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# Project Progress Report

On

# COMPARISION OF PERFORMANCES OF FACTS CONTROLLERS IN POWER SYSTEM NETWORKS

submitted for partial fulfillment for award of degree of

**BACHELOR OF TECHNOLOGY**
IN
Electrical Engineering

By

Group - 3

**Rajat Shukla** (Project Coordinator)

Under Supervision of

**Prof. Bindeshwar Singh**
(Project Guide)

**Dr. S. M. Tripathi**
(Project in charge)

Department of Electrical Engineering
KAMLA NEHRU INSTITUTE OF TECHNOLOGY, SULTANPUR (U.P.)
(An Autonomous Gov. Engineering Institute)

Affiliated to

Dr. A P J ABDUL KALAM TECHNICAL UNIVERSITY
LUCKNOW, INDIA

## Contents

| *Abbreviation Used* | |
|---|---|
| D-STATCOM | Distributed static synchronous compensator |
| ETO | Emitter Turn-Off |
| GTO | Gate turn off |
| GUPFC | Generalized unified power flow controller |
| GIPFC | Generalized interline power flow controllers |
| HVDC | High-voltage dc transmission |
| HPFC | Hybrid power flow controllers |
| IGCT | Integrated Gate-Commutated Thyristors |
| IPFC | Interline power flow controllers |
| MOV | Metal Oxide Varistor |
| OPF | Optimal power flow |
| PF | Power factor |
| PSS | Power system stabilizer |
| TCSC | Thyristor controlled series compensator |
| TC-PAR | Thyristor controlled phase angle regulator |
| UPFC | Unified power flow controller |
| SSSC | Static synchronous series compensator |
| SCCL | Short-circuit current limiter |
| SVC | Static VAR compensator |
| STATCOM | Static synchronous compensator |
| *Symbols* | |
| $f$ | Supply frequency (f = 50 Hz) |
| $\delta$ | Power Angle |

**INTRODUCTION**

Development of electrical power supplies began more than one hundred years ago. At the beginning, there were only small DC networks within narrow local boundaries, which were able to cover the direct needs of industrial plants by means of hydro energy. With an increasing demand on energy and the construction of large generation units, typically built at remote locations from the load centers, the technology changed from DC to AC. Power to be transmitted, voltage levels and transmission distances increased. DC transmission and FACTS (Flexible AC Transmission Systems) has developed to a viable technique with high power ratings since the 60s. FACTS is applicable in parallel connection or in series or in a combination of both. The rating of shunt connected FACTS controllers is up to 800 Mvar, series FACTS controllers are implemented on 550 and 735 kV level to increase the line transmission capacity up to several GW. This progress report is based on the comparisons of performances of FACTS controllers in power system.

**What are FACTS ?**

FACTS *i.e*. Flexible AC transmission system incorporate power electronic based static controllers to control power (both active and reactive power needed) and enhance power transfer capability of the AC lines. FACTS is the acronym for “Flexible AC Transmission Systems” and refers to a group of resources used to overcome certain limitations in the static and dynamic transmission capacity of electrical network. The main purpose of these systems is to supply the network as quickly as possible with inductive or capacitive reactive power that is adapted to its particular requirements, while also improving transmission quality and the efficiency of the power transmission system.

**Power System Constraints**

As noted in the introduction, transmission systems arebeing pushed closer to their stability and thermal limits while the focus on the quality of power delivered is greater than ever. The limitations of the transmission system can take many forms and may involve power transfer between areas (referred to here as transmission bottlenecks) or within a single area or region (referred to here as a regional constraint) and may include one or more of the following characteristics:

- Steady-State Power Transfer Limit
- Voltage Stability Limit
- Dynamic Voltage Limit
- Transient Stability Limit
- Power System Oscillation Damping Limit
- Thermal Limit
- Short-Circuit Current Limit

**Benefits of Control of Power Systems**

Once power system constraints are identified and through system studies viable solutions options are identified, the benefits of the added power system control must be determined. The following offers a list of such benefits:

