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Transmission Congestion Management using Phase Shifter

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Abstract - *Completion of de/re-regulation in other sectors of market also galvanized the re/de-regulation of the power sector. Over fast few decades, regulation of the power sector has been examined all around the world. New era of power market, transmission networks are not progressing at a required rate to withstand the growing in demand. Because of limited capacity of transmission network, and to accommodate all request for the power transmission service within the available corridor which leads to a state called as congestion. State of transmission network for which system unable to coordinate all transactions due to their physical and operational constraints this situation is known as Congestion.*

Here, hybrid modelling of (phase shifting transformer in any hybrid system, which consisting offer renewable energy (winding), battery energy storage system (BESS) hand conventional thermally generation) is proposed, which effectively takes predictable uncertainty offer winding generation, energy storage band demand, ramping limited band thermal capacity offer thermally generation care also taken introduce consideration. Performance offer PST examine their effect phone locational marginality price (LMP), winding powder curtailment banded it's economically benefit, sensitivity analysis this also performed tools recognize their influence offer phase shifting transformer pin decongestion alleviation.

Key Words: Phase shift transformer (PST), FACTS devices, GAMS Optimization, Congestion, Battery Energy Storage system (BESS).

1. CONGESTION IN TRANSMISSION NETWORK

In current years, power sector hast been shifted from a vertically integrated structure to a deregulated form. This procedure is envisioned they sector with the decisive goal of dropping consumer tariffs. The knowledge of de and re-regulation in this sector desires to entirely reasonable although job of the transmission network is expected to endure as a controlled domination [1]. The shift of the electricity sector from re to de-regulated leads to numerous operative and regulatory matters concerning the operation of transmission grid and its planning. In a liberalized environment, transmission system has not developed at the similar irate which is necessary to endure rising demand. This inadequate power transfer capacity can be improved by building the new transmission lines, but this is not as easy as it seems. The struggle in accomplishment of consents related to rightly off wary duet two property depreciation hand the capitalist costly tangled in the maintenance and construction of news lines. Furthermore, the introduction of the transmissions systems as a mutual carrier in an openly-access environment, leading too concentrated usages of transmissions infrastructure. This triggered unexpected bottlenecks likely congestions, depressed voltages stability boundary hand suboptimal operations off they existing infrastructure. Transmission congestion significantly reduce the competition by forming areas of the system and work with limited generation sources. [2] Congestion sometimes, also result in loss of load due to a line outages. Therefore, the prime objectives off transmission systematic operators (TSO) is too operate system securely and congestion free.

1.1 Issues in Power Systems hand needing four Congestions Managements

As the electricity dependency increases, number of interconnections also increases which results in highly dense network. Because of nature of electricity which choose least impedance flow path, few lines are under loaded and remains are overloaded. Uncertainty in demand will also cause problems in both transmission and distribution systems. EPRI (Electric Power Research Institute) developed FACTS devices to increases they powder transfer and controlling capability [3].

To make it controllable electronically, FACTS devices are based in combination with power electronic devices. The main objectives of these devices are to enhance the network available capacity, power flow and alleviate disturbances. A group of FACTS controller/devices are evolving in high voltage, owing to several technical and economic benefits and supported by many manufacturers and utilities around the world [4].

1.2 Transmissions Congestions Managements

Energy markets are relatively complex with the participation of many sellers and buyers in electricity trading. Complexity further increases due to limitations of the transmission network capacity and to maintain the uninterrupted balance between demand and supply. Increasing demand and underlying capacity of the transmission networks leads to a problem known as "Transmission Congestion". [5]

The FACTS devices comes into picture to provide the fast and dynamic capabilities to the transmission network to enhance the transmission capacity [6]. FACTS devices involve high cost of installation includes operation and capital cost, thus their optimal allocation, size and setting play significant role in utilizing maximum benefits. In order to control the active power flow by regulating the difference between voltage phase angles of two nodes of the systems phase shift transformer (PST) is used, which also enhance the transmission network efficiency. PST is a type of autotransformer which shifts the phase angle between in and out lines with inferring the ratio of voltages. It helps in enhancing the efficiency, and ensuring the efficient and reliable operation of the transmission network. Since power flow through the line depends on the voltage phase angle, thus enables the phase shift transformer to regulate the line flow.

