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POWER SYSTEM STEADINESS ADVANCEMENT BY MEANS OF "FACTS" DEVICES

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ABSTRACT

In the last two decades, power requirement has enlarged significantly while the development of power generation and transmission have been rigorously maximized due to limited stores and environmental restraints. As a result, some transmission lines are profoundly loaded and the system stability becomes a power transfer-limiting factor. FACTS controllers have been mainly used for solving a variety of power system steady state control setbacks. Flexible AC transmission systems are devices which allow the flexible and dynamic control of power systems. Development of system stability by using FACTS controllers has been examined. This paper is aspired towards the advantages of make use of FACTS devices with the purpose of improving the processing of an electrical power system. The performance assessment of different FACTS controllers has been conferred. In addition, some of the usefulness experienced and semiconductor technology development have been analyzed and recapitulated. Applications of FACTS to power system studies have also been conversed.

Keywords: FACTS, IPFC, PSS, SVC, STATCOM, SSSC, TCSC, TCPS, UPFC & AC.

1. INTRODUCTION

The Flexible AC Transmission Systems (FACTS) controllers proposes a great prospect to standardize the transmission of alternating current (AC), rising or retreating the power flow in definite lines and reacting almost instantaneously to the stability setbacks. The prospective of this technology is based on the option of directing the routes of the power flow and the capability of attaching the networks which are not sufficiently be integrated, giving the option of dealing energy between far-off negotiators. FACTS is a static apparatus employed for the AC transmission of electrical energy. It is intended to improve controllability and amplify power transmit capability. It is usually a power electronics based mechanism. The FACTS devices can be divided in three groups, dependent on their switching tools. Mechanically switched such as phase shifting transformers (PST), thyristor switches are fast switching one, by using IGBTs, which are the types of FACTS devices, such as the phase shifting transformer (PST) and the static VAR compensators and SVC etc.. are already known and are used in power systems. New improvements in power electronics and control systems have been extended the application of FACTS. In addition, irregular renewable energy resources and growing global power stream provides a new proposal for FACTS. The supplementary flexibility and controllability of FACTS allow to moderate the setbacks correlated with the unpredictable of supply issues of renewable energy. SVCs and STATCOM also the FACTS devices which are well suited to provide auxiliary services, such as voltage control to the grid and fault clear through capabilities etc., which are standardized with wind farms. In addition, FACTS devices reduce the oscillations in the grid circuit, which is especially attention able in dealing with the disordered behavior of renewable energy.

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2. CONTROL OF POWER SYSTEMS

2.1. IN ANY POWER SYSTEM: The formation, transmission, and utilization of electrical power can be separated into three areas, which conventionally resolved the way in which electric usefulness of companies had been organized. They are exemplified in Figure 1 which are: • Generation • Transmission • Distribution

Fig – 1Block diagram of generation, transmission & distribution

Though the power electronic foundation equipments are common in each of these three regions, such as with stationary excitation schemes for generators and traditional Power gear in distribution systems [8], the main focus of this paper and accompanying presentation is on transmission, i.e., moving the power from where it is generated to where it is utilized.

2.2. POWER SYSTEM LIMITATIONS: As noted in the introduction, transmission systems are being drived quicker to their steadiness and thermal limits while the center of attention on the superiority of power delivered is higher than ever. The constraints of the transmission system can takes many shapes and may engage power transfer between regions or within a single region or region and may contain one or more of the following characteristics: • Steady-State Power Transfer • Voltage Stability • Dynamic Voltage • Transient Stability • Power System Oscillation Damping • Inadvertent Loop Flow • Thermal • Short-Circuit Current • Others. Every transmission block or local limitation may have one or more of these scheme-level difficulty. The means for solving these setbacks in the most cost-effectiveness and organized way is by systematic systems engineering study.

2.3. CONTROLLABILITY OF POWER SYSTEMS

To make it sure that the power system has only certain variables which can be impacted by control, we have considered here the power-angle curve etc. As shown in Figure 2. Though it is an steady-state curve even then, the implementation of FACTS is mainly for the dynamic issues, this image demonstrates the point that, there are chiefly three main variables; which can be directly controlled in the power system to impact its presentation. These are: Voltage, Angle and Impedance

