ISSN: 2321-2152
IJMECE
International Journal of modern
electronics and communication engineering
E-Mail
editor.ijmece@gmail.com
editor@ijmece.com
www.ijmece.com

ISSN2321-2152 www.ijmece.com
Vol 8, Issuse.3 Sep 2020

What you need to know about flexible AC transmission systems controllers (FACTS)

R.Shankar[1],P.Srikanth[2],N.Mahesh[3],

ABSTRACT

As a result of FACTS controllers' actual installations, advantages and utility applications, this paper provides a wide range of information. Detailed details on the development of these devices and the first utility installation/demonstration of FACTS devices are provided. Then, a thorough list of important FACTS installations across the globe is shown. Additionally, the article examines how these gadgets might benefit the user and how much they will cost. Various FACTS devices may be used in a deregulated market, according to the report. The FACTS controllers are likewise the subject of discussion. Advanced FACTS controllers have higher losses than their traditional counterparts, and thus must be taken into consideration when designing future power systems. FACTS controller examples and analysis are provided for each major controller in the study.

INTRODUCTION

Classes [1-3] describe the AC transmission system's static and dynamic limitations. With these limitations, transmission resources cannot be used to their full potential. A typical practise in the past was to fix or physically switch shunt and series capacitive, reactive, and synchronous generator faults. Restriction on how these gadgets may be used is in place, though. Efforts to meet expectations were unsuccessful. The mechanical components were wearing out and responding slowly, which was causing issues. Solid-state electronics that were able to react fast were in high demand. Obtaining licences and rights of way for overhead transmission lines was a challenge due to the global reorganisation of electric companies, increased environmental and efficiency regulations, and the difficulty of obtaining these permissions and rights of way. Since then, a new class of power electronics devices known as FACTS controllers has emerged, using a technology known as the Thyristor switch (a semiconductor device). High-power semiconductor devices have made it feasible to transition from Thyristor-based FACTS controllers to today's ultramodern voltage source converters [1-3]. There are FACTS monitors. Static Var Compensator (SVC) has been used by utilities worldwide since 1970, when it was the first FACTS utility to be shown. In the years afterwards, a lot of research and development has taken place on FACTS controllers.

HISTORY OF DEVELOPMENT AND STATUS STATIC VAR COMPENSATOR

The Static Var Compensator, the first FACTS controller, is a simple implementation. The Electric Power Research Institute (EPRI) first made the world aware of this technology about two decades ago. Using a fast-thyristor switch, you may control the reactor or the shunt capacitor bank to compensate for shunt effects in real time as they occur. Around the globe, more than a thousand SVCs have been deployed in utility and industrial settings to date (most notably in electric arc furnace and rolling mills). SVCs have been widely used since their inception, even in less developed nations. The Asia-Pacific region only accounted for 13% of ABB's global installation total when the company pioneered SVC. In 1974, General Electric (GE) demonstrated and commercialised SVC for utility usage for the first time [1].After deregulation in the UK in 1990, it became more difficult to manage the voltage in the country. Because of the ever-changing power system circumstances and unknown future, the United Kingdom decided to use relocatable SVC (RSV). Apiece of the NGC's 12 RSVC (60 MVAr each) are now in use [5].

Professor[1], Assistant Professor[2,3],
Department of EEE Engineering,
Pallavi Engineering College,
Mail.id: srikanth1987hyd@gmail.com Mail.id: nimmalamahesh01@gmail.com,
Kuntloor(V),Hayathnagar(M),Hyderabad,R.R.Dist.-501505.

A SERIES CAPACITOR WITH A THYRISTOR IN CONTROL

A capacitor bank is controlled by silicon-controlled rectifiers via a thyristor-controlled series capacitor in the first generation of FACTS devices (TCSC). More power can be transported over a single line thanks to the TCSC. To boost the transmission line's capacity by over 30%, ABB built and installed the world's first three-phase TCSC at Kayenta Substation, Arizona, in 1992 By the end of 2004, there were seven TCSCs throughout the world. As a result of the establishment of three TCSCs in Asia, the region now has the most advanced FACTS technology in the planet. TCSCs in service across the world as of December 2004 are included in Table 1.

