Series FACTS Controller Based Power Transfer Capability Improvement

Pragati P. Vairagade[1] Chandrakala R. Gowder[2] D.B.Waghmare[3]
[1]PG Scholar [2,3]Assistant Professor
[1,2,3]Shri Sai College of Engineering & Technology, Bhadrawati, India

Abstract— Traditionally, electrical system operators have sent generation to attenuate total production prices, ignoring the pliability of the gear mechanism. Implementation of smart-grid systems may enable operators to co-optimize versatile transmission aboard generation dispatch; the technologies that may modify such co-optimization ar still regulated as a part of the monopoly gear mechanism. One explicit versatile transmission quality is variable electrical phenomenon versatile AC gear mechanism (FACTS). this idea 1) points out the positive spatial relation drawback existing in an exceedingly recent market style proposal with active transmission participation, and 2) proposes a sensitivity based mostly technique to estimate the marginal market price of FACTS changes to beat this positive spatial relation drawback. The marginal worth would counsel economical electrical phenomenon changes to the operator and supply the proper monetary incentives for the FACTS homeowners to control their assets in an exceedingly socially optimum method. The projected model style exploitation MATLAB Simulink 2013 computer code. within which series FACTS controller like SSSC and TCSC style supported variable load or supported market demand behavior for improve the facility transfer capability of power grid.

Key words: FACTS, Power Transfer Capability

I. INTRODUCTION

The annual revenue of the U.S.A. electricity trade is over 350 billion bucks [1] and plays a important role within the U.S.A. economy. there's broad recognition of the system worth of required transmission upgrades to lower prices and maintain dependableness [2], [3] though the upgrade method is dear and long. Even when restructuring within the U.S.A., the transmission sector has maintained a high degree of regulation, with payments to regulated transmission house owners reflective undetermined ratemaking instead of essentially reflective system worth.

FERC order a thousand suggests considering non-transmission alternatives in transmission coming up with comes [4]. The implementation of the “smart grid” might modify the preparation of versatile and adaptational transmission networks (e.g. topology management through switchable branches or adjustable impedance), therefore allowing transmission assets to be co-optimized dynamically,\ supported the state of the system, with the generation dispatch. Previous analysis has shown that transmission switch (TS) will improve the system dependableness [5]-[6], cut back the system value [7]-[11], and facilitate higher levels of renewable injection [12]. Continuous management of lines’ resistivity targets an equivalent goals with higher management coarseness.

One technology that might permit such management is versatile AC transmission (FACTS) [13], [14]. Current technology permits for important adjustment of a line’s resistivity [15] even to the purpose that associate degree inductive line might become electrical phenomenon. FACTS devices effectively act as analogies to pumps in water systems, providing flow management [16]. whereas FACTS devices are obtainable for several years, new communication and management technologies yet as economical machine algorithms offered by the good grid create versatile transmission improvement a break.

FACTS devices may be seen as a non-transmission different aligned with FERC order one thousand. A recent United States of America Department of Energy study acknowledges the advantages of FACTS devices and their role within the way forward for the gear for improved operation of the grid [2]. With additional flow management, transfer capability may well be hyperbolic on existing lines to boost deliverability from cheap resources like renewable [17]-[21]. Previous analysis suggests that FACTS will considerably increase the transfer capability over this transmission lines [22].

FACTS devices square measure already a vicinity of the transmission network in North America et al. ISO-NE has 13 put in and 3 planned FACTS in its territory [23]. 5 EPRI-sponsored FACTS devices square measure presently operative in AEP region in KY, BPA in Oregon, CSW in TX, TVA in Tennessee, and genus Nipa in ny [24]. Grid and project in PJM involves installation of many FACTS devices. The project aims at increasing the transfer capability from west to east, reducing congestion, and rising system stability [25]

