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Series Compensated Long Transmission Line Connected with a Shunt FACT Device by Optimal Placement

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Abstract: *This paper focuses on where Shunt FACTS devices should be placed for high power transfer levels in order to control transmissionvoltage, power flow, reduce reactive losses, and dampen oscillations in the power system. The ideal location for a shunt FACT device on an actual line model of a transmission line with series compensation at the centre is examined in this research. Unifiedpower flow controller (UPFC) Impact of change in degree of series compensation on the best location of the shunt FACTS deviceto gain the most advantage is examined as one of the most promising FACTS devices in terms of its ability to control power system quantities. The findings obtained by utilizing MATLAB/SIMULINK demonstrated that the best location for the shunt FACTS device changes when the level of series compensation is changed.*

Keywords: Optimal placement, Shunt FACTS, Series compensation, Unified power flow controller (UPFC)

I. INTRODUCTION

Throughout the past two decades, the flexible AC transmission system (FACTS) has drawn a lot of interest. To manage the voltage, power flow, and other parameters, high current power electronic devices are a transmission system's stability, among other things. Fundamentally, FACTS technologies are highly engineered power-electronics-based systems that integrate the control and operation of advanced power-semiconductor-based converters (or valves) with software-based information and control systems to produce a compensated response to the transmission network that is connected by conventional switchgear and transformation equipment. A transmission line can be connected to by FACTS devices in a number of ways, including in series (series compensation), shunt (shunt compensation), or both in series and shunt. Examples include the static VAR compensator (SVC) and static synchronous compensator (STATCOM), which are connected in shunt; the static synchronous series compensator (SSSC) and thyristor-controlled series capacitor (TCSC), which are connected in series; and the thyristor-controlledphase shifting transformer (TCPST) and unified power flow controller (UPFC), which are connected in a series and shunt configuration. The FACTS is connected to the electrical system in series for series compensation. It functions as a source of variable voltage. Long transmission lines can develop series inductance when a significant current flow results in a significant voltage drop. Series capacitors are connected as a compensation. Power system and the FACTS are coupled in a shunt during shunt compensation. It functions as a source of manageable current. Power providers are under pressure to fulfil future demand by fully utilizing the resources of existing transmission networks rather than constructing new lines due to economic and environmental constraints. As long as thermal constraints allow, FACTS devices are very efficient and can increase a line's capacity for power transfer while keeping the same level of stability. FACTS has been used in numerous contemporary applications that have shown to be economical, long-term fixes. The development of the Flexible AC Transmission System (FACTS) and the advancements in the current and voltage handling capabilities of power electronic devices have opened up the option of using several controller types for effective shunt and series compensation. broad-based FACTS application for both local and. For high power transfer levels, shunt FACTS devices are utilized to control transmission voltage, power flow, reduce reactive losses, and dampen power system oscillations. With the installation of FACTS controllers being widely and actively considered for greater controllability

1.1 There are two types of shunt compensation

Compensation for shunt capacitive: The power factor is improved with this technique. Power factor lags whenever an inductive load is connected to the transmission line due to lagging load current. A shunt capacitor that pulls current ahead of the source voltage is attached as compensation. Shunt inductive compensation: This technique is employed either while the transmission lineis being charged or when the receiving end's load is extremely low. Very little current travels across the transmission line since there is little to no load. Voltage amplification in the transmission line is brought on by shunt capacitance (Ferranti Effect). When using extremely long transmission lines, the receiving end voltage may sometimes quadruple that of the sending end. To make up for this, in the case of a no-loss line, the magnitude of the voltage at the receiving end is equal to the magnitude at the sending end: VS = VR=V.