Static Synchronous Compensation (SSC) device

Using STATCOMs (Static Synchronous Compensator) in FACTS controllers has the potential for future application. Small size, rapid response time, and absence of harmonic pollution are some of STATCOM's advantages. When it was founded, it was the world's first company.
In 1991, Mitsubishi Electric Power Products' STATCOM (80 MVA, 154 kV) was used for the first time in Japan's Inuyama substation. STATCOMs have been in use across the world since the early 1990s. Table 2 includes some of the most significant utility-scale STATCOMs.
Table 1: Complete list of TCSC installation

S.N	Year Installed	Country	Voltage level (kV)	Purpose	Place
1	1992	USA	230	To increase power transfer capability	Kayenta substation, Arizona
2	1993	USA	500	Controlling line power flow and increased loading	C.J.Slatt substation in Northern Oregon
3	1998	Sweden	400	Sub Synchronous Resonance mitigation	Stöde
4	1999	Brazil	500	To damp inter-area low freq (0.2 Hz) oscillation	One at Imperatriz and another one at Sarra de Mesa
5	2002	China	500	Stability improvement, low-frequency oscillation mitigation	Pinguo substation, State power south company, Guangzhou
6	2004	India	400	Compensation, Damping interregional power oscillation	Raipur substation
7	2004	China	220	Increase Stability margin, suppress low frequency oscillation	North-West China Power System

Table 2: Partial list of utility scale STATCOM

S.N	Year Installed	Country	Capacity, MVAR	Voltage level (kV)	Purpose	Place
1	1991	Japan	± 80 MVA	154	Power system and voltage stabilization	Inumaya substation
2	1992	Japan	50 MVA	500	Reactive compensation	Shin Shinano Substation, Nagona
3	1995	USA	± 100 MVA	161	To regulate bus voltage	Sullivan substation in TVA power system
4	2001	UK	0 to +225	400	Dynamic reactive compensation	East Claydon 400 kV Substation
5	2001	USA	-41 to +133	115	dynamic reactive compensation during critical contingencies	VELCO Essex substation
6	2003	USA	± 100	138	dynamic var control during peak load conditions	SDG&E Talega substation

STATIC sERIES sYNCHRONOUS cOMPENSATOR

Complementary second-generation FACTS controller, the Static Series Synchronous Compensator (SSSC), basically a series version of STATCOM. SSSC has failed to establish itself as an independent controller in the marketplace. An all-in-one power flow regulator.

UNIFIED POWER FLOW CONTROLLER

STATCOM and SSSC have been combined into one device with a similar control architecture in the third generation of FACTS, known as the Unified Power Flow Controller (UPFC) (UPFC). This gadget may be used to regulate both real and reactive power flow. For the first time, a utility-scale UPFC is being tested at the Inez substation of American Electricity.

During the year of 1998, there was a lot of electricity. In South Korea, work on an 80 MVA UPFC substation is now underway. Table 3 includes two UPFCs for comparison..

CONVERTIBLE STATIC COMPENSATOR

The "Convertible Static Compensators (CSC)" are the most current advancement in the area of FACTS controllers. Full flexibility is provided by being able to link CSC-converters in either series or shunt mode, as well as the ability to connect them in shunt/series Interline Power-Flow Controllers (IPFC) with two lines. New York Power Authority's Marcy 345 kV substation has the world's first CSC, which can operate in 11 distinct control modes.

Table 3: Complete list of TCSC installations

S.N	Year Installed	Country	Capacity, MVA	Voltage level (kV)	Purpose	Place
1	1998	USA	± 320	138	Dynamic voltage support and added real power supply facility	AEP Inez substation
2	2003	South Korea	80	154	Dynamic voltage support and added real power supply facility	Gangjin substation

3. FACTS APPLICATION

FACTS controllers may be utilized for numerous applications to boost power system performance. One of the main benefits of employing FACTS controllers is that it may be utilized in both the steady state and the transient and post transient stages of the power system. When a system is in a temporary or contingency state, typical devices have limited use.