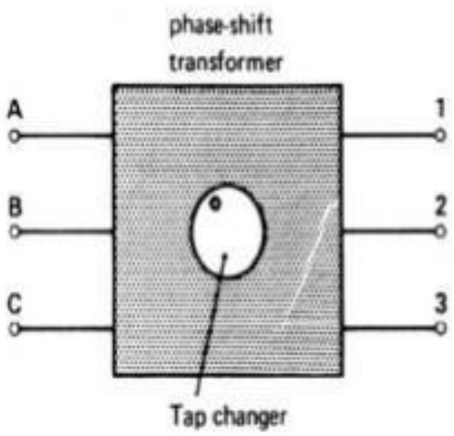

Fig - 1 : Phase Shift Transformer

2. PST Control Methods

There are four types of PST control methods.

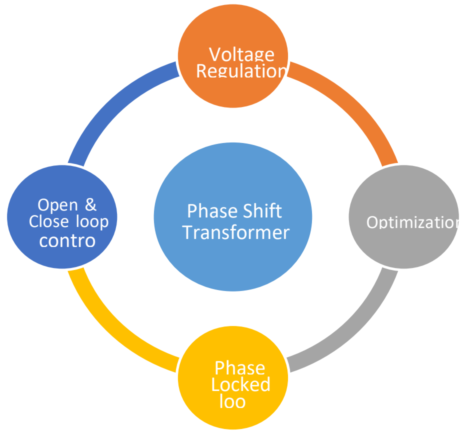

Fig - 2 : Methods of Phase Shift Transformer Control

2.1 Open & Closed Loop Control

Various power system operating on different conditions. It's mandatory to connect different systems as growing power need around the world. For this reason, high voltage direct current is used for interconnection of different system. For an asynchronous systems power flow control, variable frequency transformers (VFT) are used. VFT working principle is same as of Phase Shift Transformer power flow control and design is based on rotary machine. Thus, a varying phase shift like PST is obtained [7].

2.2 Voltage Regulation

In general, PSTs are used to control power flow. In recent years, they are also used for voltage regulation and for correction of phase shift in case of interconnected networks. PST working principle is generating a voltage from phase and inject in series to system voltage. With PST voltage regulation is performed to maintain balance between source and load side.

2.3 Phase Locked Loop

STATCOM (static synchronous compensator) is a shunt connected device, used for voltage regulation by consuming or producing the reactive power and that operate in combination with Voltage Source Inverter. This convertor is consist of four 3-phase and 3-level of inverter and four phase shift transformer. Inverter voltage is feed to the secondary of the phase shift transformer [8]. STATCOM control based on current control strategy full - decoupled with supplementary synchronous damping controller.

2.4 Optimization

The Optimization act as important part in control of phase shift transformer. Several optimization methods are utilized for the phase shift transformer [9], the coordination and allocation of phase shift transformer. Particle swarm optimization, particle swarm optimization, optimization based on analytics, genetic and fuzzy genetic algorithm, optimization having multi-objectives and multi-objective differential evolution, differential evolution, gravitational search and flow-based market coupling algorithm, and selective harmonic elimination are the different optimization methods utilized for the phase shift transformer.

2.5 Case Study

2.5.1 Test System Description

To show the applicability and efficacy of the projected model, it is applied on the IEEE RTS 24-Bus system. The modified IEEE 24-bus has 12 thermal units and 34 transmission lines, wind and battery energy storage which is depicted in Figure 4. The system data and characteristics are mentioned in appendix with some modifications including the power line limits. Table 1. Note that the demand in increased by 30% to consider the worst case and also to show the effectiveness of the method in congestion management. Figure 3 shows the variation curves of wind, and demand hourly. ESS parameters are given in Table 2.

