International Journal of Applied Electromagnetics and Communication Systems
Volume 1, Issue 01, 2025

Powerflowimprovementof220kvtransmission line using static synchronous series compensator. A case of iringa- shinyanga transmission line

Sungfvon Moon[1], wonon Koo[2]

1 Department of IT Engineering, Sookmyung Women's University, Seoul 04310, Republic of Korea

Research Article

Date of Submission: 16-05-2025 **Date of Acceptance: 20-05-2025** **Date of Publication: 13-07-2025**

Abstract

Any society's economy depends heavily on a stable electrical power infrastructure, and its collapse could have a major impact. Various studies are being conducted to attain the power system's dependable functioning. Devices from Flexible AC Transmission Systems (FACTS) can regulate power flow in the transmission system to reduce loop flows, ease congestion, and maximize asset use. A series FACTS device based on a voltage source, the Static Synchronous Series Compensator (SSSC) offers inductive or capacitive compensation that is not dependent on line current. The voltage is injected in quadrature with the line current by the SSSC, a voltage source inverter that is coupled in series with the transmission line. Due to the advancement of several mining development projects in the northwest (Geita, Musoma, and Shinyanga) and the economic growth occurring in the central (Dodoma) and northeastern (Arusha and Kilimanjaro) regions of Tanzania, the demand for electrical power has grown in recent years and is predicted to continue growing in the northern part of Tanzania. Although hydroelectric sources in the south provide the majority of the power for the north, there is an urgent need to expand the capacity for power transmission from the south to the north. There is a power shortage in the north grid as a result of rising load demand. The active and reactive power flow into the line is described in this study in order to improve the transmission line's power transmission capabilities and provide correction utilizing SSSC. Insulated gate bipolar transistors (IGBTs) were used in the design of a three-phase, three-level, neutral point clamped (NPC) voltage source converter. The Pulse Width Modulation (PWM) control technique was used in the design of the voltage source converter control circuit. Research has been done on the north regions' peak demand. In order to estimate the load for the upcoming years, the load demand forecast for Tanzania's northern areas has been completed in this article. The transmission line's single line diagram that was coupled in series with the SSSC via a coupling transformer was modelled in Simulink/MATLAB.According to the simulation results, the SSSC performed satisfactorily in terms of boosting power transmission capacity.

I. INRODUCTION

The foundation of every society's progress worldwide is electrical energy. Applications for this energy can be found in homes, businesses, hospitals, industries, and the military. Transmission networks are approaching their temperature and stability limits as a result of the rising demand for electrical energy. In mainland Tanzania, electricity generation, transmission, and distribution are handled by the state-owned Tanzania Electric Supply Company (TANESCO). Igumbilo in Iringa municipality is where the Iringa to Shinyanga line begins, and Shinyanga urban is where it terminates. The transmission line is 220 kV and 670 kilometers long. The hydroelectric power plants that supply electricity to the southern substations are Kidatu (200MW), Kihansi (180MW), and Mtera (80MW). Their capabilities are shown in brackets. This transmission line is crucial because it connects Tanzania's central and northern load centers to the country's southern power generation, both now and in the future. Due to the expansion of mining enterprises in the northwest and the economic growth occurring in Tanzania's central regions, there is a greater need for electrical energy in these two regions. Congestion occurs in a competitive energy market when system operating restrictions are violated, causing the transmission network to be unable to handle all necessary transmissions [1, 2]. Since there is no mechanism that can switch quickly for this purpose, dynamic changes in the transmission line are not immediately compensated for. As a result, the transmission line can no longer be loaded nearly to its maximum capacity. An other strategy for boosting power transmission capacity is by

establishing new transmission lines and generating electricity plants. However, this approach is time-Figure 1.

consuming, expensive, and environmentally harmful. The Tanzania grid system is seen on

Fig.1.TanzaniaGrid System

II. LITERATUREREVIEW

In order to provide end users with the high-quality power supply they require, a power system is a vast network of interconnected components that transform nonelectrical energy into electrical form. An electrical network with three subsystems is called a power system. The generating stations, transmission systems, and distribution systems are the three subsystems. A transmission system transfers electricity generated by a generating unit from generators to loads. The transmission networks serve as the conduit between distributed systems and generating stations, which in turn connect to other power systems via interconnections.