STEADY STATE APPLICATION

FACTS controllers may be used in a variety of steady-state applications, including voltage control (low and high), thermal loading, post-contingency voltage control, loop fluxes control, and power flow management. Voltage control can be accomplished using SVC and STATCOM, but loop flow control and power flow management are best served by TCSC.

CONGESTION MANAGEMENT

Modern deregulated power markets have a major concern for the Independent System Operator (ISO): the risk of unilaterally raising prices or hindering free energy trading due to congestion management. Devices such as the Thyristor-Controlled Phase Angle Regulator (TCPAR) and the Uninterruptible Power Supply (UPS) may help reduce congestion, smooth locational marginal pricing (LMP), and increase social welfare by moving power from congested interfaces to underutilised connections.

ATC IMPROVEMENT

The calculation of ATC authorises power transactions between buyers and sellers in many deregulated markets. Due to a lack of fresh transactions being accepted by the network, free competition is hampered when the ATC is low. Power transactions enabled by FACTS controllers like TCSC, TCPAR and UPFC may contribute to improving ATC [9-10]..

REACTIVE POWER AND VOLTAGE CONTROL

Shunt FACTS controllers like SVC and STATCOM are widely used for reactive power and voltage management [11-13].

LOADING MARGIN IMPROVEMENT

Voltage failure at the maximum loadability point was the primary cause of several blackouts in various parts of the world. Transmission capacity may be increased by using series and shunt compensations. New advances in FACTS controller technology have made it possible to better use these devices to increase the system's load tolerance [14-15].

POWER FLOW BALANCING AND CONTROL

With the use of FACTS controllers like as the TCSC, SSSC, and UPFC, it is feasible to optimise and regulate the load flow on parallel circuits and different voltage levels while reducing overall system losses and power wheeling.

DYNAMIC APPLICATION

FACTS controllers may be used to increase transient stability, dampen oscillations (dynamic stability), and enhance voltage stability. FACTS applications must have the ability to minimise the impact of the principal disturbance. For contingencies, dynamic voltage support (STATCOM), dynamic flow control (TCSC) or both with the use of UPFC may be used to reduce the impact.

TRANSIENT STABILITY ENHANCEMENT

Transient instability is induced by big disturbances such as transmission line or generator tripping and may be seen in the early swing of its angle of incidence. [16] FACTS devices may solve the problem by providing fast and rapid response during the first swing to regulate voltage and power flow in the system.

OSCILLATION DAMPING

There have been reports of electromechanical oscillations in numerous power systems across the world, which may cause a partial power loss if not addressed. Oscillation dampening in the power system is first accomplished using a power system stabiliser (PSS). With the appropriate location and arrangement of SVC, STATCOM, and TCSC [17-18], this function may now be more effectively handled.

DYNAMIC VOLTAGE CONTROL

With SVC and STATCOM and UPFC, shunt FACTS controllers, dynamic voltage management during system contingency may be achieved to avoid voltage collapse and blackout. An end to SSR Series compensation may be a cause of subsynchronous resonance (SSR) under certain unfavourable conditions. In Stöde, Sweden, TCSCs are used to remove SSR from the power supply since their dynamic characteristics are so distinct from those of conventional series capacitors.

CONNECTION OF THE POWER SYSTEM

Because of the growing interconnectedness of power grids, it is becoming increasingly usual for countries and regions to swap electricity. There are several examples of connection between locations that are geographically isolated in a single country. Argentina, Brazil, and the Nordic countries all have them. Long-distance AC transmission and connected power systems need precise synchronisation and stable system voltages. The adoption of series compensation has made it possible to transmit power across enormous distances of more than 1,000 kilometres. Power transmission through AC has additional potential and flexibility thanks to the development of the TCSC technology. It's legal to use in an uncontrolled setting.

