Analysing series and shunt compensation engineering essay

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Shunt compensation

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Shunt capacitive compensation

This method is used to improve the power factor. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt capacitor is connected which draws current leading the source voltage. The net result is improvement in power factor.

Shunt inductive compensation

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Theory

In the case of a no-loss line, voltage magnitude at receiving end is the same as voltage magnitude at sending end: Vs = Vr= V. Transmission results in a phase lag Î´ that depends on line reactance X.

As it is a no-loss line, active power P is the same at any point of the line:

Reactive power at sending end is the opposite of reactive power at receiving end:

As Î´ is very small, active power mainly depends on Î´ whereas reactive power mainly depends on voltage magnitude.

Series compensation

FACTS for series compensation modify line impedance: X is decreased so as to increase the transmittable active power. However, more reactive power must be provided.

Shunt compensation

Reactive current is injected into the line to maintain voltage magnitude. Transmittable active power is increased but more reactive power is to be provided.

Examples of series compensation

Examples of FACTS for series compensation (schematic)

Static synchronous series compensator (SSSC)

Thyristor-controlled series capacitor (TCSC): a series capacitor bank is shunted by a thyristor-controlled reactor

Thyristor-controlled series reactor (TCSR): a series reactor bank is shunted by a thyristor-controlled reactor

Thyristor-switched series capacitor (TSSC): a series capacitor bank is shunted by a thyristor-switched reactor

Thyristor-switched series reactor (TSSR): a series reactor bank is shunted by a thyristor-switched reactor

transmission line series capacitor compensator after the state of the system had more in-depth research, pointed out that some system problems, such as over-voltage level rise, arc current increases and the possibility of sub-synchronous resonance series capacitor compensator are derived from the inherent characteristics, through the study concluded that when the series compensated transmission line where an internal failure, such as the imposition of protective measures is triggered bypass gap was to avoid excessive levels of the system recovery voltage and arc current issues such as an effective way to increase. In addition, proposed the installation of series compensation stations to monitor sub-synchronous resonance suppressed or Secondary device to suppress and prevent system at subsynchronous resonance.

Keywords: series capacitor compensation; over-voltage; arc current; sub-synchronous resonance (SSR); transient recovery voltage (TRV); Power system

1 Introduction

Use of series capacitor compensation technique can improve long-distance transmission lines EHV transmission capacity and system stability, and the trend of the transmission channel on the distribution of a certain regulatory role. TCSC can inhibit use of the system low frequency oscillation and optimized systems to the trend of distribution;

However, the increase in the system changes the series capacitor compensation equipment, electrical system, the distance between the original, especially the high degree of series compensation, it may cause a series of system problems, and therefore pay for the project string of pre-study stage should such a possibility careful study and propose solutions to problems of the corresponding programs and measures. China Southern Power Grid is based on Guizhou, Yunnan and Tianshengqiao power grid for the sending side, through the Tianshengqiao to Guangdong’s three back to 500kV AC transmission line and a return to 500kV DC transmission line and by the end of the Guangdong power grid linked to the trans-provincial (regional) power grids, 2003 June Guizhou – Guangdong’s double-circuit 500kV AC transmission lines built and put into operation, China Southern Power Grid to form a delivery-side ‘ pay has been five’, by the end of ‘ four cross has been’ in the northern, central, south 3 west to east a major thoroughfare. As the scale of China Southern Power Grid to further expand west to east in order to enhance the delivery of these transmission channel capacity and the level of security and stability of the whole network and suppression system, low-frequency oscillation, it was decided that at Pingguo Hechi substation with the installation of controllable series compensation

(TCSC) and fixed-Series Compensation (FSC). Through the China Southern Power Grid Pingguo TCSC works and Hechi FSC systematic research on the works, the author of the EHV long-distance transmission system, the use of series capacitor compensation technique may be caused by system problems received a more comprehensive understanding of and summarizes the measures to solve these problems and programs

Series Compensation is a well established technology that primarily is used to reduce transfer reactances, most notably in bulk transmission corridors. The result is a signifcant increase in the transmission system transient and voltage stability. Series Compensation is self regulating in the sense that its reactive power output follows the variations in transmission line current, a fact that makes the series compensation concept extremely straightforward and cost effective.

Thyristor Controlled Series Capacitors adds another controllability dimension, as thyristors are used to dynamically modulate the ohms provided by the inserted capacitor. This is primarily used to provide inter-area damping of prospective low frequency electromechanical oscillations, but it also makes the whole Series Compensation scheme immune to Subsynchronous Resonance (SSR).