A. PowerFlowOverTransmission Line

B. The transmission systems serve as the conduit between the distribution system and the generating station. Effective management of voltage, line impedance, and phase angle can regulate the power flow over transmission lines [3]. Reactive One of the most important problems with energy transmission system regulation is power adjustment. Reactive power causes transmission system losses to increase and power capacity to decrease.

C. transported in transmission lines and variations in the amplitude of voltage at the lines' ends. Reactive power adjustment is required to improve transmittable power, reduce losses, and maintain voltage amplitude stability [4]. Figure 2 shows the power flow in the transmission line.

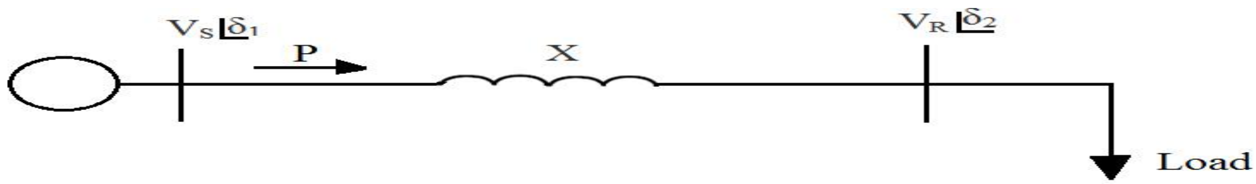

Fig.2.PowerFlowinSinglelinediagram of transmission line

D. LimitstoPowerFlowinTran smission System

transmission investment cost, increased systemsecurity andreliability, increasedpowertransfercapabilitiesand anoverallenhancement ofqualityofthe electric energy delivered to consumer[7].

Although there is a limit to the loading of transmission lines, it is desirable to make the most use of the transmission capacity while accounting for loading capabilities and contingency conditions. Thermal limits, voltage magnitude, rotational stability, dynamic stability, and transient stability are some of the constraints that affect transmission systems' ability to transport electricity [5]. The maximum transmitted power without irreversible transmission system damage is determined by these parameters. Temperature, ambient circumstances, the conductor's physical structure, and ground clearance all affect the transmission line's thermal limit. Heat degrades the conductor of power lines, and line losses turn electrical energy into heat. The voltage must not drop below a predetermined level in order for the equipment to function correctly. The maximum voltage that can be applied to transmission lines is often restricted to 5% to 10% of the sending end bus voltage [6]. The system's transmission capacity is constrained by stability phenomena, and for financial reasons, the power system must be stable and reliable. The following categories apply to various forms of power system stability: dynamic stability, transient stability,
• Sag in voltage Sub-synchronous Harmony The construction of additional transmission and generation infrastructure can alleviate the restriction on electricity transfer. As an alternative, FACTS Controller can make it possible to achieve the same goals without significantly changing the design of the system. Potential advantages of FACTS Controllers include decreased operational costs and

E. Flexible Alternating Current Transmission Systems (FACTS)

A novel technology based on power electronics devices, the Flexibility Alternating Current Transmission System (FACTS) presents a chance to improve the controllability, stability, and power transfer capacity of AC transmission systems. Reactive power is generated or absorbed by FACTS in transmission systems. Overloaded transmission lines, electricity flowing in undesirable pathways, and suboptimal line capacity functioning are some of the reasons why FACTS devices must be used in transmission lines [9]. Bringing a system under control and transmitting electricity as directed by the control centers are the goals of FACTS devices. They also enable the expansion of the useable transmission capacity to its thermal limitations. Series controllers, shunt controllers, combined series-series controllers, and combination series-shunt controllers are the several classifications for FACTS controllers.

F. ShuntFACTS controllers

At the connection point, shunt controllers introduce current into the system. By altering the current phase, the reactive power injected can be changed. Static Synchronous Compensator (STATCOM) and Static VAR Compensator (SVC) are two examples of shunt FACTS controllers. The foundation of SVC is either fixed capacitors (FC) tuned to filters, thyristor controlled reactors (TCR), or thyristor switched capacitors (TSC).

G. SeriesFACTS Controllers

In order to regulate reactive and capacitive impedance and, consequently, dampen or control different oscillations in a power system, these devices are linked in series with the lines. These controllers have the same effect as if a voltage phasor were injected in series with the line to generate or absorb reactive power. There are two ways that series controllers can function. When the injected voltage and feeder current are in quadrature, they can regulate real power; otherwise, they can regulate both real and reactive power [5, 8]. Static Synchronous Series Compensator (SSSC), Thyristor-Controlled Series Reactor (TCSR), and Thyristor-controlled Series Capacitor (TCSC) are examples of series FACTS controllers. They work well to dampen oscillations in the system and regulate the flow of power and current.

