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# Advantages of Using FACTS Controller in AC - HVDC Transmission Lines

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**Abstract:** - The search for enhanced controllability of power on ac transmission networks was initiated by newly acquired current and power controllability in HVDC transmission. Replacement of mercury-arc valves by thyristors yielded robust ac / dc converters, minimized conversion losses, and yielded fast control on transmitted power so much so that line-to-ground fault clearing became possible without the use of circuit breakers. Instead, by rapidly attaining current zero through the use of current controllers and, in addition, by rapidly recovering the electromagnetic energy stored in the energized line, the faulted dc line could be isolated by low interruption rating isolators.

The very fast power controllability in HVDC systems made them candidates for special applications in back-to-back configurations to control the power exchange between the networks they linked. The rapid control of power led to the added use of HVDC links for enhancing transient stability of connected systems through active-power damping. The enhancement in stability was accomplished by adding auxiliary signals in the current controllers of the converters.

**Key Words:-** AC Transmission line, HVDC Transmission Line, FACTS Controllers

## I. INTRODUCTION

Today, it is expected that within the operating constraints of the current-carrying thermal limits of conductors, the voltage limits of electrical insulating devices, and the structural limits of the supporting infrastructure, an operator should be able to control power flows on lines to secure the highest safety margin as well as transmit electrical power at a minimum of operating cost. Doing so constitutes the increased value of transmission assets.

The development of transmission systems follows closely the increasing demand on electrical energy. However, the performance of the power systems decreases with increasing size and complexity of the networks. This is related to problems with load flow, power oscillations and voltage quality. Such problems have even been heightened by the deregulation of the electrical power markets, worldwide. Contractual transactions now result in power flows that are much different from those of the original network design criteria, and the operational constraints of the existing network configurations bring added operational complexity. Additional problems can arise where interconnections are used, especially when the connecting AC links are weak. Fig. 1 shows trends in the power markets and Fig. 2 highlights consequences for the transmission systems.



Fig. 1: Development of Power Markets

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Fig. 2: Development of Transmission Systems

The interconnection of power systems offers numerous benefits for power transmission, such as pooling of various energy resources, reduction of reserve capacity in the systems and increasing the transmission efficiency. However, if the size of the system is too large, dynamic problems can occur which could and can jeopardize the reliability and availability of the synchronous operation of the interconnected grids. By using advanced solutions, based on modern power electronics, the transmission systems can be improved. Fig. 3 shows the basic concepts for transmission system enhancement.

### II. ENHANCEMENT OF TRANSMISSION SYSTEMS

- A. Meshed Systems and Bulk Power Transmission  
Power Flow Control
- B. Radial Systems and Parallel Lines:  
Impedance Control
- C. Weak System:  
Voltage control



Fig. 3: Planning of Transmission Systems

<b>SVC</b>	– Static Var Compensator (Standard for Parallel Compensation)
<b>STATCOM</b>	– Static Synchronous Compensator (Fast SVC, Flicker Compensation)
<b>FSC</b>	– Fixed Series Compensation
<b>TCSC</b>	– Thyristor Controlled Series Compensation
<b>GPFC</b>	– Grid Power Flow Controller (FACTS-B2B)
<b>UPFC</b>	– Unified Power Flow Controller

Fig. 4: Overview on FACTS Controllers



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## III. BENEFITS OF USING FACTS CONTROLLERS

In Fig. 4, an overview of today’s FACTS devices is shown. Fig. 5 explains the ability of each controller to improve system performance. For comparison, properties of HVDC (High Voltage Direct Current Transmission), B2B and Long Distance Transmission are also indicated. Flexible AC Transmission Systems (FACTS), based on power electronics, have been developed to improve the performance of weak AC Systems and enhance transmission capabilities over long AC lines. The technology of these systems has become mature and highly reliable and excellent system operating experience can be seen worldwide. FACTS controllers can help to solve technical problems in interconnected power systems and can also improve the synchronous operation of the interconnections and influence the load flow conditions. The evaluation in Fig. 5 is based on a large number of studies and experiences from completed projects.