Fixed Series Compensation is since long the preferred solution when vast bulk transmission corridoors shall be optimized. Inserting a capacitive reactance in series with a long (typically more than 200km) transmission line, reduces both the angular deviation and the voltage drop, resulting in increased loadability and stability. The fact that it is the current through the transmission line that directly “ drives” the Mvar output from the capacitor, makes the compensation concept “ self regulating”, and this straightforward principle assures that Series Compensation is an extremely cost effective solution. It provides:

– increased transient (angular) stability of a power corridoor

– increased voltage stability of the grid

– improved voltage profile along the power corridoor

– optimized power sharing between parallel circuits

Series Capacitor installations are installed in series with a transmission line, which means that all the equipment must be installed on a platform that is fully insulated for the system voltage in question. On this steel platform, the main capacitor is located together with the overvoltage protection circuits. The overvoltage protection is a key design factor as the capacitor bank has to withstand the throughput fault current, even at a severe nearby fault. The primary overvoltage protection typically involves non-linear metal-oxide varistors, a spark gap and a fast bypass switch. Secondary protection is achieved with ground mounted electronics acting on signals from optical current transducers in the high voltage circuit.

SC Priniciple

In a transmission system, the maximum active power transferable over a certain power line is inversely proportional to the series reactance of the line. Thus, by compensating the series reactance to a certain degree, using a

Series Capacitor, an electrically shorter line is realized and higher active power transfer is achieved. Since the series capacitor is self-regulated, i. e. its output is directly (without control) proportional to the line current itself, it will also partly balance the voltage drop caused by the transfer reactance. Consequently, the voltage stability of the transmission system is raised.

The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power (SVC capacitive). Whensystem voltage is high, it absorbs reactive power (SVC inductive).

Thyristor-controlled reactor (TCR):

reactor is connected in series with a bidirectionalthyristor valve. The thyristor valve is phase-controlled. Equivalent reactance is variedcontinuously.

Thyristor-switched reactor (TSR):

Same as TCR but thyristor is either in zero- or full-conduction. Equivalent reactance is varied in stepwise manner.

Thyristor-switched capacitor (TSC):

capacitor is connected in series with a bidirectionalthyristor valve. Thyristor is either in zero- or full- conduction. Equivalent reactance isvaried in stepwise manner.

Mechanically-switched capacitor (MSC):

capacitor is switched by circuit-breaker. Itaims at compensating steady state reactive power. It is switched only a few times a day.

What are FACTS devices?

FACTS stand for Flexible AC Transmission Systems. The term “ FACTS” covers severalpower electronics based systems used for AC power transmission. FACTS solutions areparticularly suitable in applications, which require one or more of the following qualities:- Rapid dynamic response- Ability for frequent variations in output- Smoothly adjustable output- Fast implementation to achieve considerable increase in transmission capacity. 19

FACTS CONCEPTS SIMILAR TO HVDC

While some of the relevant technology i. e., Static VAR Compensation is already in wideuse, the FACTS concept has brought to the table a tremendous potential for thyristor basedControllers which will surely revolutionize the power system. The technology offers the utilities the ability to: 1. Control power flows on their transmission routes; 2. Allow secure loading of transmission lines to their full thermal capacity. FACTStechnology, while allowing use of transmission to its thermal capacity, does not do awaywith the need for additional transmission lines or the upgrading of existing lines wherethermal limits have been reached or when evaluation of losses added to the cost of FACTStechnology shows that new lines or upgrading of existing lines is the most optimumanswer. Often, ac transmission systems are thought of as being “ inflexible”. Power flow inac networks simply follows Ohm’s law and ordinarily cannot be made to flow alongspecific desired paths. As a result, ac networks suffer from parallel-path, or “ loop” flows. The power flows from source to load in inverse proportion to the relative impedances of the transmission paths. Low impedance paths take the largest fraction of flow, but all linesin the interconnection are a part of the flow path. Thus, utilities not involved in aninterchange power transaction can be affected. A fundamental notion behind FACTS is that it is possible to continuously vary theapparent impedance of specific transmission lines so as to force power to flow along a” contract path”. This is a brand-new concept for many system planners. As illustrated inFigure 1. 3, with precise control of the impedance of transmission lines using FACTSdevices, it is possible to maintain constant power flow along a desired path in the presenceof continuous changes of load levels in the external ac network, and to react in a plannedway to contingencies. Just as in HVDC applications, FACTS controls could be designed toEnhance the behavior of the uncontrolled systems. The flexible system owes its tighter transmission control to its ability to manage the interrelated parameters that constraintoday’s systems, including series impedance, shunt impedance, phase angle, and theoccurrence of oscillations at various frequencies below the rated frequency. By adding toin this way, the controllers enable a transmission line to function nearer its thermal rating. For example, a 500-kV line may have a loading limit of 1000-2000MW for safe operation, 20