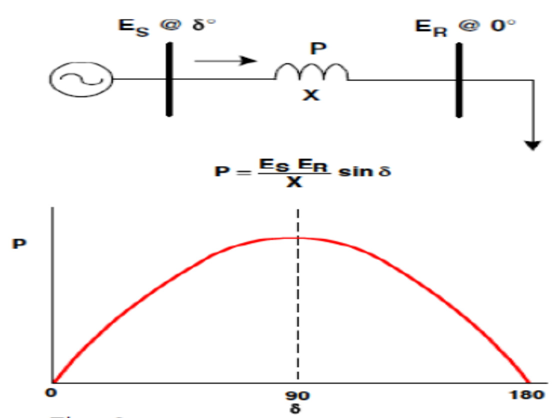

Fig – 2. Illustration of controllability of power systems

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We can also deduce the point that direct control of power is a fourth variable of controllability in power systems. With the establishment of "Which" variables can be controlled in a power system, the next question is "Why" these variables can be controlled. The answer is presented in two ways: conventional equipment and FACTS controllers. Examples of conservative apparatus For improving Power System Control are: 1. Series Capacitor Impedance Control 2. Shunt-Capacitor and Inductor Voltage Control 3. Transformer voltage Control 4. Phase Shifting Transformer angle Control 5. Synchronous Condenser voltage Control 6. Special Stability voltage Control 7. Direct power control

Example of FACTS Controllers for Improving Power System are: 1. Static Synchronous Compensator (STATCOM) voltage Control 2. Static VAR Compensator (SVC) Controls 3. Unified Power Flow Controller (UPFC) 4. Convertible Series Compensator (CSC) Controller 5. Inter-phase Power Flow Controller (IPFC) 6. Static Synchronous Series Controller (SSSC) 7. Thyristor Controlled Series Compensator (TCSC) impedance Controls 8. Thyristor Controlled Phase Shifting / angle Transformer Controls (TCPST) 9. Super Conducting & Magnetic Energy Storage (SMES) voltage and power Control. Each of the above controllers have the impact on voltage, impedance, Phase angle and power

2.4. ADVANTAGES OF POWER SYSTEM CONTROL

Once the power system restraints are identified through the system studies, the viable solution options are also identified, the benefits of the added power system control must be determined. The following are control list of such advantages: 1. Enhanced loading and more effective use of transmission passageways 2. Added Power Flow Control 3. Improved Power System Stability 4. Increased System Security 5. Increased System Reliability 6. Added Flexibility in Starting New Generation 7. Elimination or delay of the Need for New Transmission Lines

2.5. ADVANTAGES OF MAKING USE OF FACTS DEVICES

The advantage of using FACTS devices in electrical transmission systems are summarized as Under [1]:1. Better utilization of existing transmission system assets 2. Increased transmission system reliability and availability 3. Improved dynamic and transient grid steadiness and fall of loop surges 4. Increased quality of supply for sensitive industries 5. Environmental benefits, Better utilization of existing transmission system assets

SECOND GENERATION: Semiconductors with ignition and extinction controlled by using gate Controllers, such as GTO´s , MCTS, IGBTS, IGCTS, etc. The classifications of two generations (i.e. First and Second Generation are independent of existing devices). For example, devices of a first group of classification are belong to various groups of the second classification. The main difference between first and second group generation devices is the generating capacity of reactive power and to exchange the active power. The first generation FACTS devices work as passive elements/circuits, by using impedance or tap changing transformer controlled by thyristors. In second generation the FACTS devices work as control angle and phase module devices to control voltage sources without inactivity, which are based upon converters used. By employing sensitive electronic pressure, the sources such as three-phase inverters sources, auto-witched voltage sources, synchronous voltage sources, controlled voltage sources and also fast shared static synchronous voltage and current sources etc.

3. FIRST GENERATION OF FACTS

3.1. STATIC VAR COMPENSATOR (SVC)

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A VAR compensator is a Power electronic device for supplying fast generating reactive power with tall voltage transmission schemes. SVCs are the Flex FACTS device, which are used for changing voltage and steady the scheme. The word static indicates the fact that, SVC has no stirring parts, but it is like circuit breaker and disconnector, which does not move under normal SVC operation. So earlier to the creation of the SVC, power factor recompense was the conserve of huge revolving mechanisms such as synchronous condensers. The SVC is an computerized impedance similar device, designed to convey the system quicker to unity power factor. If the power system's reactive load is capacitive , the SVC will use reactors (usually in the form of Thyristor-Controlled Reactors) to consume VARs from the system, reducing the system voltage. Under inductive states, the capacitor pool are regularly switched in, thus to provide a higher system voltage. They may be put close to high and quickly changeable loads, such as arc furnaces, where they can smooth flicker voltage. It is known that the SVCs with an auxiliary injection of a suitable signal can considerably improve the active stability presentation of a power system . It is viewed that SVC controls can appreciably manipulate nonlinear system performance particularly under high-stress working conditions and enlarged SVC gains.