Principle	Devices	Scheme	Impact on System Performance		
			Load Flow	Stability	Voltage Quality
Variation of the Line Impedance: Series Compensation	FSC (Fixed Series Compensation)		●	●●●●	●
	TPSC (Thyristor Protected Series Compensation)		●	●●●●	●
	TCSC (Thyristor Controlled Series Compensation)		●●	●●●●	●
Voltage Control: Shunt Compensation	SVC (Static Var Compensator)		○	●●	●●●●
	STATCOM (Static Synchronous Compensator)		○	●●	●●●●
Load-Flow Control	HVDC (B2B, LDT)		●●●●	●●●●	●●
	UPFC (Unified Power Flow Controller)		●●●●	●●●●	●●●●

Influence: \*

- low or no small
- medium
- strong

\* Based on Studies & practical Experience

Fig. 5: FACTS – Overview and Functions

The mostly used FACTS application is the Static Var Compensator (SVC), providing fast voltage control, reactive power control and power oscillation damping features. As an option, an SVC can also control system voltage unbalance. A view of an SVC installation in South-America and the benefits for the system operation are given in Fig. 6.



Fig. 6: SVC – Site View and Control Functions

For long AC lines, series compensation is used for reducing the transmission angle, thus providing stability enhancement. The simplest form of series compensation is the Fixed Series Compensator (FSC). Thyristor Controlled Series Compensation (TCSC) is used to control load-flow, and it also is very effective in damping power oscillations. A view of a TCSC installation in Brazil (at Serra da Mesa) is given in Fig. 7. self-commutated devices such as GTO, IGBT or IGCT) and the UPFC (Unified Power Flow Controller), which uses coupled shunt and series converter branches. The control response time of a STATCOM is faster than that

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of an SVC. However, for most applications in transmission systems, SVC, TCSC and FSC are used fulfilling normal requirements of the grid. STATCOM and UPFC are tailored solutions for special needs.

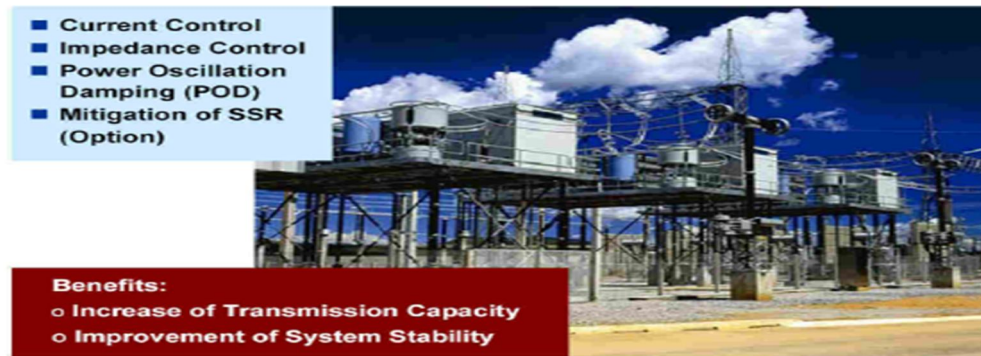


Fig. 7: TCSC in Brazil: 500 kV AC Long Distance Transmission

A large number of different FACTS devices have been put into operation either as commercial projects or proto type systems. Static Var Compensation (SVC) is mainly used to control the system voltage. Over the past decades it has become a well developed technology and the demand for SVCs is increasing further. Fixed series compensation is widely used to improve the stability in long distance transmissions systems. The market for FACTS equipment applied for load-flow control is expected to develop faster in the future, also as a result of the liberalization and deregulation in power industry. TCSC has already been used in different projects for load-flow control, stability improvement and to damp power oscillations in interconnected systems.