There are new applications for FACTS controllers because of the deregulation, including power flow control and raising steady state and dynamic limits. Among other things, it regulates "parallel flow" or "loop flow". Loop flow results in a reduction in transmission capacity that might otherwise benefit another utility. Utility tie lines may also include FACTS controllers, either to protect them from the effects of their surroundings, such as wheeling trades, or to participate in such transactions themselves... In order to guarantee operational efficiency, FACTS devices may be used to send the most cost-effective generators more often. Another possibility is to use it in order to reduce overall losses. FACTS may also be utilised to ease system congestion in a different way. FACTS devices placed in strategic locations may minimise congestion costs, curtailment, and price volatility.

EFFECTIVENESS AND COST

There are several advantages to using FACTS devices, but not all of them can be seen. FACTS devices, on the other hand, are prohibitively expensive. When Keepco's power system went into service at the end of 2004, the second-largest UPFC in the world was up and running. Keepco has never made a single purchase order with such heft before. In light of this, it is evident that these technologies are very costly. However, the expense must be weighed against the projected advantages in order to make an informed decision. Low FACTS deployment is due to a number of factors,There has been relatively little done to demonstrate their profitability. Devices like FACTS can keep the system from going down, which would have disastrous ramifications for the rest of the economy. It may be of use in preventing a widespread blackout. It is important to take into account the FACTS controller's opportunity cost in these scenarios.

BENEFITS TO THE ENVIRONMENT

The construction of a new electricity transmission line has negative effects on the environment. Existing infrastructure

may be used more effectively to distribute electricity, reducing the demand for additional transmission lines. For example, there are eight 400 kV lines that extend from the north to the south of Sweden. In all of these broadcasts, FACTS is present. Researchers estimate that four more 400 kV transmission lines will be required if FACTS is not installed on the present systems. The level of security has been raised.

As a result of long transmission lines and interconnected grids, fluctuating loads and line failures contribute to system instability. Line flows are restricted or the line may trip entirely because of the system's instability. System stability is provided by FACTS devices that improve capacity while minimising line trip risk. The quality of the supply has gone raised.

Modern industrial processes need a constant voltage and frequency electrical supply that is dependable and of high quality. Due to voltage dips, frequency changes, or lack of supply, industrial processes may be suspended. FACTS devices may help enhance supply.

UPTIME AND FLEXIBILITY

FACTS can be deployed in 12 to 18 months, while new overhead transmission lines might take many years to implement. Allows for future upgrades while taking up little storage space.

INCOME INCREASE

In addition to the higher sales, greater wheeling costs, and delays in the installation of high voltage transmission lines or even new power production facilities, FACTS devices have a financial advantage. Forced outages are less likely in a deregulated market, thanks to a more stable electricity infrastructure, which means less money is lost and fines are less severe.

COST REDUCTION IN MAINTENANCE

The surrounding environment (such as tree branches) must be periodically removed from the overhead transmission wires. As a result, the expense of FACTS upkeep is negligible. As the number of transmission lines grows, the likelihood of a line fault also rises. As a result, maintenance costs are reduced by using FACTS to maximise the usage of transmission systems, which reduces the number of line faults. COSTS

Due to the high cost of the controllers, FACTS controllers are not widely used. Various conventional devices and FACTS controllers are compared in Table 4 [19] in terms of their average cost per kVar output. The cost per kVar of FACTS controllers falls with increasing capacity, on the other hand. The overall cost of the FACTS controllers also relies on the size of the fixed and controllable parts. Only half of the entire FACTS project cost is accounted for by the purchase of FACTS equipment. About half of the total cost of the FACTS project is allocated to other expenses, such as civil construction, equipment installation and commissioning, insurance, engineering and project management.