3.2.THYRISTOR-CONTROLLED SERIES CAPACITOR (TCSC)

TCSC controllers use thyristor-controlled reactor (TCR) in parallel with capacitor sections of series capacitor pool. The grouping of TCR and capacitor permit the capacitive reactance to be efficiently controlled above a broad variety and switched upon control to a condition where the bidirectional thyristor couples conduct constantly and put in an inductive reactance into the line. TCSC is an efficient and inexpensive means of solving setbacks of transient stability, active permanence, stable state constancy and voltage steadiness in long transmission lines. TCSC, the first generation of FACTS, can manage the line impedance throughout the beginning of a thyristor controlled capacitor in series with the transmission line. A TCSC is a series controlled capacitive reactance that can supply nonstop control of power on the ac line over a large range. The implementation of TCSC can be comprehend by analyzing the actions of a changeable inductor connected in series with a fixed capacitor

3.3. THYRISTOR-CONTROLLED PHASE SHIFTER (TCPS)

In the TCPS control method the phase swing angle is settle on a nonlinear role of rotor angle and velocity. However, in genuine-life power method with a big number of generators, the rotor angle of a single generator computed with respect to the arrangement position will not be very significant.

4. SECOND GENERATION OF FACTS

4.1 The STATCOM: which is a type of FACTS devices and is meticulous GTO thyristor-based technological power electronic device to be suggestd as serious aggressive alternative to conservative SVC [21]. A static synchronous compensator is a modifiable device used A C transmission networks. It is based on a high power electronics voltage-source converter and can be active as a source or sink of reactive A C power to an electrical network. It can also act as source of power if provided to active A C power requirement. It is also a member of FACTS devices. Usually a STATCOM is installed to support electrical networks which have a poor power factor and poor voltage regulation. The most common use of the STATCOM is to provide better damping characteristics than the SVC as it is capable for transiently exchanging active power with the system.

4.2. STATIC SYNCHRONOUS SERIES COMPENSATOR (SSSC)

This device works same as the STATCOM. It has a voltage source converter successively connected to a transmission line through a transformer. It is essential to provide a continuous voltage through a condenser and to recompense the losses of the VSC. A SSSC is able to switch over on active and reactive power with the

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transmission system. But if our aim is to balance the reactive power, the energy source could be quite small. The inserted voltage can be managed with phase and magnitude of voltage provided if an energy source much enough for the purpose. With hasty power recompense the voltage is convenient, because the voltage vector forms 90° with the line strength. In this case the sequential added voltage can delay or move ahead the line current. This denotes that the SSSC can be regularly controlled in any value, in the VSC working period.

4.3. UNIFIED POWER FLOW CONTROLLER (UPFC)

A unified power flow controller is the majority talented device in which the FACTS concept is available. It has the capability for adjusting three controllable parameters, (i) the bus voltage, (ii) transmission line reactance (iii) phase angle between two buses, either simultaneously or independently. The UPFC performs this function, through the control of the in-phase voltage, quadrature voltage, and shunt recompense. It is most adaptable and composite power electronic apparatus that has appeared for the control and optimize of power flow in power transmission schemes. It tenders major probable benefits for the stationary and active operation of transmission lines. The UPFC is devised for the actual-time control and lively recompense of ac transmission schemes, provide several functions elasticity required to solve many of the crisis facing the power industry. In the structure of customary power transmission thoughts, the so called UPFC is able to control, concurrently or selectively, all the factors influencing power flow in the transmission line. On the other hand, it can separately controls both the actual and hasty power flow in the line not like all other regulators.

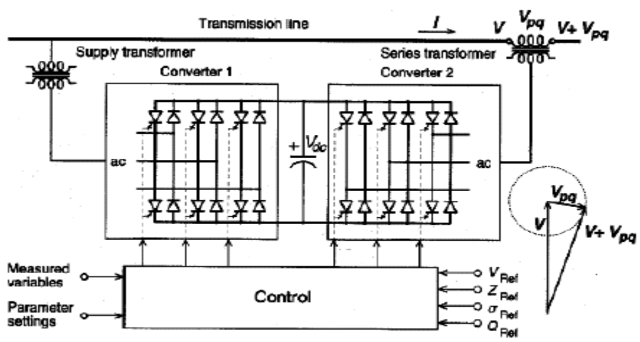

Fig – 3. Unified Power Flow Controller

5. TYPES OF NETWORK CONNECTION

5.1. SERIAL CONTROLLERS.

The serial controller consists of a changeable impedance consisting of condenser inductor or a variable electronics based source at a fundamental frequency. The function of all serial controllers is to inject a serial stress in the line. A uneven impedance will be increased by the current which flows through it to represent the serial pressure. While the tension is in quadrature with the line current the sequential controller only consumes reactive power; any other phase angle represents managing of active power. A typical controller is successive Synchronous Static Compensator (SSSC).

5.2. CONTROLLERS IN DERIVATION.

As it so happens that the sequential controller, consists the derivation which will have a variable impedance and a variable source or the combination of both. The derivational controllers inject the current in to the system at the point of connection/junction. And the variable impedance which has been connected to the line stress causes variable current flow, which represents an injection of current to the line. While the injected current

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will be quadrature to the line tension, the controller in origin only consumes reactive power; any other phase angle represents running of active power. A typical controller is called as (STATCOM).