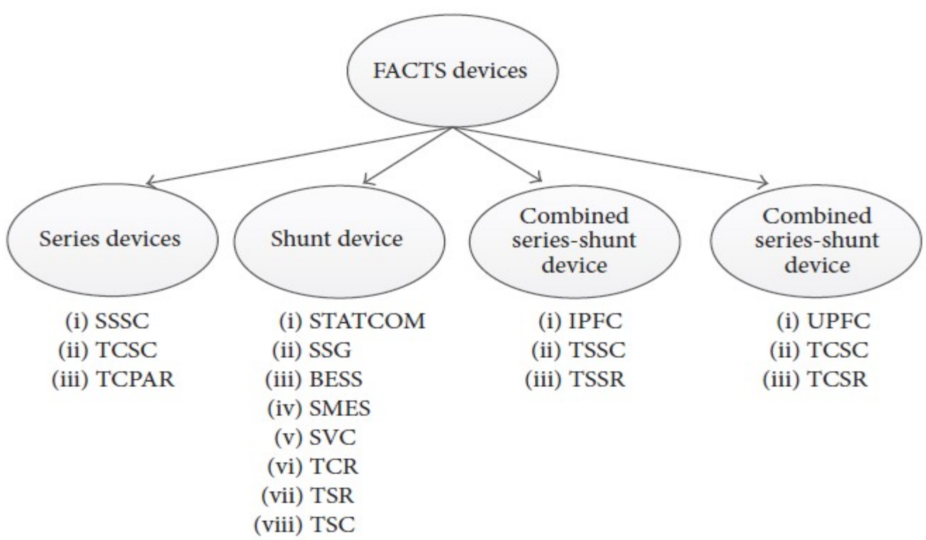
- Increased Loading and More Effective Use of Transmission Corridors
- Added Power Flow Control
- Improved Power System Stability
- Increased System Security
- Increased System Reliability
- Elimination or Deferral of the Need for New Transmission Lines

**Controllable parameters of FACTS**

In flexible (or) controllable AC systems, the controllable parameters are

a) Control of line reactance.
b) Control of phase angle $\delta$ when it is not large(which controls the active power flow)
c) Injecting voltage in series with line and at $90°$ phase with line current *i.e.* injection of reactive power in series. This will control active power flow.
d) Injecting voltage in series with line but at variable phase angle. This will control both active & reactive power flow.
e) Controlling the magnitude of either both side bus voltages.
f) Controlling or variation of line reactance with a series controller and regulating the voltage with a shunt controller. This can control both active and reactive power.

Examples of various FACTS controllers are shown in following Figure :



## Progress of work

Original flow of work:

→COLLECTION OF MATERIALS: LITERATURE

→STUDY

→COMPILATION OF PAPERS → Completed till here

→STUDY MATPOWER AND LOAD FLOW ALOGORITHMS → Work underway

→ MATPOWER 4.1 MERGE

→ PROGRAM RUN

→RESULT

→PLOTS

**Comparisons of performances of FACTS controllers in power systems on basis of our study:** A comparative analysis of series, shunt, shunt-series and series–series FACTS is shown in the following tables 1-4 respectively.

**Table 1:** Performances of various series FACTS controllers in power system

| Facts device | Rating | Presently installed in India | Performance | Connection | First installation date |
|---|---|---|---|---|---|
| TCSC | 120-350 MVAR<br>220-500KV | Raipur 400 KV Substation. | Controls the current hence the load flow.<br>Mitigation Of Sub Synchronous Resonance.<br>Damping Of Oscillations | SERIES | First installed in USA(2*165 MVAR Capacity,230 KV) in 1992. |
| SSSC | 220KV | No | Active and reactive power control.<br>Maintain high X/R ratio.<br>Power factor correction. | SERIES | Proposed in SPAIN, EUROPE and yet to be installed. |
| TCSR | Blocks up to 4KV to 9 KV and conduct current up to 6000A | No | Limits the fault current.<br>Controls the inductive reactance. | SERIES | - |
| TCPAR | 250 MVA | No | Phase shift<br>Doesn't inject any active power but controls active power flow. | SERIES | - |
| TSSR | 120-350 MVAR<br>220-500KV | No | Provide variable impedance .<br>Controls the fault level. | SERIES | - |
| TSSC | 100-150 MVA | No | Active and reactive control.<br>Power factor correction.<br>Maintain high X/R ratio | SERIES | - |