Among the various forms of FACTS devices, the subsequent square measure notable for capability in power flow control: thyristor protected series compensator (TPSC), thyristor controlled series compensator (TCSC), and unified power flow management (UPFC). These devices have an effect on resistivity, voltage magnitude and angle [26]. Here the term “FACTS” refers broadly speaking to a family of devices that square measure capable of considerably adjusting the resistivity of the lines. A vital feature of FACTS devices may be a dynamically manageable point. The dynamic controllability is already being utilised for dynamic stability applications [26]. Whereas the power of FACTS devices to boost transfer capability is well-recognized, FACTS set points for this application don't seem to be adjusted often. For instance, ISO-NE uses the dynamic setting of FACTS devices for stability functions in closed management loops [27], however the set points don't seem to be modified typically as a result of the requirement for the sweetening of transfer capability. This underutilization of the present assets is as a result of the dearth of economic incentives also as economical modules at intervals energy and market management systems for handling FACTS flexibility [28]-[29]. associate degree economical technique for identification of the worth of those devices would address each of the mentioned shortcomings. Additionally, FACTS devices square measure regulated equally to alternative transmission assets. Once they're designed the owner receives a regulated rate of come, that we have a tendency to argue doesn't give incentives for operation of the devices in a very means that maximizes system profit. In fact, it's against the owner's interest to alter the point a lot of often to avoid extra stress on the device and better maintenance prices. a more robust compensation mechanism, like a market-based value signal [30], will facilitate reaching a lot of economical operational state.

II. PROPOSED METHODOLOGY

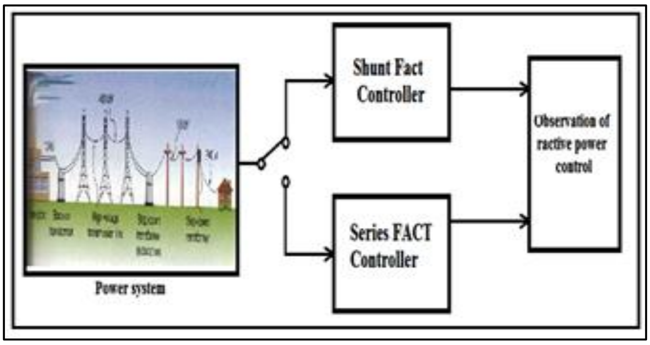

Fig. 1: Generalized block diagram of proposed approach

Figure 1 shows the generalized block diagram of proposed approach. The block diagram consists of electrical power system (generator, transmission line, transformer etc), FACT controller (Series, shunt and series-shunt) and scope for observing the results of system.

Power maintaining the power quality of power system and transient response of power system during power system overloading or under loading condition that means depend on power system load. For improvement of power system transient and response we connect the FACTS controller like TCSC and SSSC in power system for achieving desired goal.

That FACTS controller design using MATLAB 2013b software and power system performance analyzed for different types of loading conditions and observed the performance of system parameters and reactive power, response time of FACTS controller, FACTS controller controlling parameters etc in display provided in simulation model.

In power system model we analyzed the system by simulating the different loading conditions and fault conditions based on reference data set. This different conditions simulated by simply changing the parameters of each blocks of power system or load block of power system then after successful data simulation we run the model. Hence we analyzed the transfer capability of power system with and without FACTS controller.

III. SIMULATION MODEL

A. TCSC Model

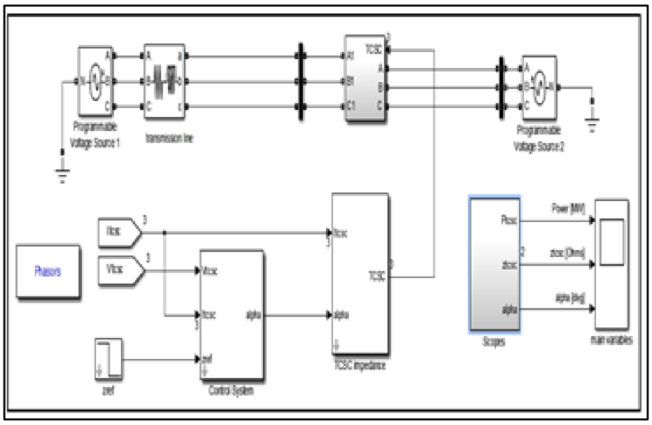

Fig. 2: Complete MATLAB simulation for TCSC coupled power system

The phasor model but uses the equivalent impedances at the basic frequency, neglecting all transients, and thus it's not as correct because the thyristor model. notwithstanding, the phasor model is far easier and also the speed of simulation is accumulated. Some little discrepancies square measure caused by the thyristor resistance and alternative TCSC losses that aren't enclosed within the phasor model.