5.3. SERIAL-SERIAL CONTROLLERS.

These controllers are the combination of synchronized sequential controllers in a several lines transmission system. Otherwise a unified controller which is also serial controllers provide the serial reactive compensation for each line and also transfers active power between the lines through the link of power. The active power transmission capacity which is presented by a unified serial controller or power fed through the line to controller, makes possible for the active and reactive power flow to balance and makes ultimately the use of transmission of power in high level. In such case, the term “unified "means various DC terminals of all the converters controllers are connected to achieve a transfer of active power between each other. A typical controller which performs this is the Interline Power Flow Compensator (IPFC).

5.4. SERIAL-DERIVATION CONTROLLERS.

It is a device with the combination of sequential and sources controllers which are separated and are coordinately controlled otherwise a unified power flow controller with sequential and source elements. The function of this controller is to inject the current into the system through the component in source of the controller, and serial stress with the line using the serial constituent. When the serial and derivation controllers are both unified, then they can exchange the active power between them through their links. controller which performs this is and is called as Unified Power Flow Controller (UPFC), which incorporates with filtering and air-conditioning units and becomes as a Universal Power Line Conditioner (UPLC).

6. APPLICATIONS OF FACTS CONTROLLERS TO STEADY STATE POWER SYSTEM PROBLEMS: For the sake of study review of the FACTS devices, the applications to other steady state power system performance problems are represented in this fragment. In particular the applications of FACTS devices in optimal power flow and deregulated of electricity market will be reviewed.

6.1. OPTIMAL POWER FLOW APPLICATION USING FACTS DEVICES: Since last two and half decades, researchers have been developed several new algorithms for the solution of optimal power flow problem which incorporates various FACTS devices [11]. In general in the case of power flow studies, thyristor controlled FACTS devices, such as SVC and TCSC, are commonly used and modeled as controllable impedances [4, 9, 10, 12-14]. though, the Voltage Source Converters is based on FACTS devices which is also included along with IPFC and SSSC, which are shunt devices. STATCOM, and UPFC, are more composite and typically modeled as controlling sources [4, 9,13-17, 20]. The Interline Power Flow Controller is one of the voltage sources of (VSC) which is also based on FACTS devices and can be efficiently managed the power flow by using multi-line Transmission scheme.

6.2. FACTS Applications to Deregulated

Electricity demand is rapidly increasing now a days with no major strengthening developments to improve power transmission set-up. Also, the electricity promotion is advancing towards open advertisement and de-regulation produces a background for strength of rivalry and negotiating. FACTS devices can be an alternative asset to reduce the flow of power in heavily loaded lines, by which load baring ability of line will increase, also the other advantages are low system loss, improved stability of the network, possible reduced cost of construction, and fulfils agreement obligations by managing the power flow in the system. Usually, the unstable nature of the electricity supply trading is to introduce many new subjects into power system operation related for trading in a deregulated aggressive sell. profitable demands on acquiring superior returns from live asset advises an ever more imperative role for active set-up of running FACTS devices and energy storeroom as an significant resource in generation, transmission, distribution, and consumption. There has been an increased applications of the FACTS devices in the electricity sell having group and deal transmit.

7. APPLICATIONS AND TECHNICAL BENEFITS OF FACTS

The technological advantages of the main dynamic uses of FACTS devices is in concentrating on different crisis in transitory steadiness, damping, post emergency voltage control and voltage constancy are reviewed in Table-1. The devices are required when there is a need to take action to dynamic set-up states. The predictable resolutions are usually cheaper than FACTS devices, but bounded in their active performance. It is the assignment of the conspirator to recognize the mainly financial resolution.

Table 1. Technical benefits of the main FACTS devices

	Load Flow Control	Voltage Control	Transient Stability	Dynamic Stability
SVC	●	●●●	●	●●
STATCOM	●	●●●	●●	●●
TCSC	●●	●	●●●	●●
UPFC	●●●	●●●	●●	●●

● → ●● → ●●● Better

8. CONCLUSION

The significant quality of FACTS devices and their potential is to get better structural dependability is the main concern for successful & cost-effective process of the power system. The position and reaction indications employed for the design of FACTS-based damped controllers were conversed. The synchronization crisis amongst dissimilar managed scheme was also judged. The presentation contrast of diverse FACTS devices have been reviewed. The probable prospect track of FACTS technology, was argued. Additionally, usefulness practice and chief authentic-world wise setting up and semiconductor expertise growth have been reviewed. A brief review of FACTS uses to the best power flow and deregulated electricity sell has been presented.

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