Shunt inductors are linked across the transmission lines to create a phase lag that is dependent on line reactance X. series compensation level. To achieve the highest power transfer and compensation efficiency for the chosen rating of the shunt FACTS device, a series capacitor is positioned in the middle of the device. To achieve the most benefit from maximum power transfer and stability under steady state conditions, the shunt FACTS device is operated at that rating that can manage the bus voltage of the shunt FACTS device equal to transmitting end voltage. The proper positioning of these devices in power systems is becoming more crucial. Improperly placed FACTS controllers fail to deliver the optimum performance and can possibly be counterproductive. Thus, it is important to consider how these devices should be placed. In order to maximize power transfer and system stability, this study analyses the best place for a shunt FACTS device in a series compensated transmission line. A shunt FACT device's rating is chosen in a way that controls the voltage equal to the transmitting end voltage at the device's bus. It has been noted that the best spot for a shunt FACT device moves away from the line's center and towards the generator side.

II. TRANSMISSION LINE MODEL

The transmission line parameters are assumed to be evenly distributed in this study, and the line can be described by a 2-port, 4-terminal network as illustrated in Figure 1. The exact line model is seen in this figure. The line's sending end (SE) and receivingend (RE) quantities can be expressed as follows:

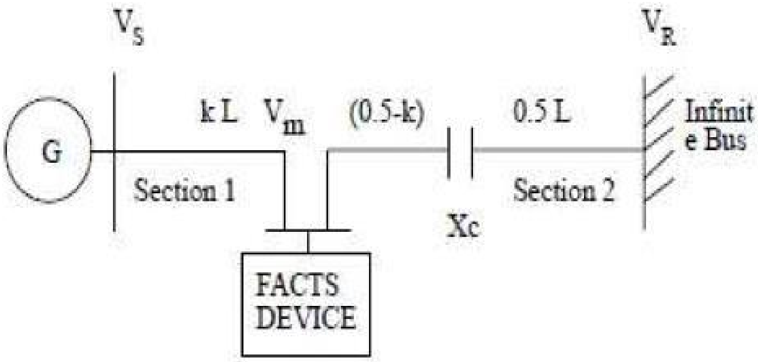

Fig 1. 2-Port, 4-terminal model of a transmission line

It is obvious that as the angle becomes, the RE power achieves its maximum value. Yet, at = ( ), the SE power PS of reaches its maximum. This analysis takes into account a 450 km long 345 kV single circuit transmission line. It is assumed that each phase of the line comprises a bundle of two conductors that are fully transposed and have a diameter of one million c-millimeters apiece.At 50 Hz, it is discovered that the line's series impedance and shunt admittance are Z = (0.02986 + j0.2849) /km and y = j3.989 106 S/km, respectively. The PSCAD/EMTDC software suite is used to obtain the parameters. The line's data are displayed in p.u.on a 100 MVA, 345 kV.

III. SERIES COMPENSATED TRANSMISSION LINE WITH SHUNT FACTS DEVICES

Imagine a line that is used to transport energy from a sizable producing station to an endless bus and is fitted with a shunt FACTdevice at point m. The percentage of the line length at which the FACTS device is positioned is displayed by the parameter k. Theshunt FACTS device, which is often connected to the line by a step-down transformer, may be an SVC or STATCOM. The transmission line is divided into two portions, sections 1 and 2, and sections 2 are further

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divided into length-based subsections, (0.5-k) and half-line length. Taking into account the actual line model, each section is represented by a distinct 2-port, 4-terminalnetwork with its own ABCD constants.

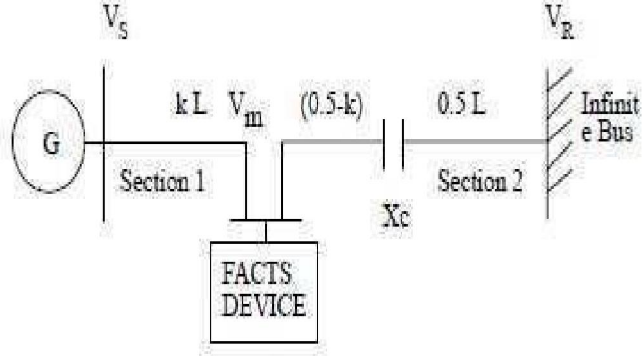

Fig 2. Series compensated transmission line with a shunt FACT device.

