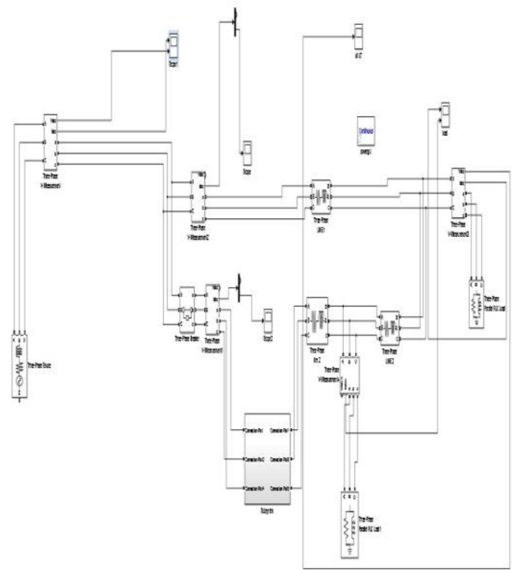

Fig. 4. TSSC Simulation diagram

III. SIMULATION MODELS AND RESULTS

A. SIMULATION PARAMETERS

The simulation parameters using in Figure 4 is given below. It consists of the behavior of compensated and uncompensated lines. This simulation basically consists of two transmission lines. One with TSSC and other without TSSC.

Source voltage: 100Kv

Line 1(compensated): 6.25uH*20K=125mH, 39.26ohm

Line 2: 6.25uH*10K=62.5mH, 19.6ohm

Capacitance: 70uF, Xc=45.47ohm Load 1: 50MW

Load 2: 3MW

The TSSC subsystem is represented in figure 5.And its simulation parameters are given below.

Pulse generator Ts=5s, 50 percentage, duty ratio, 2.5ms delay.

The basic objective of this simulation is to demonstrate the effectiveness of the compensation technique that we dis- cussed in this simulation. A double circuit transmission line with a source and some loads(as specified in the above parameter section).These are used to demonstrate the com- pensation technique. The transmission lines are modelled as RL branch neglecting the effect of shunt capacitance and the equivalent impedance is made higher for one line and lower for other, in order to incorporate the effect of length over impedance of the line. The line with higher impedance is incorporated with our TSSC block to provide compensation as required. Measurements are provide for currents in both lines and a trigger is provided for the TSSC block. Which helps to engage the TSSC block as required. The effect on power delivered by each transmission is observed with and without

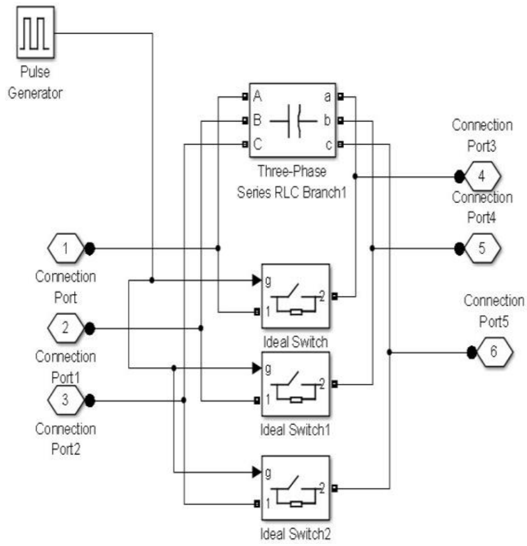

Fig. 5. TSSC Subsystem.

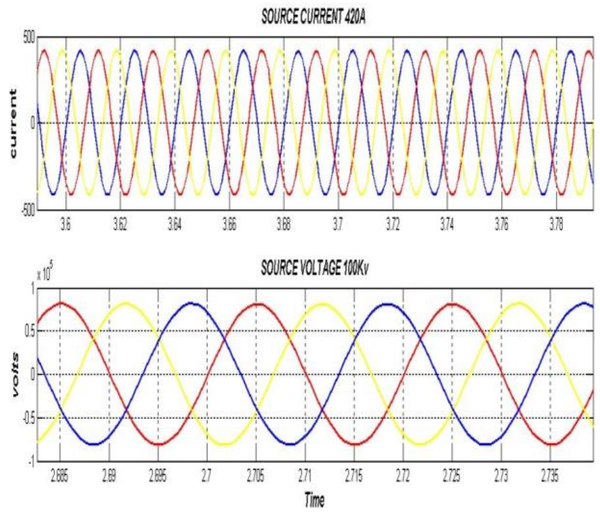

Fig. 6. Source current and source voltage for the overall TSSC system.