Lines/Branch	Limit(MW)
1-2, 1-3, 1-5, 2-4, 2-6, 3-9, 4-9, 5-10, 6-10, 7-8, 8-9 and 8-10	122.5
3-24, 9-11, 9-12, 10-11 and 10-12	280
11-13, 11-14, 12-13, 12-23, 13-23, 14-16, 15-16, 15-24, 16-17, 16-19, 17-18, 17-22 and 21-22	350
15-21, 18-21, 19-20 and 20-23	700

Table – 1: Lines Limits

Parameter	Values
SOC_0	100 MW
SOC_{max}	300 MW
pd_{max}	0.2 SOC_{max}
pd_{min}	0
pc_{max}	0.2 SOC_{max}
pc_{min}	0
n_c	95 %
n_d	90 %

Table – 2: Lines Limits

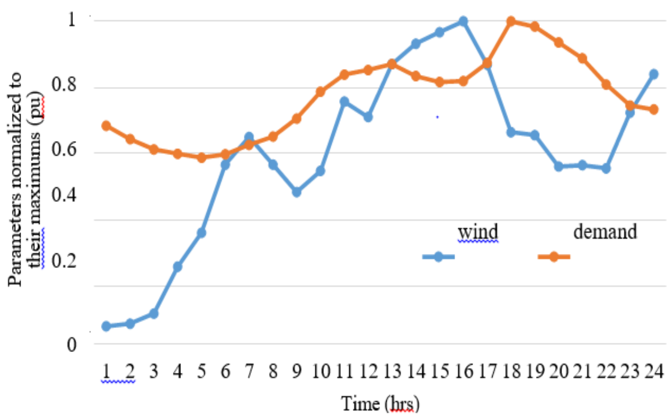

Fig – 3: Hourly variation of the Parameters

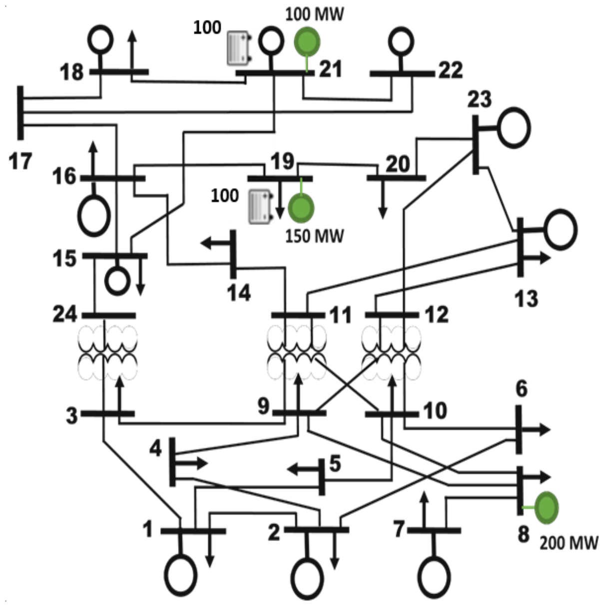

Fig -4: Modified IEEE RTS 24-bus test system

2.5.2 Impact of phase shifter on System operation and congestion

The economic benefits of adding of phase shifters are presented in this section. The operating costs are shown in figure 5, which decreases from $ 498000 for case 1 to $418320 & $418090 for case 2 & 3.

In test case, we analyzed the system with and without phase shifter. Results shows the investment in phase shifter increase the system efficiency, lower the costs (operating & congestion) and make system further reliable. Capital costly and feasibility may be considered to obtain more practical results with some developed formulation.

