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CONTROL STRATEGIES FOR POWER QUALITY IMPROVEMENT IN MICROGRID

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ABSTRACT:

Transformers are an essential part of the electrical grid and provide a number of functions, such as voltage conversion and electric isolation. It serves as both a series and shunt transformer in the Power Quality Conditioners. When employed at low frequencies, the transformer is substantial and expensive. The performance and maintenance of the existing 50 Hz power transformer are restricted in many applications, such as wind energy conversion, electric ships, and power quality conditioners, due to its enormous weight and mass. This limitation is lifted by replacing the big transformer with the smaller transformer. Since it is achieved by increasing the transformer's working frequency. Since changing the working frequency is both feasible and inexpensive, and there is a good possibility that the Power Electronic Converter will be built for high-frequency operation, it is employed. The power electronics-based transformer concept has advanced greatly because of its adaptability, small size, and higher power handling capacity.

1 Introduction

Initial magnetization current, or the transformer's inrush current, flows through the main side of the transformer during transformer energization (Faulkenberry & Coffer 1996). Large inrush currents are generated in the transformer as a result of the saturation of the core. Inrush currents are produced as a result of the transformer's reactance being unusually low as the transformer core saturates. As a result, the system's equipment is built to withstand these first inrush currents.

Higher magnetic flux density B and magnetic field strength H cause the B-H curve to become nonlinear, although it remains mostly linear close to the origin. As a result, the core's non-linear characteristics are predictable. The B-H curve is non-linear, causing the flux in the core to lag the main voltage by 90°. As a result, the magnetising current also becomes non-linear, forcing a sinusoidal flux in the core. The harmonic content of this magnetization current might cause the transformer output voltage to distort.

By extending the capabilities of the conventional power transformer and enhancing its operating characteristics, the power electronic based transformer improves upon the aforementioned drawbacks of the conventional power transformer and allows it to work better in the power supply system. As a result, it enhances the quality and dependability of the power supply.

It is suggested that the standard distribution transformer be replaced by the PET. By using power electronics on both the primary and secondary sides of the transformer for the high-frequency functioning of the transformer, the PET offers a fundamentally new and more comprehensive approach to transformer design. The size of the transformer is greatly decreased when the transformer core is operating at high frequencies. Low-frequency and high-frequency transformer sizes are contrasted.

At the input side of the high-frequency transformer, the PET has a high-frequency power electronic converter that converts incoming alternating current (AC) voltage to a high-frequency signal. A high-frequency transformer is used to produce galvanic separation. The necessary voltage is produced by a low-frequency power electronic converter on the high-frequency transformer's output side. Thus, an output signal that has the same output frequency as the line frequency is formed. In order to minimise the size of the transformer, high operating frequency power electronic technology, or PET, is created.

PET is sometimes referred to as an intelligent universal transformer, a solid state transformer, or an electronic transformer. It is a new kind of transformer that transforms the voltage of the power system by transferring energy utilising power electronic technology. Power electronic converters and high-frequency transformers make up the majority of a PET.

The conventional transformer works fairly well for its intended purpose. However, the conventional 50/60 Hz transformer is insufficient for the future energy systems, which need extra capabilities (in addition to stepping up or down voltages) (she et al. (2012); Kolar & Ortiz (2014)). Examples of these features include the following:

2 Literature Survey

Momentary overload of the transmission components causes congestion in the system, but if it is not well controlled, it might lead to the breakdown of vital gearbox pathways, endangering the system's security. To ensure that permitted contracts do not clog up the market, not even in an emergency, due caution must be taken while executing contracts in a day-ahead market. The system operator is in responsibility of figuring out what has to be done to ensure that network constraints are not broken in a deregulated power market. The control of congestion in the deregulated electrical system has been the subject of various efforts during the last three decades. This chapter reviews the many approaches of mitigating congestion that have been discussed in the literature.

The transmission network is often subject to a variety of restrictions, including stability limitations, voltage limits, and heat limits, the majority of which are applicable at any one time, in order to operate the electric network safely. The increased demand for power throughout the world forced the electrical utilities to increase output. After deregulation, the primary objective of the electrical utilities is to efficiently and economically manage this vast electric power network. The least expensive price generator is given precedence in order to economically meet demand. With an increase in the amount of power flowing through the gearbox lines necessary for optimal operation, there is a greater chance of exceeding the limits. The system is deemed to be congested once this threshold is achieved [1]. The electrical system must function under a set of constraints to maintain network security;