Table 4: Cost of conventional and FACTS controllers

FACTS Controllers	Cost (US $)
Shunt Capacitor	8/kVar
Series Capacitor	20/kVar
SVC	40/kVar controlled portions
TCSC	40/kVar controlled portions
STATCOM	50/kVar
UPFC Series Portions	50/kVar through power
UPFC Shunt Portions	50/kVar controlled

5. ISSUES

There are a number of basic issues that need to be addressed while using FACTS controllers. FACTS controllers have a long history of study, proven technology, and a long list of benefits, yet they are not frequently used because of their high cost.

Another major issue is the lack of readily available FACTS controllers. SVC is widely accessible and is not prohibitively expensive. There is practically little competition in the procurement of TCSC and STATCOM. For UPFC, there's an excellent likelihood that there will be no competition at all.

FACTS devices, on the other hand, have bigger losses than conventional ones, and this is a major concern. Additional research is needed to build fast semiconductor switches with low switching and conductivity losses. Increasing expenses necessitate that controller size be taken into account. In order to get the desired outcome, both the setting and the location are equally important. These are some of the early design considerations for the FACTS project. There will be a need for additional inquiry into the relationships amongst FACTS controllers in a power system when more controllers are added.

6. CASE STUDIES Selected

In Thailand, SVC

There was a fast transformation of Thailand's political system throughout this decade (1990-2000). The weakest link in the overall system was the connection between the huge generating capacity in the central area and the heavy demand in the southern region. Two continents are connected by this 700-kilometer long bridge. This interconnection's capacity to transmit electricity was hindered by its inability to handle transient stability. From 50 MVAr to 300 MVAr, an SVC was built in 1994 at Bang Saphan substation. The system's power transmission capacity must be greatly boosted by employing the SVC if transient stability is to be improved. When working in a broad variety of conditions, the SVC keeps the voltage constant. Bang Saphan's SVC allows for much more power to be supplied to the south (Southern Voltage Corridor). It would have been impossible to transmit more than 200 MW without the SVC. The SVC, which currently transports power at more than 300 megawatts, was responsible for more than half of the increase in capacity over existing lines (MW).

A NORTH-SOUTH TCSC CONNECTION IN BOLIVIA

Brazil serves as an example of a country's several power systems being connected through alternating current (AC). Until recently, the country's two major electricity networks (the North and South systems) were not integrated. It was linked to a 500 kV AC cable approximately 1,000 kilometres long and corrected at many points.

These two connectivity locations, Imperatriz and Sarra de Mesa, are where the TCSC is based. Power oscillations between power systems on either side of an interconnection are dampened by TCSC. These 0.2 Hz oscillations would otherwise pose a risk to the stability of the power grid.

TALEGA SUBSTATION STATCOM

Transmission system restrictions in the Talega 138kV substation region are alleviated by dynamic var control applied to the STATCOM installed in the SDG&E system. Is running as a STATCOM with around 100 MVAr's dynamic reactive capacity. In order to regulate and control the 138 kV AC system voltage, to provide dynamic reactive power support following system contingencies, and to provide high reliability with redundant parallel converter design and modular construction and operational flexibility through auto-reconfiguration design, the Talega STATCOM is designed.

STATION OF AEP INEZ UNDER UPFC CONTROL

America Electric Power's Inez substation received the first UPFC (320 MVA) in 1998. (AEP). At the time, the 138 kV conductors on the transmission lines supporting Inez's power requirements were enormous and intensively used. When the system was in normal operation, the voltage stability margin was quite small. Multiple outages at the same site might cause a wide-area blackout when there are multiple contingency outages in a region. By implementing UPFC, the Inez substation gained real power supply capabilities and reliable power supply. The voltage support on the Inez bus was remarkable, resulting in a reduction in real power loss of almost 24 MW.

7. CONCLUSIONS

Over the course of more than three decades of research and development, FACTS controllers have been generally acknowledged as a proven and mature technology. The operational adaptability and controllability that FACTS can give in the continually changing utility environment will be much appreciated by system operators. In view of the many restrictions of the power system, FACTS is the most reliable and efficient choice. It is necessary to use appropriate techniques and processes to estimate the benefits of FACTS because of its high initial cost.