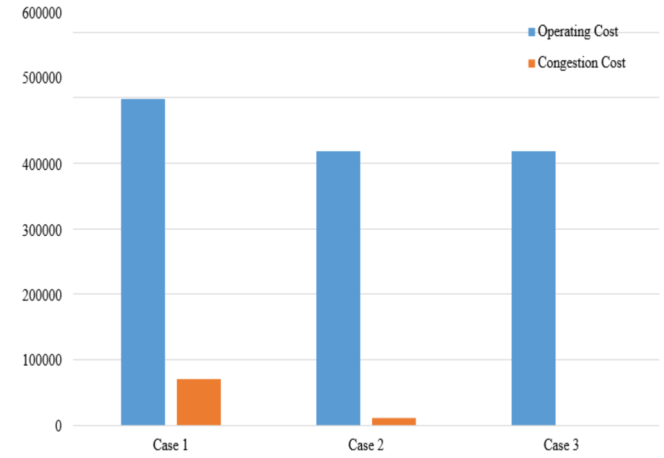

Fig -5: Comparison of Congestion & Operating cost for Different Cases

2.5.3 Impact of phase shifter on BESSs operation

In this research there is no, direct impact of phase shifter on the operation of BESS. But in AC – optimal power flow formulation (impact of BESS), phase shifter is employed to manage the charging and discharging operations of the BESS based on power generated by thermal and renewable output power and battery voltage. Phase shifters protect the battery energy storage from being over charged and discharged.

2.5.4 Sensitivity of the power flows to Phase shifters

Transmission network operating with PSTs and it is concluded that action imposed by single PST unit will leads to changes in line flow of the network. The changes could be severe, less or even negligible.

Line flow in which PST accounted is directly relate with PST tap position. Moreover, tap position effect on the line flow depends on generation and demand at the moment. The variation of 'line shift factor' or 'phase shift distribution factor' (PSDF) for the line in which PSTs are installed shown in fig -6.

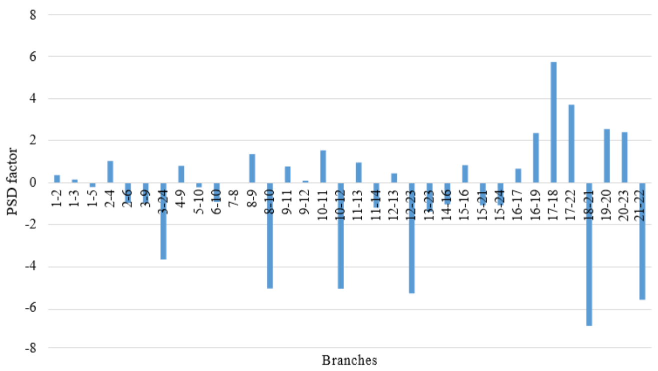

Fig -6: Variation of Phase Shift Factor

4. CONCLUSIONS

There is any needed for better utilization of their existing transmission infrastructure to meet out the growing demand. Facts devices care used two increase the line capacity of the existing transmission system. In this work, Phase-shifting transformer as a phase shift is utilized to mitigate the transmission congestion.

A mathematical model of security constrained economic dispatch integrating PST with wind energy and BESS. The case studies confirmed the efficacy of the model proposed and the advantages of phase shifters. It permits entree two future generation (predominantly renewable) resources which roots considerable cost saving in power production. From results, it is clear that PST can mitigate congestion by readdressing the line flow. The proposed methodology offers an alternative to the system in making critical decisions, system operational planning tool inn their days ahead has welling bas longest termed planning, banded any levelling off flexibility two operated their systematic closer to its limits.

In this work, the study this carried out for the steady-state condition i.e. their fixed proportion of the renewable generation (wind), however, in the interest of exhaustive study, the effect of incremental change in wind generation is planned to be considered. The planned work is a separate research topic and is a time consuming work and hence k it is to be included in the future scope of this work. The effect of the incremental rise in the renewable generation can be considered with a fixed conventional generation.

By changing the proportion of renewable to conventional and applying the same logic the study may be readily extended near any real-world systematic with any higher number off buses.

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