A TCSC is placed on a 500kV, long cable, to boost power transfer. While not the TCSC the ability transfer is around 110MW, as seen throughout the primary zero.5s of the simulation once the TCSC is bypassed. The TCSC is sculptural as a voltage supply mistreatment equivalent resistance at fundamental frequency in every section. The nominal compensation is seventy fifth, i.e. assumptive solely the capacitors (firing angle of 90deg). The natural oscillating frequency of the TCSC is 163Hz, which is 2.7 times the elemental frequency.

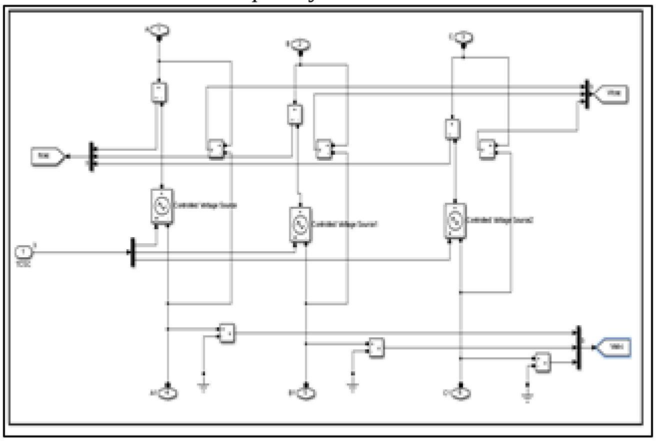

Fig. 3: TCSC subsystem for TCSC based phasor power system model

The TCSC will operate in electrical phenomenon or inductive mode, though the latter is never utilized in follow. Since the resonance for this TCSC is around 58deg firing angle, the operation is prohibited in firing angle vary 49deg - 69deg. Note that the resonance for the system (when the road resistance is included) is around 67deg. The electrical phenomenon mode is achieved with firing angles 69-90deg. The resistance is lowest at 90deg, and thus power transfer will increase because the firing angle is reduced. In electrical phenomenon mode the vary for resistance values is or so 120-136 Ohm. This vary corresponds to or so 490-830MW power transfer vary (100%-110% compensation). Examination with the ability transfer of MW with an unpaid line, TCSC permits important improvement in power transfer level.

Sr. No.	Name of simulation block	Parameter specification
1.	Three phase programmable voltage source 1	Phase to phase rms voltage = 539 KV Frequency = 60Hz; Amplitude = 1.0 at 0 sec, 0.96 at 3.3 sec and 1.0 at 3.8 sec.
2.	Transmission line (series RLC branch)	R = 6.0852 Ohm, Inductance L = 0.4323 H.
3.	Three phase programmable voltage source 2	Phase to phase rms voltage = 477 KV Frequency = 60Hz; Amplitude = 1.0 at 0 sec.

Table 1: Parameters Used For Simulation

To change the operative mode (inductive/capacitive/manual) use the on/off switch within the management block dialog. The inductive mode corresponds to the firing angles 0-49deg, and therefore the lowest ohmic resistance is at 0deg. within the inductive operative mode, the vary of impedances is 19-60 Ohm, that corresponds to 100-85 MW vary of power transfer level. The inductive mode reduces power transfer over the road. a continuing firing angle may be applied and therefore the same limits was apply.

When TCSC operates within the constant ohmic resistance mode it uses voltage and current feedback for scheming the TCSC ohmic resistance. The reference ohmic resistance indirectly determines the ability level, though AN automatic power management mode may even be introduced.