H. SSSC

The transmission line is coupled in series with the SSSC, a FACTS device. It has been stated that SSSC has reduced the cost of series compensation by adding dielectric capacitors [10]. As seen in Figure 3, it is typically connected in series with a transmission line. Through a transformer, the device's voltage source converter is serially connected to a transmission line.

.

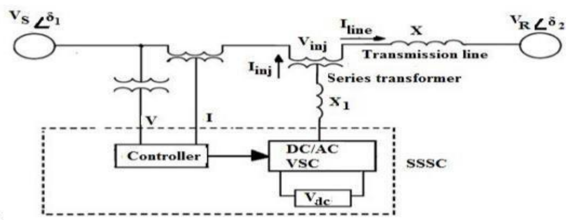

Figure3.Block diagramof SSSC

I. WorkingPrinciple ofSSSC

The transmission line is coupled in series with the SSSC, a FACTS device. It has been stated that SSSC has reduced the cost of series compensation by adding dielectric capacitors [10]. As seen in Figure 3, it is typically connected in series with a transmission line. Through a transformer,

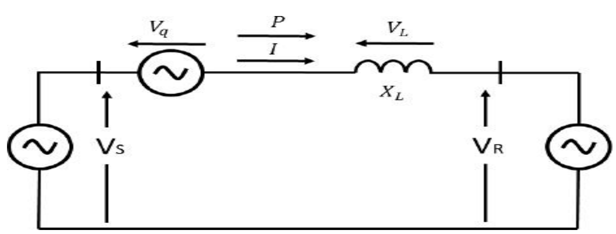

Figure5Phasordiagram ofSSSC compensation

= =

$$P=\frac{|V_S|\times|V_R|}{X_L}\sin\delta \quad (1)$$

The realpower transfer throughthe transmission line is expressed by following formula [11]

$$=\frac{|V_S|\times|V_R|}{X}\sin\delta+ V\cos(\ /)$$

elements contributing significantly to the rise in power consumption. Increased economic activity, especially in the mining industry, is driving up the need for power in Tanzania's north. The annual peak demand

The control system and energy storage are further parts of the SSSC. Figure 3 depicts a simplified example of a transmission line with series correction. It was assumed that the two buses' voltage magnitudes were equivalent, and that their phase angle was δ. A line reactance X was used to represent the transmission line, which was considered to be lossless.

the device's voltage source converter is serially connected to a transmission line. The control system and energy storage are further parts of the SSSC. Figure 3 depicts a simplified example of a transmission line with series correction. It was assumed that the two buses' voltage magnitudes were equivalent, and that their phase angle was δ. A line reactance X was used to represent the transmission line, which was considered to be lossless.

Figure4:Equivalentcircuitof SSSC

As shown in figure 5, SSSC simulates a series capacitive or inductive reactance in the transmission line by injecting a voltage in quadrature with the line current.
rise in the North Regions connected to the Iringa-Shinyanga transmission line between 2014 and 2018 is displayed in Table 1.

Figure 4 illustrates the patterns of the north regions' rising electricity demand between 2014 and 2018.

, =Activepowersourcevoltages

=SSSCinjectedvoltage

=Powerangle

Power flow in the transmission line changes as a result of voltage injection. As a result, the power flow is independent of the line current since the SSSC is an effective tool for controlling transmission line impedance. Additionally, angle control is employed to govern the active power exchange, while the magnitude of the injected voltage to the transmission line controls the reactive power exchange. The injected voltage phase angle in relation to the transmission line current determines whether the device operates inductively or capacitively. The SSSC functions in inductive mode when the injected voltage is leading the line current and absorbs reactive power; in capacitive mode, the injected voltage lags the line current and injects reactive power into the transmission line. One of the most crucial FACTS components for power transmission line series correction is the SSSC [12].

III. METHODOLOGY

A transmission line model has been simulated in the MATLAB Simulink environment to examine the transmission line's performance both before and after simulating the SSSC in order to enhance the power handling capacity of a 220kV transmission line. TANESCO provided the technical specifications for a 220kV transmission line. The way a transmission line with and without SSSC in the system has beenanalyzed. The dataof220kV transmissionline has been shown in Table 1.