but a thermal limit of 3000 MW. It is often not possible both to overcome these constraintsand maintain the required system reliability by conventional mechanical means alone, such as tap changers, phase shifters, and switched capacitors and reactors(inductors). Granted, mechanical controllers are on the whole less expensive, but theyincreasingly need to be supplemented by rapidly responding power electronics controllers. The new technology is not a single, high-power electronic controller, but rather acollection of controllers, which can be applied individually or collectively in a specificpower system to control the five interrelated functions already mentioned. The thyristor istheir basic element, just as the transistor is the basic element for a whole variety of microelectronic circuit. Because all controllers for the flexible transmission system areapplications of similar technology, their use will eventually benefit from volumeproduction and further development of high-power electronics. Electric power networksintegrate generation and load centers within each utility system and throughinterconnections among neighboring systems, share power with vast regional grids. Thepurpose of this is to take advantage of the diversity of loads, changes in peak demand dueto weather and time differences, the availability of different generation reserves in variousgeographic regions, power sharing arrangements among utilities, shifts in fuel prices, regulatory changes, and other discrepancies.

Applying Flexibility to the Electric Power System:

The power industry term FACTS (Flexible AC Transmission Systems) covers a number of technologies that enhance the security, capacity and flexibility of power transmissionsystems. FACTS solutions enable power grid owners to increase existing transmissionnetwork capacity while maintaining or improving the operating margins necessary for gridstability. As a result, more power can reach consumers with a minimum impact on theenvironment, after substantially shorter project implementation times, and at lower investment costs – all compared to the alternative of building new transmission lines or power generation facilities. The two main reasons for incorporating FACTS devices inElectric power systems are: 21

- Raising dynamic stability limits- Provide better power flow control

Neuro-Control Approach for Flexible AC Transmission Systems:

A neuro-control approach for flexible AC transmission systems (FACTS) based on radialbasis function neural network (RBFNN) is presented in this paper. The proposed schemeconsists of a single neuron network whose input is derived from the active or reactivepower or voltage derivation at the power system bus, where the FACTS device (in thiscase a unified power flow controller) is located. The performance and usefulness of thisapproach is tested and evaluated using both single machine infinite-bus and two machinepower system subjected to various transient disturbances. It was found that the newintelligent controller for FACTS exhibits a superior dynamic performance incompensation to the existing classical control schemes. Its simple architecture reduces thecomputational overhead, thereby real-time implementation. Benefits of FACTS: Whenimplemented on a broad-scale basis,

FACTS technologies deliver the following benefits.

- A Rapidly Implemented Installations: FACTS projects are installed at existingsubstations and avoid the taking of public or private lands. They can be completed in lessthan 12 to 18 months a substantially shorter timeframe than the process required for constructing new transmission lines.- Increased System Capacity: FACTS provide increased capacity on the existing electricaltransmission system infrastructure by allowing maximum operational efficiency of existing transmission lines and other equipment.- Enhanced System Reliability: FACTS strengthen the operational integrity of transmission networks, allowing greater voltage stability and power flow control, whichleads to enhanced system reliability and security.- Improved System Controllability: FACTS allow improved system controllability bybuilding “ intelligence” into the transmission network via the ability to instantaneouslyrespond to system disturbances and gridlock constraints and to enable redirection of power flows. 22

Flexible AC transmission system

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A flexible alternating current transmission system (FACTS) is a system composed of static equipment used for the AC transmission of electrical energy. It is meant to enhance controllability and increase power transfer capability of the network. It is generally a power electronics-based system.

FACTS is defined by the IEEE as “ a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability.”[1]

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Technology

Transmission on a no-loss line.

Series compensation.

Shunt compensation.

History

The first FACTS installation was at the C. J. Slatt Substation in Northern Oregon. This is a 500 kV, 3-phase 60 Hz substation, and was developed by EPRI, the Bonneville Power Administration and General Electric Company. [2]

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Examples of shunt compensation

Examples of FACTS for shunt compensation (schematic)

Static synchronous compensator (STATCOM); previously known as a static condenser (STATCON)

Static VAR compensator (SVC). Most common SVCs are:

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