It is assumed that the shunt FACTS device's rating is sufficient to provide the reactive power necessary to keep the magnitude ofthe voltage at bus m constant, and that the device neither consumes nor supplies any active power.

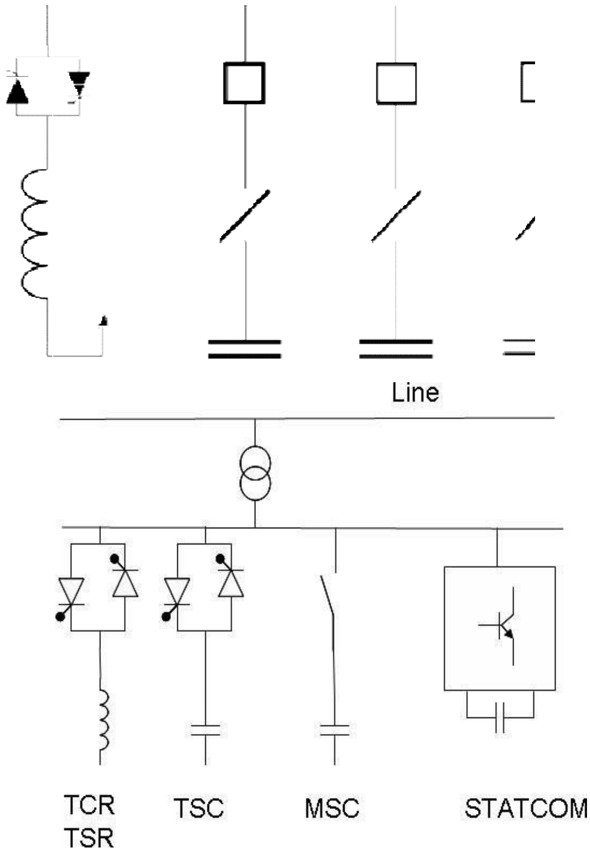

Fig 3. Examples of FACTS for shunt compensation

IV. MAXIMUM POWER TRANSFER CAPABILITY

For a simplified model, the maximum power transfer across the line is stated when there isn't a FACTS device connected to the line. Several researches have determined that, in the absence of series compensation in the line, K= 0.5 is the ideal placement for the shunt FACTS device in a simplified model. Such situations result in a doubling of the maximum power transmission capability(Pm) and the maximum transmission angle (m). Finding the maximum power and associated position of the shunt FACTS devicefor various series compensation levels (%S) at the line's center is one of the goals of this work. To determine the various properties of the system using a real model of the line sections, a sophisticated computer programme was created. The problem incorporatesthe constant of the same RE power of section (1) and SE power of section (2) (PR1 = PS2). Unless otherwise stated, VS = VR =VM = 1.0 p.u. For different values of location, the maximum power Pm and related angle m are already computed (K).