A. Peak demand for Central and North Regions of Tanzania

Tanzania's need for electricity has been rising. Rapid population growth, an increase in customer connections, mining project development and industrialization, and the introduction of power to isolated villages are alltransmissionline

Table 1: Peak demand for Seven Regions Connected to Iringa–Dodoma Transmission Line

No	REGION	PEAK LOAD(MW)				
		YEAR				
		2014	2015	2016	2017	2018
1	Dodoma	17.70	18.00	18.70	19.20	19.80
2	Singida	6.00	6.00	6.20	7.00	7.10
3	Shinyanga	65.53	73.70	74.30	74.30	78.00
4	Mwanza	41.00	41.43	42.00	43.60	45.80
5	Arusha	53.20	53.00	53.83	54.74	54.21
6	Tabora	7.00	7.00	7.70	8.00	9.72
7	Musoma	17.30	18.00	20.20	22.00	23.00
	Total	208.73	217.13	222.93	228.64	237.63

B. Power demand forecast

The estimation of a variable's value at a future point in time is known as forecasting. Typically, a forecasting exercise is conducted to support future planning and decision-making. The trend approach was used in this study to forecast power demand. For this study, raw data on peak demand over a five-year period was employed. Peak loads for seven (7) regions, spanning from 2014 to 2018, were utilized. Table 1 displays the tabulated data for each region. Three categories can be distinguished based on the time period load forecast.

- **Shorttermforecast**

  Typically, short-term forecasts range from one hour to a week. It offers a foundation for scheduling generating unit start-ups and shutdowns, reserve planning, and transmission constraint analysis.

- **Mediumterm forecast**

Typically, medium-term forecasts range from one week to a year. mostly used for financial planning, maintenance schedules, fuel supply scheduling, and tariff creation.

- **Longtermforecast**

  A long-term projection often spans more than a year. It makes it easier to plan economically for new transmission networks and producing capacity. Trend, end-use, and econometric approaches are the methods utilized for forecasting short-, medium-, and long-term loads. The trend approach was applied in this article. To determine

the trends of the rise in actual peak demand, trend line analysis was employed. Since demand growth has been steady over the past five years, several attempts have been made to fit mathematical curves to this trend. One of the most basic curves is $P = P0ea(t-t0)(3)$, where a is the average growth rate per unit, P is the year's peak demand, and $t0$ is the base year.
Peak demand in year $t0$ is equal to $P0$. TANESCO provided the annual peak demand for seven locations used in this study. Figure 6 displays the average growth rate per unit from 2014 to 2018.

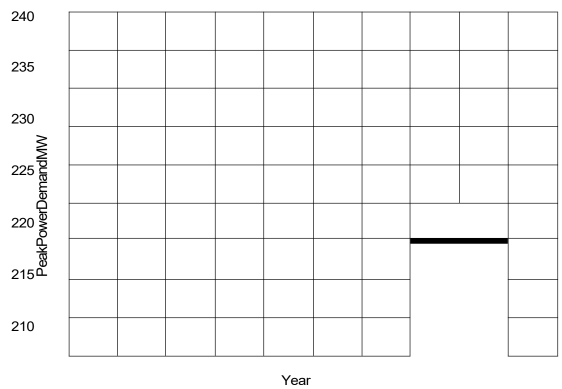

Figure7:PeakDemandfrom 2018to2023

IV. DATAPRESENTATION,ANALYSISAND DISSCUSSION OF THE RESULTS

A transmission line model has been simulated in the MATLAB Simulink environment to examine the transmission line's performance both before and after simulating the SSSC in order to enhance the power handling capacity of a 220kV transmission line. TANESCO has provided the technical data for a 220kV transmission line. Table 2 displays the data for the 20kV transmission line.

A. Development of Iringa-Shinyanga 220kV Transmission Line Model without SSSC

Figure6TrendLineanalysisforpeak demand

Data for each region is tabulated and Matlab script is drafted to compute peak demand in the years to come (From 2018 to 2023). Matlab made the realization ofthe power forecasting with exponential equation. The equation is verysimple since it gives the researcher the freedomto determinethegrowthofpowerdemand over a range of years using the peak power demand. Theplot ofthepredicateddemandisshowninFigure7.