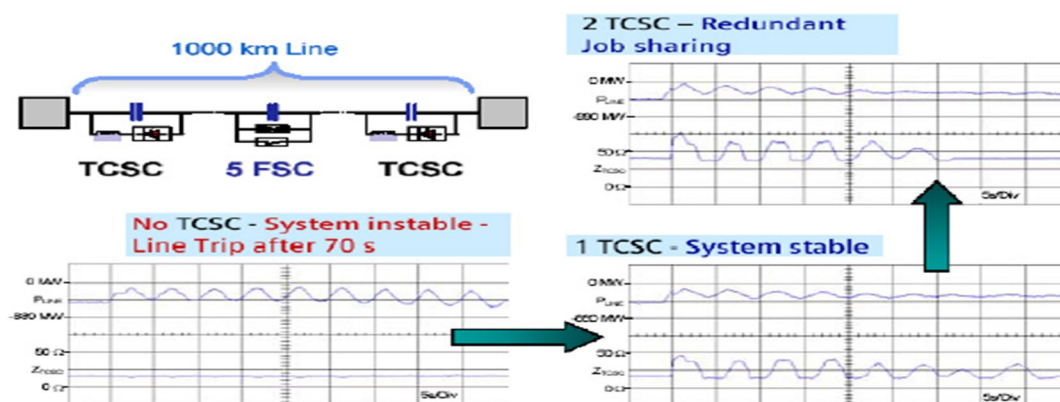


Fig. 8: 500kV Staged Fault Tests for TCSC Serra da Mesa

In Fig. 8 it is shown, how problems with inter-area oscillations have been solved in the Brazilian System. There, the situation is relatively critical because of a very long transmission distance between the interconnected systems: a 1000 km 500 kV AC interconnection between North and South systems has been realized. In the interconnection two TCSC devices have been installed at both ends of the line which damp the inherent oscillations that occur between the systems. Additionally, 5 FSC have been necessary to reduce the transmission angle. The dynamic recordings from on-site tests show that the interconnection would become unstable without the damping function of TCSC. If only one TCSC is in operation, the interconnection becomes stable, with both devices acting the inter-area oscillations are quite well damped, and redundancy is provided. From field experience, it has been reported, that under increased load conditions, the TCSC damping function is activated up to several hundred times per day. Recent developments in the area of FACTS are the TPSC (Thyristor Protected Series Compensation) and the Short-Circuit Current Limiter (SCCL), both innovative solutions using special high power thyristor technology.

#### IV. DISCUSSION

For nearly 100 years, electrical power utilities worldwide have been vertically integrated, combining generation, transmission, distribution, and servicing loads. Also, most such utilities have operated as monopolies within their geographic regions. Their

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method of operation has been “power at cost,” and their principal financiers have been governments. Therefore, to many people the pressure of electrical power utilities to operate efficiently has been missing.

Operating the electrical energy sector competitively requires the unbundling of generation, transmission, and distribution. Competition is expected to exist among generators as well as retailers. The transmission and distribution (i.e., the controlling wires) must, out of necessity, be regulated. The new order requires new agencies taking the responsibility to link customers (loads) with generators (market operators) and, at the same time, to clearly understand the limitations and capabilities of power transmission and distribution networks.

On becoming responsible for its own business, a power transmission company must make the best use of its transmission capacity and ensure that transmission losses are reduced to their lowest values. Also, any loss of transmission capacity means loss of income for the company; therefore, all actions must be taken to ensure that unwanted circulating power is not clogging the available transmission capacity. In addition, energy congestion in critical transmission corridors must be avoided to eliminate the risk of missed business opportunities. Finally, to offer the greatest flexibility to market operators, a transmission company must create the maximum safe operating limits to allow power injection and tapping from its buses without risking stable operation. The success of a transmission company depends on offering the maximum available transmission capacity (ATC) on its lines.

### V. SUMMARY

From the foregoing discussion, it is evident that in the emerging electrical energy business, transmission companies have a greater need to make their networks more flexible. Fortunately, advances in power-electronics technology now offer new fast, controllable FACTS controllers to secure the needed flexibility.

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