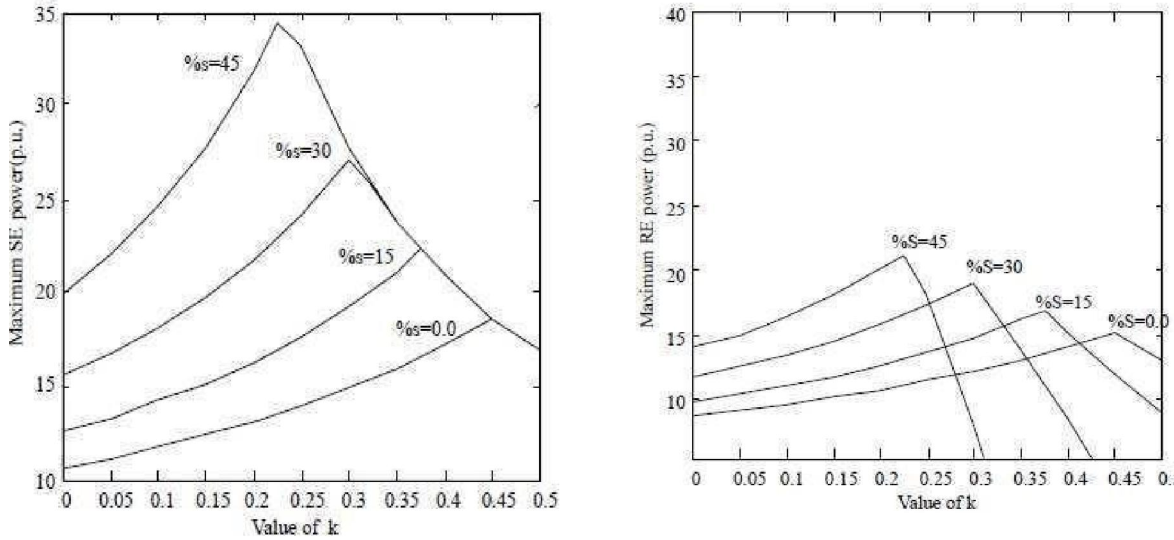

Fig 4. Variation in maximum RE power and SE power for diff. value of %S.

Transmission angle (m) at maximum sending end power. The ideal location of the shunt FACTS device shifts towards the generator side when series compensation in the line is taken into consideration. Figures 4 and 5 show that when S = 15, PS m rises from 12.5 p.u. (at K = 0) to its highest point of 22 p.u. (at K = 0.375). K is farther That implies that if the series compensation level varies, the best place for the shunt device to be placed will change for maximum power transfer capabilities.

As PS m rises from 15.2 p.u. (at K = 0) to its highest value of 26.8 p.u. (at K = 0.3), the best location further moves to the generatorside when%S = 30. can be seen in Figure 3 for various amounts of series compensation. Figure 4 shows that the angle at the maximum SE power grows from 95.8° at K = 0 to its maximum value 171.1° at K = 0.45 in the absence of series correction (%S

= 0). With %S = 15, m grows as K grows and reaches its maximum value of 180.5o at K = 0.375. When%S = 30, m increases asK increases and reaches its maximum value at K = 0.3, but for %S = 45, it is at K = 0.225, which is 188o. The system becomes more stable and the best place for the shunt FACTS device changes as the degree of series compensation level (%S) grows.

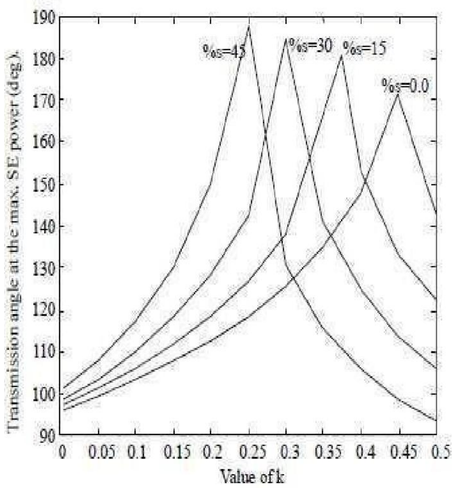

Fig 5. Variation in transmission angle at the max. SE power for diff. %S.

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V. OPTIMAL LOCATION OF SHUNT FACTS DEVICES

For various series compensation levels (%S), Figure 4 depicts the variation of the maximum RE power of Section 1 (PR1m) andthe maximum SE power of Section 2 (PS2m) against the value of K. As observed in Figure 4, the maximum power curves for anuncompensated line intersect at K = 0.45, which is also the transition point.