REFERENCES

1. N. G. Hingorani and L. Gyugyi, “Understanding FACTS”, IEEE Press, 1999.
2. Y. H. Song and A. T. Johns, “Flexible AC Transmission System (FACTS)”, IEE Power and Energy Series 30, 1999.
3. “FACTS Application”, IEEE Power Engineering Society, FACTS Application Task Force, 1998.
4. A. Sode-Yome and N. Mithulananthan, “Comparison of shunt capacitor, SVC and STATCOM in static voltage stability margin enhancement,” International Journal of Electrical Engineering Education, UMIST, Vol.41, No. 3, July 2004.
5. C. P. Gupta, S. C. Srivastava and R. K. Varma, “Enhancement of static voltage stability margin with reactive power dispatch using FACTS devices”, 13th PSCC in Trondheim, June 28- July 2nd, 1999.
6. John J. Paserba, “How FACTS Controllers Benefit AC Transmission Systems”, IEEE Power Engineering Society General Meting, Denver, Colorado, 6-10 June 2004 http://www.nationalgrid.com, 2005
7. Y Xia, YH Song, CC Liu, YX Sun, “Available Transfer Capability Enhancement Using FACTS Devices”, IEEE Trans. P. S, 2003
8. C. A. Canizares, A. Berizzi, P. Marannino, “Using FACTS Controllers to Maximize Available Transfer Capability”, Bulk Power System Dynamcis and Control IV- Restructuring, August 24-28, 1998, Santorini, Greece.
9. P. Rao, ML Crow, Z Yang, “STATCOM Control for

Power System Voltage Control Applications”, IEEE Trans. Power Delivery, 2000.
10. JY Liu, YH Song, P Metha, “Strategies for Handling UPFC Constraints in Steady-State Power Flow and Voltage Control”, IEEE Trans.Power System, 2000.
11. S.N. Singh, A.K. David, “Optimal Location of FACTS Devices for Congestion Management”, Elsevier Science, Electric Power SystemResearch 58 (2001) 71-79
12. K.S. Verma, S.N. Singh, H.O. Gupta, “Location of Unified Power Flow Controller for Congestion Management”, Electric Power System Research 58 (2001) 89-96.
13. N. Mithulananthan, C. A. Canizares, J. Reeve and G. J. Rogers, “ Comparison of PSS, SVC, and STATCOM Controllers for Damping Power System Oscillations”, IEEE Trans. PS Vol. 18, No. 2, pp. 786-792, May 2003.
14. N. Yang, Q. Liu, and J. D. McCalley, “TCSC Controler Design for Damping Interarea Oscillation”, IEEE Trans. PS, Vol 12, pp. 941- 946, Apr. 1997.
15. C. A. Canizares, Z. T. Faur, “Analysis of SVC and TCSC Controllers in Voltage Collapse”, IEEE Trans. PS. Vol. 14, No. 1, pp. 158-165,
16. Feb 1998
17. L. Gyugyi, “Dynamic Compensation of AC Transmission Lines by Solid-State Synchronous Voltage Sources”, IEEE Trans. PD, Vol. 9, No. 2, pp. 757-763, April 1994.
18. B.A. Renz, A. Keri, A.S. Mehraban, C. Schauder, E. Stacey, L. Kovalsky, L. Gyugyi,
19. Edris, “ AEP Unified Power Flow Controller Performance”, IEEE Trans. PD, Vol. 14, No. 4, pp. 1374-1381, 1999.R.J. Nelson, J. Bian, D.G. Ramey, T.A. Lemak,
20. T.R. Rietman, J.E. Hill, “Transient Stability Enhancement With FACTS Controllers”, Sixth Internatinal Conference on AC and DC Power Transmission, 29 April-3 May 1996.