B. SSSC Model

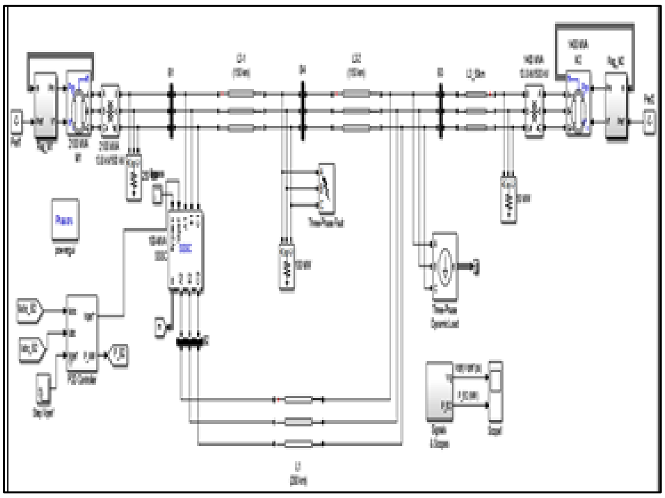

Fig. 4: Complete MATLAB simulation model of SSSC coupled power system

The Static Synchronous Series Compensator (SSSC), one in every of the key FACTS devices, consists of a voltage-sourced device and a electrical device connected nonparallel with a conductor. The SSSC injects a voltage of variable magnitude in construction with the road current, thereby emulating AN inductive or electrical phenomenon electrical phenomenon. This emulated variable electrical phenomenon nonparallel with the road will then influence the transmitted power. The SSSC is employed to damp power oscillation on an influence grid following a three-phase fault.

The power grid consists of 2 power generation substations and one major load center at bus B3. the primary power generation station (M1) features a rating of 2100 MVA, representing half dozen machines of 350 MVA and also the alternative one (M2) features a rating of 1400 MVA, representing four machines of 350 MVA. The load center of roughly 2200 MW is sculptured employing a dynamic load model wherever the active & reactive power absorbed by the load may be operate of the system voltage. The generation station money supply is connected to the current load by 2 transmission lines L1 and L2. L1 is 280-km long and L2 is split in 2 segments of one hundred fifty kilometre so as to simulate a three-phase fault (using a fault breaker) at the point of the road. The generation station M2 is additionally connected to the load by a 50-km line (L3). Once the SSSC is bypass, the ability flow towards this major load is as follows: 664 MW flow on L1 (measured at bus B2), 563 MW flow on L2 (measured at B4) and 990 MW flow on L3 (measured at B3).

The SSSC, placed at bus B1, is serial with line L1. it's a rating of 100MVA and is capable of injecting up to 100% of the nominal system voltage. This SSSC could be a phasor model of a typical three-level PWM SSSC. If you open the SSSC panel and choose "Display Power data", you may see that our model represents a SSSC having a DC link nominal voltage of forty kV with constant capacitance of 375 uF. On the AC facet, its total equivalent resistivity is zero.16 Pu on one hundred MVA. This resistivity represents the electrical device outflow electrical phenomenon and also the part reactor of the IGBT Bridge of associate actual PWM SSSC.The SSSC injected voltage reference is generally set by a POD (Power Oscillation Damping) controller whose output is connected to the Vqref input of the SSSC. The POD controller consists of a vigorous power measure system, a general gain, a low-pass filter, a washout high-pass filter, a lead compensator, associated an output electric circuit. The inputs to the POD controller area unit the bus voltage at B2 and also the current flowing in L1.

