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Improvement of Transmission Capacity by FACTS devices in Central East Europe power system

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Abstract: The increased demand for power transfer in combination with environmental and economic issues which set constraints to building new lines, force the implementation of new technologies into the existing system in order to improve its power capability. This paper investigates the use of specific FACTS devices and WAMS systems to maximize total transfer capability generally defined as the maximum power transfer transaction in Central-East-Europe power system. Optimal allocation and control of these devices will be very important for TSO or other power market regulators. Effectiveness, optimal allocation and utilization of phasor measurement units (PMUs) for different types of FACTS devices designed for power flow control and increasing transfer capacity were investigated. Paper also compares the economic aspects of these devices.

Keywords: WAMS, FACTS, power flow, transfer capacity, PMU

1. INTRODUCTION

By liberalization of the electricity market we have gained new opportunities and possibilities for electricity market participants. On the other hand, liberalization also causes considerable problems for operators of transmission system operators (TSO). Unsolved problem of our time is the constantly increasing number of unpredictable renewable energy in northern Europe and insufficient power generation in south. Due to unplanned power flow, the security criterion N-1 is unfulfilled cause of overloading of interconnecting transmission lines. This facts brings operation of existing transmission systems closer to their physical limits.

One of the opportunities for solving this problems was building of new power transmission lines or effectiveness utilization of existing transmission system capacity by utilization of specialized systems such as flexible alternating current (AC) transmission systems (FACTS). This special devices can perfectly control the power flow across transmission lines and helps operators to maintaining stable operation of power systems. In combination with sophisticated WAMS systems it can solve this problem.

Transmission system operators of each power systems talk about the need of increase of the reliability and safety of the power system. Transmission system operators sometimes have to manage the power system to its safety operational limits. Moreover, in some cases, it may also occur a large area outages (Black out), that have negative consequences for society as a whole. Due to the facts, the monitoring of power systems are made through a SCADA (Supervisory Control and Data Acquisition) systems and EMS (Energy Management Systems), which do not work in real time and thus the results are not applicable for fast transient processes occurring in the system. Moreover, both these control schemes are not time synchronized.

2. WIDE-AREA MONITORING SYSTEM

First PMU (GPS based) was invented in 1988. Synchrophasor technology has developed for the last few years. During this time, it was designed and implemented by advice promising new concepts, such as the wide-area measurement / monitoring system (WAMS). It brings huge potential for the modernization of the management, operation, supervision and protection of energy systems.

WAMS (Wide Area Monitoring System) systems is synchronous measurements of phasors and mainly used in the transmission lines.

Furthermore the surface monitoring and visualization of the network in real time or consequential off-line analysis of the operating situations These subsystems are used also for monitoring of system stability, operational management of the network and early warning systems. Application of WAMS systems can also be found in distribution networks, for example in the management of distributed energy resources. Synchronous measurement error generally decreases in subsequent calculations and control systems, resulting in an improvement of dispatching management network.

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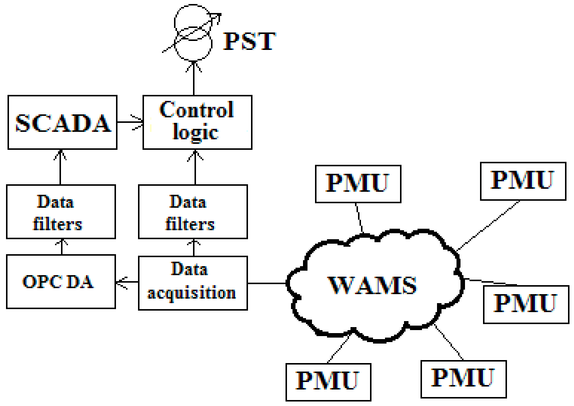

Fig. 1. PST control scheme with WAMS

Use of PMU for data acquisition for regulation of FACTS devices can bring new possibilities for further development of the network control. Measurement of phasors at different part of the power system, can be used for optimization of power flow, minimize power loses or to maximize transmission capacity between various TSO. Example of utilization of WAMS for control of phase shift transformer is shown on Fig 2.