ISSN: 2057-5688

when these constraints are breached, there are massive outages that have detrimental social and economic effects. Therefore, controlling the transmission network for congestion management is the most crucial problem [2]. System operators often use rescheduling, load reduction, and active and reactive power assistance to reduce congestion. The market operator in a deregulated system uses the resources almost to their rated capacity as each participant tries to optimise his or her profit [3]. Therefore, in a deregulated environment, rescheduling is the system operator's more general approach [1]– [4], with load curtailment as the operator's last resort. Congestion reduction becomes a challenging problem when power transactions experience unpredictable fluctuations. The optimal generator selection is thus necessary for the distribution of power in a congested line to lessen congestion. The most common method for managing congestion in big power networks has been described in [5]–[10], and it entails selecting the generator with the best rescheduling based on the generator sensitivity index. The generation is either increased or decreased during rescheduling to maintain network congestion. The technological advancement of the power system has led to the widespread usage of Distributed Generators (DG) for congestion management in recent years [11–14]. Instead of using a traditional central power plant, DG is used to fulfil local load [15]. Among the many DG kinds are fuel cells, wind, photovoltaic (PV), geothermal, biomass, and gas turbines. The technical advantages of DG penetration include congestion management, voltage profile improvement, loss reduction, and system reliability. Benefits of DG may be attained if they are put in the optimal location and size, which are more evident in more crowded regions [16]. Incorrect installation might lead to a network's collapse, which would be very bad for society and the economy.

In a deregulated environment, network congestion produces a significant variation in Locational Marginal Price (LMP), which may be used to gauge the level of network congestion. In markets like NYISO, CAISO, etc., the LMP pricing approach is often used. Costs for electricity, traffic, and network losses make up the price in LMP. LMP at each

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bus alters as a consequence of growing losses and congestion. LMP values are greater in crowded locations than in non-congested areas [17]. When the demand exceeds the transmission capacity, DG may transmit power in a certain route at a specified time, which might have a significant impact and be very helpful in reducing LMP disparity. Congestion management was addressed by the authors of [18] by carefully locating and scaling DG. The optimal size was determined by setting the DG at the largest LMP node and reconstructing the OPF while taking into consideration the cost function. The results show that the LMP was considerably reduced. After that, authors in [12] made the case that the highest LMP method would produce congestion on other lines and provided a transmission congestion rent (TCR)-based strategy for the appropriate placement of DG. According to the authors' analysis of the optimum size of DG, the size that produces the greatest amount of social benefit is thought to be the best size for DG. The results show that the LMP difference was greatly minimised. The authors [17]–[19] recommend a TCR-based approach and get extremely good findings for the appropriate placement of DG and FACTS. All of the authors discussed in this paper used different methods to find the best sites, but they gave little thought to choosing the appropriate DG size. Either they adjusted the OPF by including DG cost factors, or they determined the DG size after weighing all possible sizes.

3 Methodology

"Electricity for all by 2012" is the proclaimed objective of India. Installing a significant amount of generating capacity is required to increase Indians' per capita energy demand to above 1000 units by 2012 [2]. In addition to expanding generation, transmission and distribution network capacity also has to be increased. To do this, it is necessary to use the limited financial resources and get over sociopolitical barriers.

The transmission lines become more loaded as power demand rises, which might result in voltage collapse owing to a lack of reactive power provided to the load centres. This is brought on by the load's characteristics as well as the increased consumption of reactive power in the transmission lines and distribution systems. Generator rotors may swing as a consequence of disturbances on transmission or distribution networks, which contributes to power swings in the transmission lines. The system may exceed the transient stability limit when more power is transferred.

By having enough margins in the power transported through the transmission lines, the stability issue of the power system was solved using electro-mechanical switchgear and reactive power controllers. In order to have an efficient and secure operation, the notion of delivering additional power across the transmission lines became incompatible. Fast dynamic control over reactive and active powers introduced by power electronic controllers may significantly lower the necessary safe operating margin. Because of this, the ac transmission network is more 'flexible' and may change to accommodate the variable circumstances brought on by contingencies and load situations. The FACTS (Flexible ac Transmission Systems) controllers are a kind of power electronic controllers that improved controllability and boosted power transfer capabilities over existing lines. A line may transport electricity closer to its thermal rating thanks to FACTS controllers.

The brain of the DSTATCOM is the CC-VSC (Current Controlled Voltage Sourced Converter). A reverse diode is connected across the self-commuting solid-state controlled turn-off components (GTO, IGBT, IGCT, etc.) in the VSC configuration. The inverter action is handled by the controlled turn-off devices, while the rectifier action is handled by the diodes. The solid state devices are either run in PWM mode, which uses high switching frequencies throughout an operating cycle, or in square wave mode, with switching occurring once every supply cycle. It is also possible to apply selective harmonic elimination modulation with low switching frequencies.

A source of energy is ideally not needed on the VSC's dc bus since it is only required to produce or absorb reactive power. To keep the dc voltage constant, a capacitor is mounted on the dc bus. The DSTATCOM functions as an inductive load, pulling current from the

ISSN: 2057-5688

supply bus when the voltage produced by the VSC is in phase with and lower than the voltage of the system bus to which it is attached. When a DSTATCOM's produced voltage is greater than the system voltage, however, it behaves as a shunt capacitor and generates var into the supply bus. The DSTATCOM's losses are often covered by active power taken from the power system.

4 Experiments & Results

In order to increase voltage stability, the power system is run under contingency conditions. Continued power flow is implemented, the maximum loading parameter is discovered, and a weak bus is thus discovered where SVC is linked. To identify the weakest bus, the Fast Voltage Stability Index (FVSI) is computed. For the two bus system shown in Figure 3.2, the FVSI calculation is given.