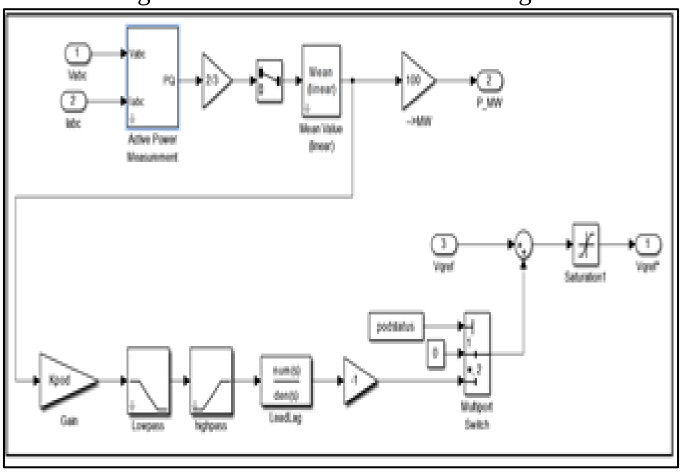

Fig. 5: POD controller subsystem model for SSSC control

IV. MATLAB SIMULATION RESULTS

A. *TCSC dynamic response*

The TCSC is within the electrical phenomenon electrical resistance management mode and also the reference electrical resistance is about to 128 Ohm. For the primary zero.5s, the TCSC is bypassed (assuming a circuit breaker), and also the power transfer is one hundred ten MW. At 0.5s TCSC begins to control the electrical resistance to 128 Ohm and this will increase power transfer to 610MW. Note that the TCSC starts with alpha at 90deg to alter lowest shift disturbance on the road.

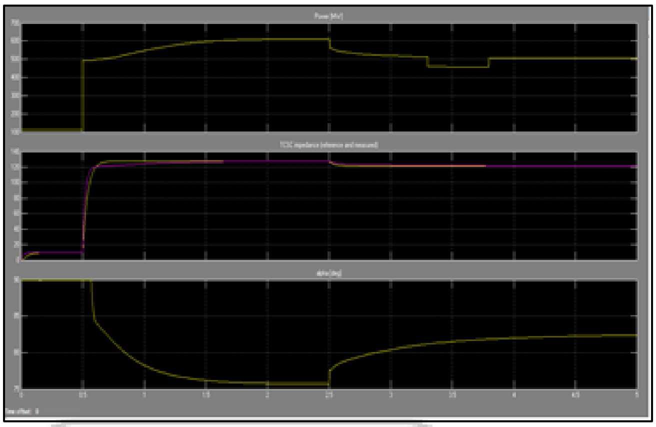

Fig. 6: MATLAB simulation model of TSCS dynamic response

In figure 6, At 2.5s a five-hitter modification within the reference resistivity is applied. The response indicates that TCSC permits trailing of the reference resistivity and therefore the subsidence time is around 500ms. At 3.3s a forty five reduction within the supply voltage is applied, followed by the come to 1p.u. at 3.8s. It's seen that the TCSC controller compensates for these disturbances and therefore the TCSC resistivity stays constant. The TCSC interval is 200ms-300ms. Note that the form of transient response is inaccurate with phasor models and therefore the thyristor based mostly model ought to be used for finding out transients.

B. *SSSC dynamic response*

In the "Step Vqref" block (the red timer block connected to the "Vqref" input of the POD Controller).This block ought to be programmed to change the reference voltage Vqref as follows: ab initio Vqref is ready to zero pu; at t=2 s, Vqref is ready to -0.08 element (SSSC inductive); then at t=6 s, Vqref is ready to zero.08 element (SSSC capacitive). Double-click on the POD Controller block and set the POD standing parameter to "off". this can disable the POD controller. Also, certify that the fault breaker won't operate throughout the simulation (the parameters "Switching of section A, B and C" mustn't be selected).

At the Scope1, graph displays the Vqref signal (magenta trace) along side the measured injected voltage by the SSSC. The second graph displays the active power flow (P_B2) on line L1, measured at bus B2. we will see that the SSSC regulator follows fine the reference signal Vqref. looking on the injected voltage, the facility flow on line varies from 575 to 750 MW. in an exceedingly real system the reference signal Vqref would generally be modified much more bit by bit so as to avoid the oscillation we tend to see on the transmitted powe (P_B2 signal). Double-click on the SSSC block and choose "Display management parameters".