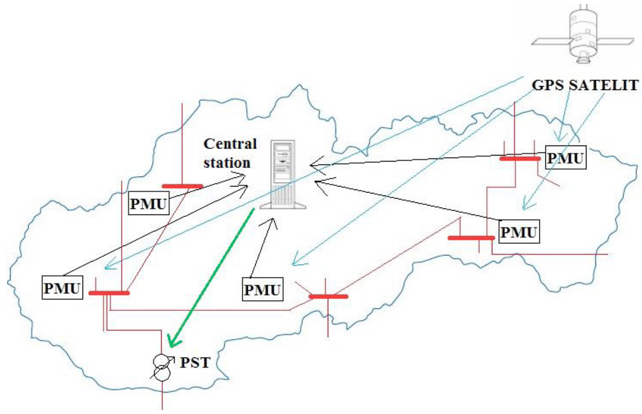

Fig. 2. Slovak power system with PMUs and PST.

3. PHASE SHIFT TRANSFORMER

Phase shift transformer is mainly used for active power flow control at the interface between two large independent power systems.

Phase-shifting transformers are mainly used to control the active power flow in related networks or to control the active power flow at the profiles between two large and independently controlled power systems.

PST transformer principle is based on the use of adjustable angle ratio of the transformer. Winding of the serial unit is connected directly into HV level (e.g. 400 kV), in which the phase angle is controlled. It means, that the overall voltage is consists of primary voltage and phase shifted (additional) voltage. Regulating transformer with tap changer is supplied from serial unit (Fig. 3).

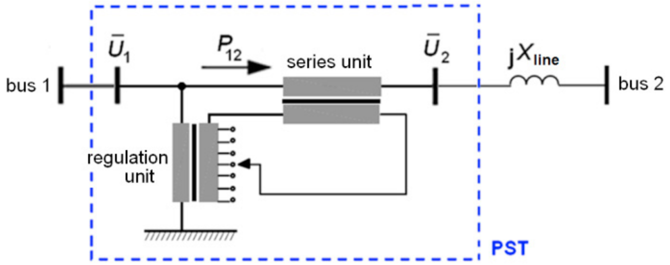

Fig. 3. Simplified scheme of PST

Key parameters for any transmission line, determine the line impedance, power flow: phase angle between the starting and receiving nodes and terminal bus voltages. U_1 and U_2 are magnitudes of the bus voltages at both ends of the line with the angle $\delta = \delta_1 - \delta_2$ among them. The impedance of the line is marked as X_{12}. In this case, the expression for active power flow across transmission line is: (1)

$$P_{12} = \frac{U_1 \cdot U_2}{X_{12}} \cdot \sin(\delta_1 - \delta_2) \quad (1)$$

If the PST is inserted in to outgoing feeder, the transferred power flow by transmission line is given:

$$P_{12} = P_{12} \pm \Delta P = \frac{U_1 \cdot U_2}{X_{line} + \Delta X} \cdot \sin(\delta_1 - \delta_2 + \Delta\delta) \quad (2)$$

where:

ΔP – additional power flow due to PST regulation,
ΔX – additional reactance in PST outgoing feeder,
$\Delta\vartheta$ – angle between primary and secondary voltage of PST.

In case, when the phase shift between primary and secondary winding equals zero ($\Delta\delta = 0°$), the power flow across the line with PST is limited only by its own reactance ΔX .

Without PST, the loading angle is $5° - 10°$. The maximum regulation range of Phase shift transformer is $\Delta\vartheta = 30° - 40°$.

Control angle of phase shift transformer has a significant impact on the power flow across transmission line. Function $\sin(\delta_1 - \delta_2 + \Delta\delta)$ can be considered as linear in operation area. Hence, the regulation angle $\Delta\delta$ is proportional to tap setting, the resulting flow of active power influenced by regulation of taps will be in proportion with tap setting of PST.

Impact of PST on power flow can be simply demonstrated on a power flow analysis in simply case of parallel lines according to the following figure.

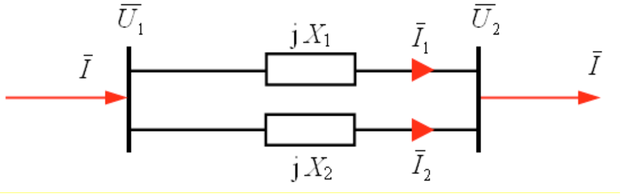

Fig. 4. Network with parallel lines