

Fact Device in Electrical Power System Network

Janavi Dipak Raut¹ and Mr. Amit Nanaji Akkewar²

¹Research Scholar, Department of Electrical Engineering

²Research Guide, Department of Electrical Engineering

DBATU University, Chandrapur, India

Abstract: Flexible AC Transmission System (FACTS) devices play a crucial role in enhancing the performance, stability, and controllability of modern electrical power system networks. With the increasing demand for electricity and the limitations of conventional transmission infrastructure, efficient power flow control has become essential. This research focuses on the application of FACTS devices to improve voltage stability, reduce transmission losses, and increase the overall efficiency of the power network.

The study analyzes the performance of commonly used FACTS devices such as Static VAR Compensator (SVC), Static Synchronous Compensator (STATCOM), and Unified Power Flow Controller (UPFC). Simulation models are developed to evaluate their impact on power flow, voltage regulation, and system stability under different operating conditions. The results demonstrate that the integration of FACTS devices significantly enhances system reliability, minimizes congestion, and supports better utilization of existing transmission lines..

Keywords: Flexible AC Transmission System

I. INTRODUCTION

The rapid growth in electricity demand and the increasing complexity of modern power networks have created significant challenges in maintaining stability, reliability, and efficient power transmission. Traditional power systems are often limited by fixed infrastructure and lack the flexibility required to handle dynamic load variations and disturbances. As a result, there is a growing need for advanced technologies that can enhance the controllability and performance of electrical power systems.

Flexible AC Transmission System (FACTS) devices, based on power electronics, have emerged as an effective solution to these challenges. These devices enable real-time control of key transmission parameters such as voltage, impedance, and phase angle, thereby improving power flow and system stability. Common FACTS devices include Static VAR Compensator (SVC), Static Synchronous Compensator (STATCOM), and Unified Power Flow Controller (UPFC), each offering specific advantages in power system operation.

By integrating FACTS devices into transmission networks, it is possible to increase the load-carrying capacity of existing lines, reduce transmission losses, and enhance voltage regulation without the need for extensive infrastructure expansion. Moreover, FACTS technology plays a vital role in the development of smart grids by supporting efficient energy management and facilitating the integration of renewable energy sources.

Key Idea:

- Improves voltage stability in power systems
- Enhances power flow control and system flexibility
- Reduces transmission losses
- Increases system reliability and efficiency
- Helps in congestion management of transmission lines
- Supports better utilization of existing infrastructure



Key devices studied: SVC, STATCOM, UPFC
Suitable for smart grid applications
Provides both technical and economic benefits

Concept Of Fact Technology

The concept of FACTS technology is based on the application of advanced power electronic controllers to enhance the controllability, flexibility, and power transfer capability of AC transmission systems. In conventional power systems, parameters such as voltage, line impedance, and phase angle are mostly fixed or can only be adjusted slowly using mechanical devices. This limits the ability of the system to respond quickly to changes in load demand, faults, or disturbances.

FACTS devices are broadly classified based on how they are connected in the system:

- Shunt devices (e.g., SVC, STATCOM): control voltage by injecting or absorbing reactive power
- Series devices (e.g., TCSC): control line impedance to regulate power flow
- Combined devices (e.g., UPFC): provide simultaneous control of voltage, impedance, and phase angle

The core idea of FACTS technology is to increase the utilization of existing transmission lines without the need for building new infrastructure. It helps in:

- Improving voltage stability and dynamic response
- Enhancing power transfer capability
- Reducing transmission congestion and losses
- Damping power system oscillations
- Supporting integration of renewable energy sources

Moreover, FACTS devices contribute to the development of smart grids by enabling automated, flexible, and reliable operation of power systems under varying conditions.

In essence, the concept of FACTS technology is to transform a rigid and slow-responding power system into a flexible, fast, and intelligently controlled network using power electronics.

Working of Fact Device In Electrical Power System

Flexible AC Transmission System (FACTS) devices operate based on the principle of controlling power system parameters using advanced power electronic converters. In conventional power systems, the control of voltage, impedance, and phase angle is limited and slow due to mechanical switching devices. FACTS technology overcomes these limitations by providing fast, continuous, and dynamic control of these parameters in real time.

The working principle of FACTS devices is derived from the fundamental power flow relationship:

This equation shows that the real power flow in a transmission line depends on the sending-end voltage (V_1), receiving-end voltage (V_2), line reactance (X), and the phase angle difference (δ). FACTS devices work by controlling one or more of these parameters to regulate power flow as per system requirements.