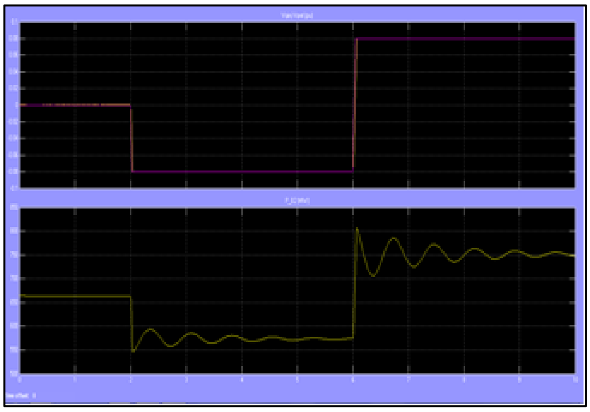

Fig. 7: SSSC dynamic response when maximum rate of change of Vqref = 3pu/sec

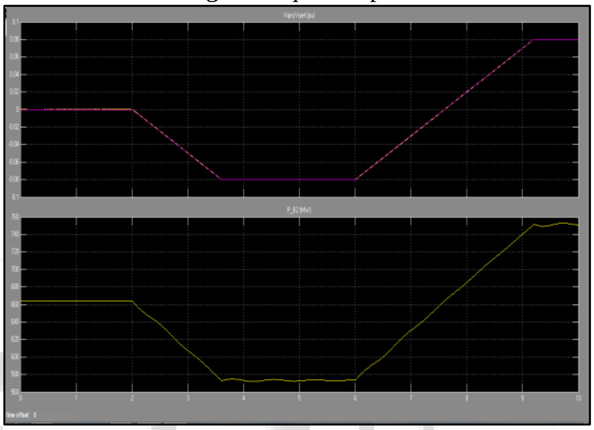

Fig. 8: SSSC dynamic response when maximum rate of change of Vqref = 0.05pu/sec

Modify the "Maximum rate of change for Vqref (pu/s)" parameter from 3 to 0.05. The power oscillation on the active power should now be very small show in figure 8. SSSC damping power oscillation response

In this section we tend to compare the operation of our SSSC with and while not POD management. Set the "Step Vqref" block and multiply by a thousand the time vector so as to disable the Vqref variations. assault the fault breaker and choose the parameters "Switching of section A, B and C" to simulate a three-phase fault. The transition times ought to be set as follows: [20/60 30/60]+1; this implies that the fault are going to be applied at one.33 s and can last for ten cycles. it had been determined that, the ability oscillation on the L1 line (second graph on Scope1) following the three-phase fault.