**Table 2:** Performances of various shunt FACTS controllers in power system

| **Facts device** | **Rating** | **Presently installed in India** | **Performance** | **Connection** | **First installation date** |
|---|---|---|---|---|---|
| SVC | 50 TO 300 MVAR at 230 KV.<br>270 MVAR at 500 KV. | 1988 Madurai(45 MVAR,132 KV)<br>1988 Trichur(45 MVAR,132 KV) | Regulate transmission voltage.<br>To improve power quality. | SHUNT | 1981 CHINA (120 MVAR,500KV) |
| STATCOM | -41 TO 133 MVAR AT 115 KV.<br>50 MVA AT 500 KV. | No | Voltage stabilization and Reactive compensation . | SHUNT | 1991 JAPAN (+/- 80 MVAR , 154 KV) |
| D STATCOM | ±250 KVAr | No | Reduce voltage sags ,surges and flicker.<br>Reduces power loss in distributed systems. | SHUNT | ±250 kVAr D-STATCOM was designed and installed for the Khoshnoodi substation in Tehran |
| DVR | Used below 400 KV | No | Provide voltage sag mitigation.<br>Provide voltage swell mitigation. | SHUNT | - |

**Table 3:** Performances of various shunt-series FACTS controllers in power system

| **Facts device** | **Rating** | **Presently installed in India** | **Performance** | **Connection** | **First installation date** |
|---|---|---|---|---|---|
| UPFC | +/-320 MVA at 138KV. | No | Dynamic voltage support. | SHUNT-SERIES | 1998 USA (320 MVA , 138 KV) |
| HPFC | 400 MVA | No | Use SVC, TCSC along with VSCS and CSCS.<br>Simultaneously control real and reactive power. | SHUNT - SERIES | Future trend |

**Table 4:** Performances of various series-series FACTS controllers in power system

| Facts device | Rating | Presently installed in India | Performance | Connection | First installation date |
|---|---|---|---|---|---|
| IPFC | Up to 900 MW | No | Independent control of reactive power.<br>Consist of two series SSSC's.<br>Decrease chances of overloading of transmission line.<br>Equalize power flow among lines | SERIES-SERIES | - |
| GIPFC | +/-200 MVA AT 220KV | No | Controllability of each line in multi line system. | SERIES-SERIES | Future trend |

## Summary of tables:

| Operating problem | Corrective action | FACTS devices |
|---|---|---|
| **(i) Voltage limit** | | |
| (a) Low voltage at heavy load Supply | Supply reactive power | STATCOM, SVC |
| (b) High voltage at low load | Absorb reactive power | STATCOM, SVC, TCR |
| (c) High voltage following an outage | Absorb reactive power, prevent overload | STATCOM, SVC, TCR |
| (d) Low voltage following an outage | Supply reactive power; prevent overload | STATCOM, SVC |
| **(ii)Thermal limits:** | | |
| (a) Transmission circuit overload | Reduce overload | TCSC,SSSC,UPFC |
| (b) Tripping of parallel circuits | Limit circuit loading | TCSC,SSSC,UPFC |
| **(iii) Loop flows:** | | |
| (a) Parallel line load sharing | Adjust series reactance | SSSC,UPFC, TCSC |
| (b) Post-fault power flow sharing | Rearrange network or use thermal limit actions | TCSC,SSSC, UPFC |
| (c) Power flow direction reversal | reversal Adjust phase angle | SSSC, UPFC |

**ABOUT MATPOWER 4.1:** MATPOWER is a package of MATLAB M-files for solving power flow and optimal power flow problems. It is intended as a simulation tool for researchers and educators that is easy to use and modify. MATPOWER is designed to give the best performance possible while keeping the code simple to understand and modify.

It uses NEWTON RAPSON method in rectangular form to solve load flow equations for given bus matrix. We will use this software to test the performances of the each given FACTS controller.

**Submitted By:** GROUP - 3

| Sr. No. | NAME OF MEMBERS | SIGNATURE |
|---|---|---|
| 1 | RAJAT SHUKLA (14340) | |
| 2 | PIYUSH DIXIT (14627) | |
| 3 | NEERAJ SINGH (14328) | |
| 4 | SURAJ DUBEY (14351) | |
| 5 | ABHISHEK RANJAN (4303) | |
| 6 | ASHUTOSH SINGH (14315) | |

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