As seen in figures 8 and 8, respectively, two scenarios were taken into consideration: the simulation without SSSC in the first case and the model with SSSC in the second.

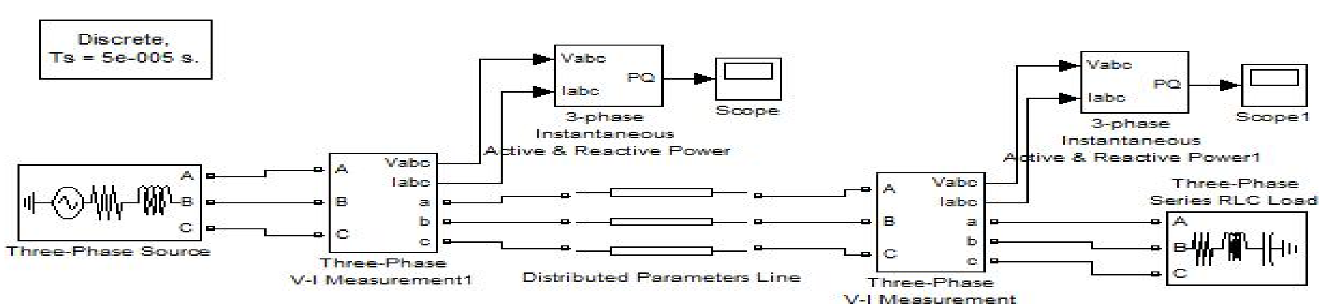

Figure8:The 220kVTransmissionLineModelwithoutSSSC.

Active power and reactive power waveforms prior to SSSC implementation in the simulation model are displayed in the graphs referenced in Figure 9. The green waveform in Figure 9 represents the flow of reactive power via the transmission line. For 0.87 seconds, the reactive power fluctuates between 0.8MVAR and 1.2kVAR. Throughout the simulation period, the variations were negligible at 1.2 kVAR. The transmission line's active power flow is represented by the blue waveform. For 0.87 seconds, the active power fluctuates between 1.3kW and 1.75kW. Reactive power was 1.75kW, and there were only slight variations in power over time.

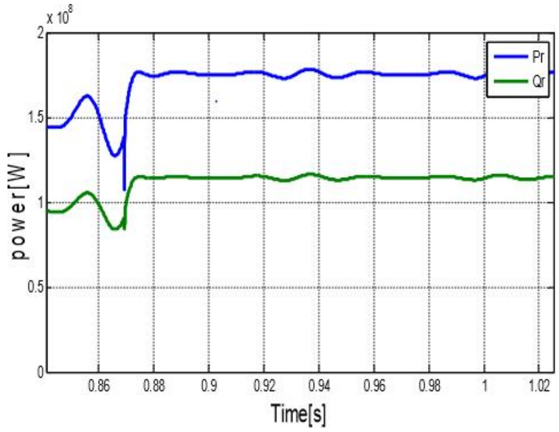

Figure9:SimulationResultsof220kVTransmissionlinewithoutSSSC

B. Development of 220kV Iringa-Sinyanga Transmission Line Model with SSSC

Figure 10 displays the 220 kV transmission line simulation model with a unified power flow controller.

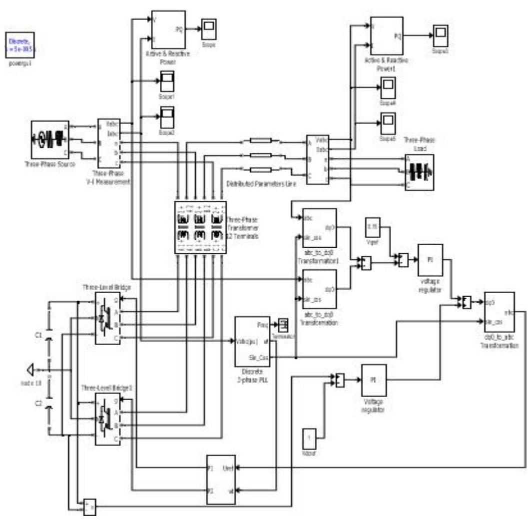

Figure10:The220kVTransmissionLineModelwithSSSC.

The green waveform in Figure 11 depicts reactive power passing via the transmission line.