Shunt-connected FACTS devices, such as Static VAR Compensator (SVC) and Static Synchronous Compensator (STATCOM), control the bus voltage by injecting or absorbing reactive power. This helps in maintaining voltage stability and improving power factor. Series-connected devices, such as Thyristor Controlled Series Capacitor (TCSC), adjust the effective reactance of the transmission line, thereby controlling the amount of power flowing through the line. Combined devices like the Unified Power Flow Controller (UPFC) provide simultaneous control of voltage, impedance, and phase angle, offering comprehensive power flow management.

FACTS devices utilize high-speed semiconductor switches like thyristors and IGBTs, which allow them to respond quickly to system disturbances, load variations, and faults. This rapid response improves system stability, reduces transmission losses, increases power transfer capability, and enhances overall system reliability.



Advantages

- Improves voltage stability and regulation
- Enhances power transfer capability
- Reduces transmission losses
- Provides fast dynamic response
- Improves system stability (transient & dynamic)
- Reduces transmission congestion
- Enables better utilization of existing lines
- Supports renewable energy integration
- Enhances reliability and efficiency
- Reduces need for new transmission infrastructure

Disadvantages

- High installation and capital cost
- Complex control and design
- Requires skilled operation and maintenance
- Generates harmonics and power quality issues
- Increases system complexity
- Limited overload capability

Practical Implementation

- Identify problem areas in the network (voltage instability, congestion, losses)
- Perform system studies (load flow, fault analysis, stability analysis)
- Select appropriate FACTS device (SVC, STATCOM, TCSC, UPFC)
- Determine optimal location for installation
- Install devices in substations or transmission lines
- Integrate with SCADA/control systems for real-time monitoring
- Use harmonic filters to maintain power quality
- Provide cooling systems for power electronic components
- Implement protection and safety systems
- Ensure coordination with existing grid equipment

Future Scope

- Increasing use in smart grid systems
- Supports renewable energy integration (solar, wind)
- Development of advanced and cost-effective devices
- Integration with AI and automation systems
- Improves power quality and system stability
- Enables real-time monitoring and control
- Reduces transmission losses and congestion
- Helps in building sustainable and efficient power systems
- Expanding role in modern and future power networks



Applications

- Voltage regulation and stability improvement
- Power flow control in transmission lines
- Reduction of transmission losses
- Congestion management in heavily loaded networks
- Enhancement of transient and dynamic stability
- Integration of renewable energy sources
- Power quality improvement
- Load balancing in power systems
- Use in smart grid systems
- Support for industrial and utility power networks

II. CONCLUSION

Facts devices improve power system stability, efficiency, and reliability by providing fast control of voltage and power flow. They help reduce losses, manage congestion, and support modern smart grid and renewable energy integration.

REFERENCES

- [1]. N. G. Hingorani and L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, IEEE Press, 2000.
- [2]. Y. H. Song and A. T. Johns, *Flexible AC Transmission Systems (FACTS)*, IET Power and Energy Series, 1999.
- [3]. P. Kundur, *Power System Stability and Control*, McGraw-Hill, 1994.
- [4]. K. R. Padiyar, *FACTS Controllers in Power Transmission and Distribution*, New Age International, 2007.
- [5]. T. Johns and Y. H. Song, "Flexible AC Transmission Systems (FACTS)," *IEE Proceedings – Generation, Transmission and Distribution*, vol. 140, no. 4, pp. 323–331, 1993.
- [6]. IEEE Power & Energy Society, "FACTS Overview," IEEE Publications.
- [7]. R. M. Mathur and R. K. Varma, *Thyristor-Based FACTS Controllers for Electrical Transmission Systems*, Wiley-IEEE Press, 2002.
- [8]. L. Gyugyi, "Unified Power Flow Control Concept for Flexible AC Transmission Systems," *IEEE Proceedings*, 1992.
- [9]. X. P. Zhang, C. Rehtanz, and B. Pal, *Flexible AC Transmission Systems: Modelling and Control*, Springer, 2006.
- [10]. T. J. E. Miller, *Reactive Power Control in Electric Systems*, Wiley, 1982.
- [11]. IEEE/CIGRÉ Joint Task Force, "Definition and Classification of FACTS Devices," *IEEE Transactions on Power Delivery*, 1995.
- [12]. P. M. Anderson and A. A. Fouad, *Power System Control and Stability*, IEEE Press, 2003.
- [13]. CIGRÉ Working Group Reports on FACTS Controllers, CIGRÉ Publications.
- [14]. S. N. Singh and A. K. David, "Optimal Location of FACTS Devices for Congestion Management," *Electric Power Systems Research Journal*.

