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Assessment of techno-economic contribution of FACTS devices to power system operation

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ABSTRACT

In contemporary power system studies, the optimal allocation and utilization of Flexible AC Transmission System (FACTS) devices are important issues primarily due to their cost. In this study four types of FACTS devices (Static VAr compensator (SVC), Thyristor-Controlled Series Capacitor (TCSC), Thyristor-Controlled Voltage Regulator (TCVR), and Thyristor-Controlled Phase Shifting Transformer (TCPST)) are optimally placed in a multi-machine power system to reduce the overall costs of power generation. The placement methodology considers simultaneously the cost of generated active and reactive powers and cost of selected FACTS devices for a range of operating conditions. The optimal power flow (OPF) and genetic algorithm (GA) based optimization procedure are employed to solve the allocation task. The net present value (NPV) method is used to assess the economic value of the proposed methodology. In addition to net reduction in generation cost allocated FACTS devices increased power transfer across the network and improved damping of electromechanical oscillations.

1. Introduction

Power transfer limits and directions in transmission system are constrained by thermal capacities of transmission lines (i.e., the material of the line) and voltage magnitude and voltage angle deviations across the line. In case of short lines the first limit that is typically reached is the thermal limit of the line governed by material of the line. In case of medium length lines the voltage magnitude at the receiving end reaches the statuary lower limit, i.e., drops typically below 0.9 p.u. or 0.95 p.u. (limit varies depending on voltage level and country), before the thermal limit of the line is reached and such limits further increase in power transfer. This is generally referred to as voltage stability limit which, if exceeded, might lead to improper operation or disconnection of end-user devices and ultimately to wide spread black-outs. Finally, in case of long transmission lines, voltage angle at the receiving end is the first that hits the limit and restricts further increase in power transfer due to endangered angular stability of the system. The thermal limits of the line are most difficult to alleviate as this would require change of material of the line (new conductors). Voltage and stability limits, however, could be increased by modifying line impedance and admittance and additional control of voltages and currents. FACTS devices offer possibility to influence line parameters (series and shunt impedances) and currents and voltages across the line and such increase allowed power transfer over existing lines without endangering system security [1]. Changes in power flows in the system, however, affects the generation scheduling and such could lead to different economics of power generation.

FACTS devices installed in existing power systems have been successfully used for several purposes including congestion management, reactive power support and enhancement of system damping. Their use has been evolving ever since the Electric Power Research Institute (EPRI) introduced this technology, in 1980s. Several studies, based on OPF calculations, were carried out to determine the optimal placement of such devices in the system in order to get the most out of their capabilities, e.g., [2,3]. Some of the previous studies [4–7] took into account the cost of FACTS devices as well, and showed that they could be a cost effective solution. Generally, there are still very few studies [8–10] of economic benefits arising from installation of FACTS devices.

The review of the past research identified that the economic contribution of FACTS devices was not thoroughly examined. There are a few studies, compared to the large volume of the researches in the area, that did consider the cost of FACTS devices though not in a comprehensive way that could justify the installation decision in a long run. Furthermore, these studies did not consider a wide range of operating conditions in order to ensure the robustness of the device installations. Moreover, a panoramic overview for the

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