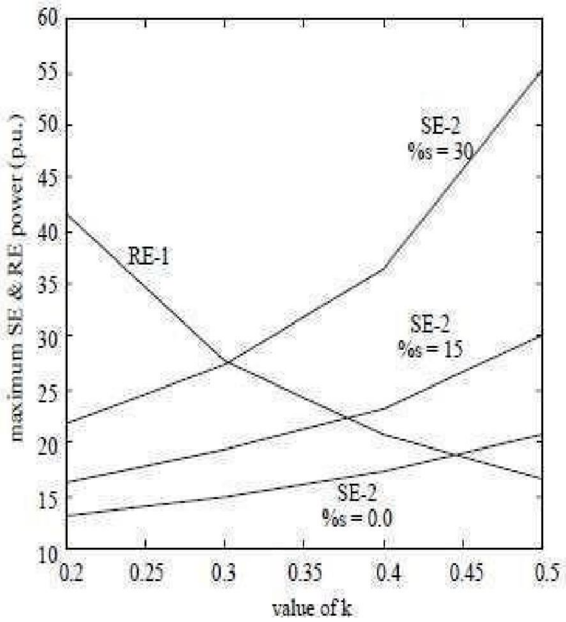

Fig 6. Variation in the maximum RE power of section-1 and SE power of section-2 against k for diff. value of %S

Hence, the shunt FACTS device must be positioned at K = 0.45, which is somewhat off-center, in order to achieve the optimum benefit in terms of maximum power transfer capability and system stability. The maximum power curves cross at K = 0.375 for %S = 15 when the series compensation level is taken into consideration, increasing the maximum power transfer capability. Thisindicates that as the series compensation level (%S) is raised, the generator side becomes the preferred site for the shunt device.

Similar to how the best placement is at K = 0.3 for %S = 30 and K = 0.25 for %S = 45. Figure 5 depicts the variation in the shuntFACTS device's ideal off center placement in relation to the degree of series compensation level (%S) for the specified R/X ratioof the line. Figure 5 shows that 10% off-center is the ideal location for the uncompensated line. The best off-center location growslinearly as series compensation level (%S) is raised, peaking at 55% for %S = 45. The series and shunt branches must have the appropriate power rating in order for the UPFC to operate. The rating must let the UPFC to accomplish the predetermined powerflow objective.

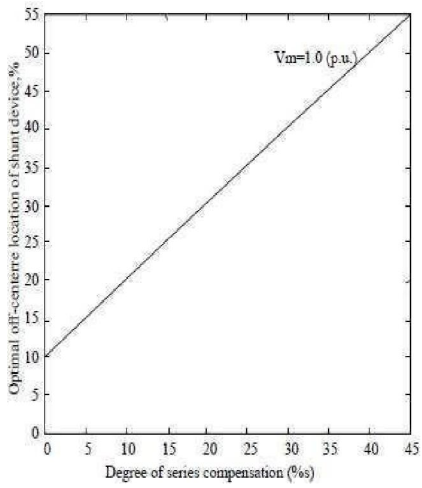

Fig 7. Variation in the optimal off-center location of shunt FACTS device against degree of compensation of line(%S).

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VI. CONCLUSION

This paper investigates the effect of series compensation on the optimal location of a shunt FACTS. maximum power transfer andstability of the system. For an actual line model of a series adjusted 345 kV, 450 km line, various outcomes were discovered. Asopposed to what many studies claimed in the case of uncompensated lines, it has been discovered that the ideal location of the shunt FACTS device changes depending on the degree of series compensation. The degree of series compensation determines thedivergence of the shunt FACT device's ideal location from the transmission line's centre point, and it rises roughly linearly from there. As the degree of series compensation (%S) is raised, the deviation of the shunt FACT device's ideal location from the transmission line's centre point grows practically linearly from the transmission line's centre point to the generator side. If the shunt FACTS device is installed at the new ideal location rather than near the middle of the line, both the system's ability to transfer power and its stability can be enhanced significantly more. The potential for SVC and STATCOM controllers to increase power system stability has been studied. Although both devices can increase the system's damping, studies have shown that STATCOM is much more effective in enhancing system performance. where system voltages are very much depressed. Also, because of its fast response time, STATCOM control is superior to that of SVC.

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