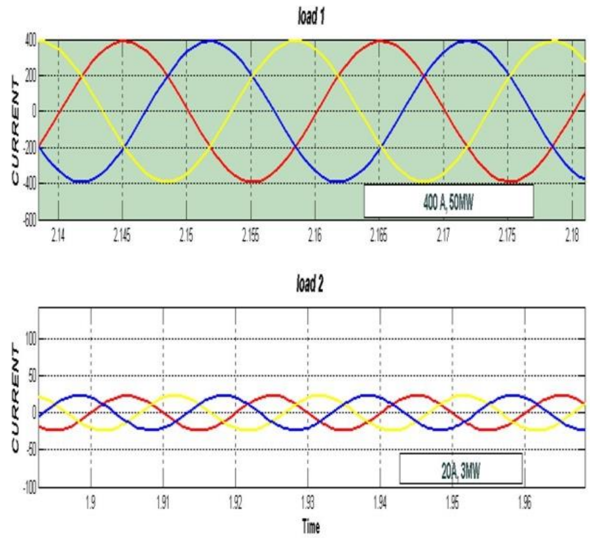

Fig. 7. Loads representation of overall TSSC system.

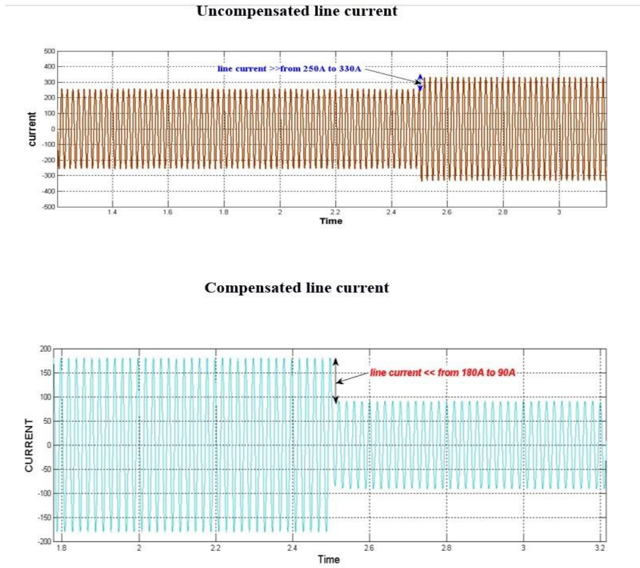

Fig. 8. Uncompensated and compensated line currents

compensation, and simulation is done for various performance parameters.

IV. CONCLUSION

From our simulation model it is observed that the line current in compensated line increased about 50 percentage. Thus relieving the adjacent line current by about 24 percent- age. From power system point of view now the compensated system as whole can handle more power without over loading individual lines. From the simulation it is clear that using TSSC partially offsets the inductive reactance and improves line loading characteristics thereby enabling the power transfer more efficiently.

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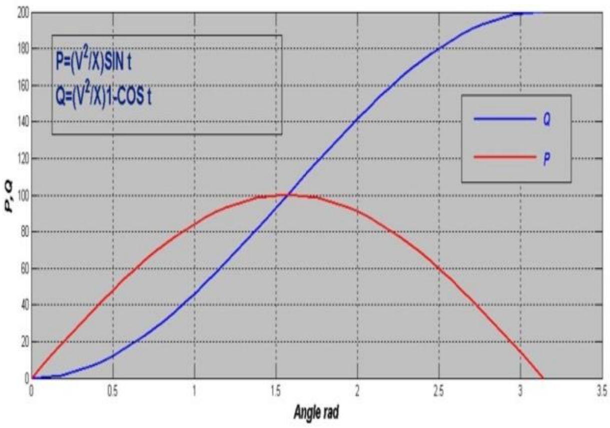

Fig. 9. Powerflow without compensation

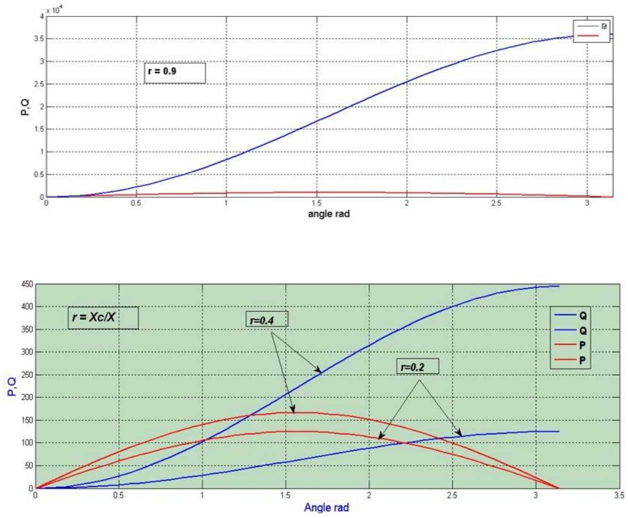

Fig. 10. Powerflow with compensation for various compensation ratio r

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