However, after adding the SSSC to the simulation, the blue waveform represents active power passing over the transmission line. Throughout the simulation, the reactive power is maintained at 1.4 kVAR and the active power is maintained at 2.75kW, as seen in figure 11.

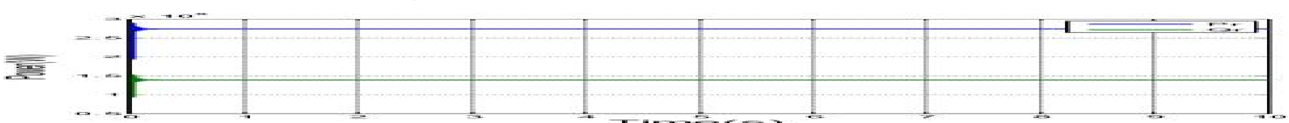

Figure11:SimulationResultsof220kVTransmissionlinewithSSSC

C. ComparisonofResults

V.

The findings shown in Table 2 demonstrate that the installation of an SSSC-based controller improves the active and reactive power of a 220kV transmission line. Both real values and p.u. quantities are used to generate the findings for the transmission line's active and reactive power flow. This demonstrates that the SSSC-based controller is appropriate and applicable for the transmission line.

VI. CONCLUSION

LISTOFABBREVIATIONSANDACRONYMS

FACTS	Flexible Alternating Current Transmission
FC	FixedCapacitors
NPC	NeutralPointClamped
SSSC	Static Synchronous Series Compensator
STATCOM	StaticCompensator
SVC	StaticVAR Compensator Systems
TANESCO	TanzaniaElectricSupplyComp
any TCR	Thyristor Controlled Reactors
TCSC	ThyristorControlledSeriesCapacitor
TCSR	Thyristor-ControlledSeriesReactor
TSC	ThyristorSwitched Capacitors
UPFC	UnifiedPowerFlowConditioner

REFERENCES

[1] Naresh A, Mithulananthan N (2006). "*Locating Series FactsDevices For Congestion Management In DeregulatedElectricity Markets*". ElectricPower Systems Research.

[2] Acharya N, Sody-Yome A, Mithulananthan N (2005). "*FactsAbout Flexible Ac Transmission Systems (FACTS)Controllers: Practical Installationsm and Benefits,in:Australasian Universities Power*".

[3] Hingorani, G.N., and Gyugyi, L. (1999), "*UnderstandingFACTS: Concepts andTechnology of Flexible ACTransmissionSystems*, *IEEE Press Marketing* pp. 297 – 352

[4] Dudhe,S.(2015), "*Reactive Power Compensation Techniquesin Transmission Lines*". International Journal onRecent andInnovationTrendsinComputingandCommunication, Volume:3issue:5Mumbai,Maharashtra,India

[5] Georgilakis, P., Vernados, P., "*Flexible AC TransmissionSystemControllers:AnEvaluation*",Materials ScienceForum, TransTechPublications,Switzerland,2011

[6] Mehta,K.V.,andMehta.R.(2009) *PrincipleofPowerSystem*.New Delhi: Chand Ltd,pp. 119 – 128.

[7] Murali, D., Rajaram, M., and Reka, N. (2010),"*Comparisonof FACTS Devices for Power System Stability Enhancement*",*International Journal of Computer Application*, Vol. 8, no. 4,

The load flow across the 220kV transmission has improved after the SSSC simulation. The system's active power has been increased. The cost per unit will decrease as power flow improves. By expanding the capacity of existing transmission lines, the financial burden of newly constructed transmission lines may be lessened. There are less technical losses along the transmission line. Consequently, a transmission line's total performance is enhanced.

pp.1-6.

[8] Kumar, P., et al, "*Static Synchronous series Compensator forSeries Compensation of EHV Transmission Line*",International Journal of AdvancedResearch in Electrical,Electronics and Instrumentation Engineering, Vol. 2, Issue 7, July 2013

[9] Srivastava,K. S.(2010)"*Advanced PowerElectronics BasedFACTS Controllers*", Asian Power Electronics Journal, Vol.4,no.3, pp. 1 – 6.

[10] Kavitha, M., Ratnakar, N., and Reddy, M.(2013),"*Integration of FACTS into Energy Storage systems for futurepower systemsapplications*", International Journal ofAdvanced Research in Electrical, Electronics andInstrumentation Engineering, Vol.2, no.2,