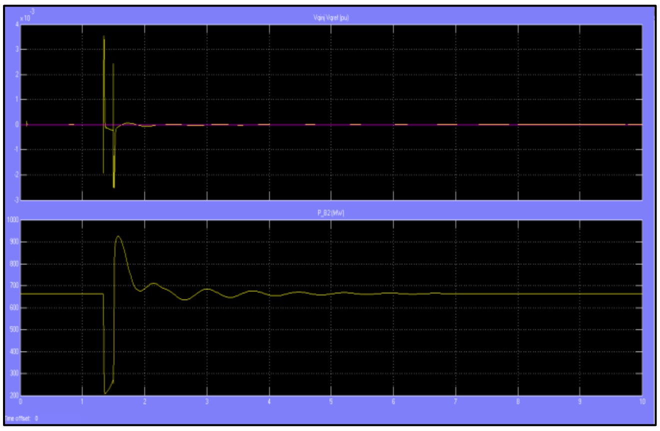

Fig. 9: SSSC dynamic response for damped out oscillation without POD controller

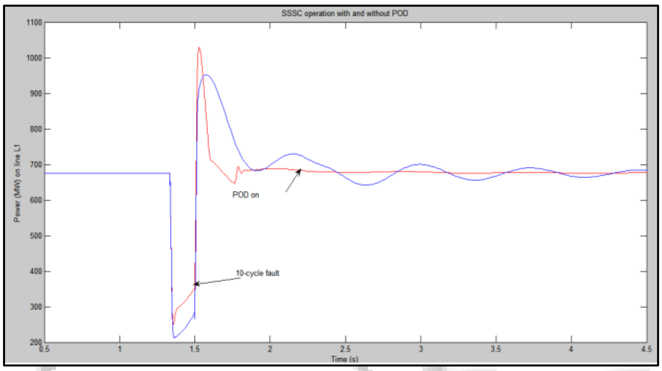

Fig. 10: Comparison of SSSC operation with and without POD control

V. CONCLUSION

The computer code for each steady-state study and dynamic study of enormous power systems embedded with FACTS devices are developed. the appliance of FACTS damping controllers, exploitation standard approach supported the residue technique clad to lack lustiness underneath modified in operation conditions. Poorly damped or perhaps unstable oscillations may result in instability, since the controller parameters yielding satisfactory damping for one in operation condition might now not be valid for one more one. In those cases, a re-tuning is important. That provided the motivation for developing associate degree adaptative management strategy.

A simple adaptive standardization technique supported the residue approach has been developed and applied to the TCSC. The disadvantage of this straightforward approach is that the system model needs to be obtainable so as to seek out best location for FACTS devices and consequently to calculate the values of residues for the controller style. this can be the rationale for the implementation of a additional versatile self-tuning controller. The pole shifting technique was applied within the management style. because the system dynamics area unit known on-line, supported the automated detection of oscillations in power systems exploitation dynamic knowledge from the system, the foremost dominant oscillation mode gift at any time is known. Hence, the management provides most damping of the known frequency all the time, underneath completely different in operation conditions, resulting in associate degree improvement of the damping characteristic.

In general, the best location of the FACTS controller obtained in keeping with the dynamic criteria isn't constant because the one obtained in keeping with the static criteria. A compromise needs to be found for every specific case, considering multiple tasks, for instance power flow management and damping of oscillations. The procedure for considering the TCSC location so as to satisfy the mentioned necessities has been given. Because the static criteria (for best location of the facility flow controller), power flow sensitivity analysis has been used; because the dynamic criteria (for best location of the damping controller), residue analysis has been used. Verification by simulation matched expected location as optimally elect TCSC location with relation to each management objectives.

Flexible transmission is at the same time co-optimized with generation during a approach that improves the potency of electricity market operations. This thesis studied the chance of getting a marketplace for FACTS devices so as to manage the resistance of the lines. The positive spatial relation downside during a recent study geared toward inclusion of transmission within the wholesale electricity market was mentioned. This thesis addressed the matter by proposing a sensitivity-based technique to calculate the marginal price of FACTS resistance changes.

The marginal price would facilitate the operator by suggesting useful changes and providing a value signal. it'd conjointly give right monetary incentives for the FACTS homeowners to utilize their assets during a socially best approach. we've got provided an indication that our projected mechanism are going to be revenue adequate within the category of cases wherever FACTS dispatch will increase a line susceptance, and our examples illustrated revenue adequacy even in those cases wherever it couldn't be well-tried.

The simulation studies showed that the projected technique would be useful for the system by reducing the value and also the FACTS homeowners by providing revenue streams. Simulation of MATLAB simulation installation models system showed that 2 hundredth adjustment of the electrical phenomenon of 2 lines would cut back the system value by twelve-tone system.

The initial ends up in this thesis counsel that FACTS device homeowners shouldn't be allowed to carry FTRs. any analysis is required to research metrics for measure of FACTS market power, additionally as FTR revenue adequacy. Dynamical the approach FACTS devices operate nowadays would have an effect on another operational protocols. as an example, by dynamical the resistance of a line, the protection relay settings ought to be adjusted consequently. Moreover, the FACTS setting ought to be communicated to the neighboring systems in order that they would have the proper model for his or her transmission.