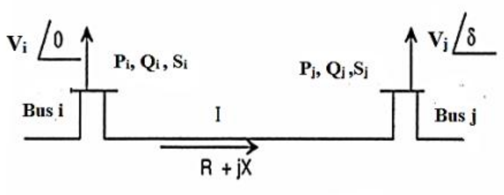

Figure 4.1: Two bus system

$$\text{FVSI}=\frac{4Z^2Q_j}{V_i^2X}$$

Where X : transmission line reactance,

Z : transmission line impedance,

V_i : Voltage at sending end

Q_j : Reactive power at receiving end

FVSI's value ranges from 0 to 1. The weakest transmission line and bus connecting to it are identified by values of this index that are closer to 1. To prevent additional voltage collapse, SVC might be linked to the bus with the least strength. Voltage stability is ensured under normal circumstances and even after a contingency situation by connecting SVC at the ideal position. Connection of SVC at ideal position enhances the factors covered below.

Voltage stability margin is calculated while load is steadily raised. The maximum load that a power system can support and at which voltage stability is maintained while the voltage at each bus is within safe limits. Voltages are not within limits after the critical point, which is indicated by the maximum loading parameter, and voltage stability is affected. CPF may determine this maximum loading setting.

ISSN: 2057-5688

After attaching SVC, the voltage at bus number 6 increased from 0.91 pu to 1 pu. Bus number 6 is discovered to be a weak bus.

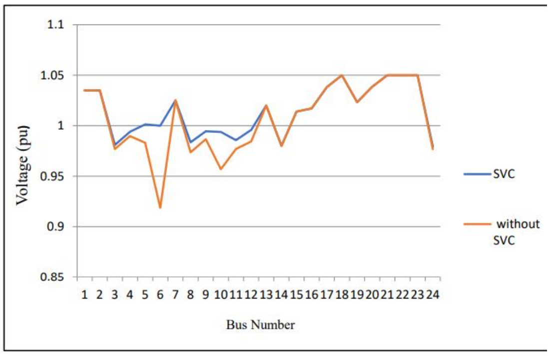

Figure 3.6: Voltage Profile comparison

The Line Utilisation Factor (LUF), which assesses whether a given line is over or underutilised, is the ratio of the line's actual power flow to its rated power flow. all transmission lines LUF

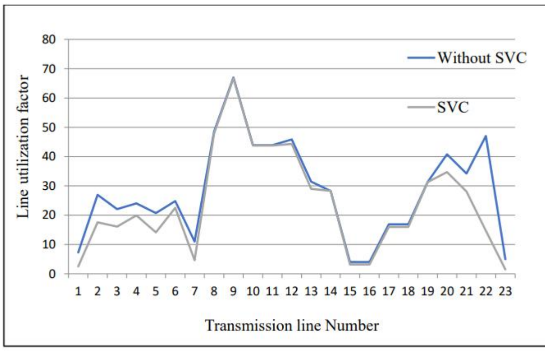

Figure 4.2: Line Utilization Factor

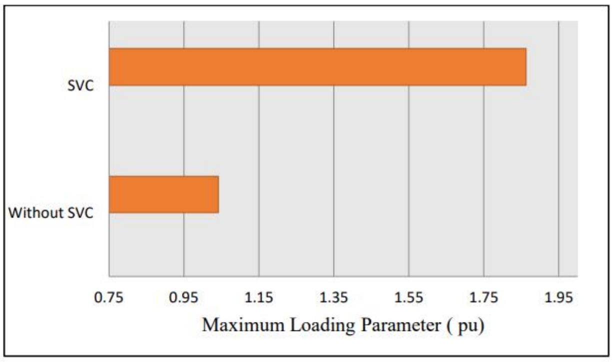

Figure 4.3: Maximum Loading Parameter (pu)

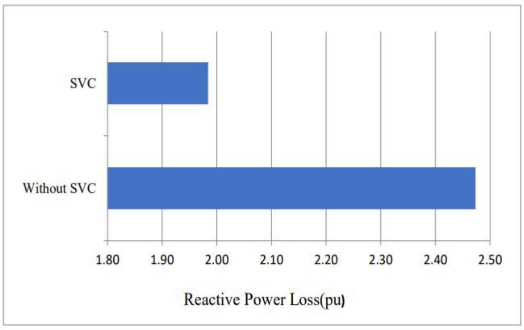

Figure 4.4: Reactive Power Loss (pu)

5 Conclusion

The optimal location of the SVC is determined in this study using the CPF analysis and the FVSI index. Bus 10 has been recognised as the weakest bus, and SVC has been connected to that bus to increase the system's voltage stability buffer in both normal and emergency situations, reduce power losses, and increase the loading parameter. The goal of congestion management is to increase social welfare and SVC. The hourly rate for social assistance has increased from 1700 to 2710. There are also higher voltage levels, LMP, and line usage factors. The maximum loading parameter has increased from 1.04 pu to 1.86 pu.Additionally, real power loss is reduced by 90.6%, and reactive power loss is decreased by 80.2%. This proposes enhanced congestion management, higher voltage stability, and the operation of the most trustworthy and economical power system.

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