REFERENCES

[1] E. Acha, C. Fuerte-Esquivel, H. Ambriz-Perez and C. Angeles- Camacho. FACTS Modelling and Simulation

in Power Networks, John Wiley & Sons LTD, England, 2004.
[2] R. Mohan Mathur and R. K. Varma. Thyristor-based FACTS Controllers for Electrical Transmission Systems, IEEE Series on Power Engineering, US, 2002.
[3] Y.H. Song and A.T. Johns. Flexible AC Transmission Systems. IEE Power and energy series, UK, 1999.
[4] G. Rogers, Power System Ocillations, Kluwer Academic Publishers, USA, 2000.
[5] M.E. Aboul-Ela, A.A. Salam, J.D. McCalley and A.A. Fouad, Damping Controller Design for Power System Oscillations Using Global Signals, IEEE Transactions on Power Systems, Vol. 11, No. 2, May 1996, 767-773.
[6] J. Chow, J.Sanchez-Gasca, H. Ren and Sh. Wang. Power System damping Controller Design Using Multiple Input Signals. IEEE Control Systems Magazine, Volume 20, 82-90, August 2000.
[7] N.G. Hingorani and L. Gyugyi. Understanding FACTS. IEEE Press, USA, 2000.
[8] L. Fan and A. Feliachi, Robust TCSC Control Design for Damping Inter-Area Oscillations, Power Engineering Society Summer Meeting, 2001. IEEE Vol. 2, 15-19 July 2001, 784 - 789.
[9] N. Yang, Q. Liu and J.D. McCalley, TCSC Controller Design for Damping Interarea Oscillations, IEEE Transactions on Power Systems, Vol. 13, No. 4, November 1998, 1304 - 1310.
[10] R.Sadikovic, G. Andersson and P.Korba. A Power Flow Control Strategy for FACTS Devices. WAC 28 June - 1 July 2004, Seville.
[11] K. J. Astrom and B. Wittenmark, Adaptive Control, Addison- Wesley, 1989.
[12] L. B. do Bomfim, G. N. Taranto and D. M. Falcao, Simultaneous Tuning of Power System Damping Controllers Using Genetic Algorithms, IEEE Transactions on Power Systems, Vol. 15, No. 1, February 2000, 163-169.
[13] Y. L. Abdel-Magid and M. A. Abido, Optimal Multiobjective De- sign of Robust Power Systems Stabilizers Using Genetic Algorithms, IEEE Transactions on Power Systems, Vol. 18, No. 3, August 2003, 1125-1132
[14] K. Hongesombut and Y. Mitani, Implementation of Advanced Genetic Algorithm to Modern Power System Stabilization Control, IEEE PES, Power Systems Conference and Exposition, Vol 2, October 2004, 1050 - 1055.
[15] Joe H. Chow, Felix F. Wu and James A. Momoh, (Eds.) Applied Mathematics for Restructured Electric Power Systems Optimization, Control, and Computational Intelligence, ISBN: 0-387-23470-5, Springer 2005.
[16] Juan Castaneda, Johan David Elizondo Nagy "Application of STATCOM with Energy Storage for Wind Farm Integration", 978-1-4244-6547-7/10 © 2010 IEEE, pp. 1-6.
[17] Metin D., M. Kenan DOG, Dinçer M., Salih T., and Ali Ozturk, "investigation of the Best Placement for Voltage Stability by STATCOM" pp. i-117- i-121.
[18] M.Bhaskar, S.S.Dash, & C.Subramani, "NON LINEAR CONTROL OF STATCOM" "2010-International Conference on Recent Trends in Information, Telecommunication and Computing" pp.190-195.
[19] Rajive, K. Varmma, Shriram and Vinay, "Novel application of a PV solar Plant as STATCOM during Night and day in a Distribution Utility network", 978-1-61284-788-7/11 ©2011 IEEE, pp. 1-8.
[20] R. Howard and D. J. Cooper "A Novel Pattern-Based Approach for Diagnostic Controller Performance Monitoring" published in Elsevier Journal in 2009.
[21] S.Teleke, A. Yazdani B.Gudimetla, "Application of STATCOM for Power Quality Improvement" 978-1-61284-788-7/11 ©2011 IEEE, pp. 1-6

