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REVIEW ON INFLUENCE OF THE TRANSFORMER TAP CHANGER ON VOLTAGE STABILITY

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ABSTRACT: Electricity market activities and a growing demand for electricity have led to heavily stressed power system. This requires operation of the network closer to their stability limits. Power system operation of the network closer to stability related problems, leading to unpredictable system behaviour. Voltage stability refers to the ability of the system to sustain appropriate voltage levels through large and small disturbances. Steady state voltage stability is concerned with limits on the existence of steady state operating points for network. Facts devices can be utilized to increase the transmission capacity, the stability margin and dynamic behaviour or serve to ensure improved power quality. The main capabilities are reactive power compensation, voltage control and power flow control. The work proposed in this paper is done with on load tap changer as tap changer is one of the devices used to control the voltage. The algorithm is developed for voltage level control with on load tap changer operation. Normally the tap changer operation is done manually nowadays but the main purpose of this work is to introduce the automatic operation of tap changer.

I. INTRODUCTION

Introduction of Voltage Stability and Reactive Power

The control of voltage and reactive power is a major issue in power system operation. This is because of the topological differences between distribution and transmission systems, different strategies have evolved. This paper contains contributions of novel reactive power control and voltage stability schemes for distribution and transmission systems. A particular interest is taken to the development of control schemes to avoid so-called voltage collapse, which can result in widespread outages. In order to achieve efficient and reliable operation of power system, the control of voltage and reactive power should satisfy the following objectives.

1) Voltages at all terminals of all equipment in the system are within acceptable limits.

2) System stability is enhanced to maximize utilization of the transmission system.

3) The reactive power flow is minimized so as to reduce R I 2 and X I 2 losses.

This ensures that the transmission system operates mainly for active power. Thus the power system supplies power to a vast number of loads and is feeding from many generating units, there is a problem of maintaining voltages within required limits. As load varies, the reactive power requirements of the transmission system vary. Since the reactive power cannot be transferred or transported over long distances, voltage control has to be effected by using special devices located through the system which possess difficulties in keeping sufficient levels of voltage in the power system network. This has been occurring practically since the first power systems started. Increasing requirements regarding both the supply reliability and quality of supplied power force using more modern (faster, more reliable, with a broader range of applications) devices. The proper selection and coordination of equipment for controlling reactive power and voltage stability are among the major challenges of power system engineering. These challenges gave birth to some selected devices to control or compensate reactive power. In order to cover the additional demand for reactive power and maintain the ability to control voltage stability within the target range, various sources of reactive power, such as SVC (Static Var Compensator) – static compensators of reactive power, STATCOM-type systems (Static Compensator) static reactive power generators and systems that combine both these solutions, which are referred to as SVC based on STATCOM. In recent decades, there has been significant progress in terms of equipment designed to improve the stability of voltage in power systems. This is mainly due to the development of power supply systems in the world, which requires seeking better ways of adjusting and controlling power flows and voltage levels.

Problem Statement

In Power System Transformer Tap Changer is one of the devices used to control the voltage level. Presently OLTC are operated manually. If transformers are connected in parallel then Tap changers are to be operated simultaneously that means one tap changer will be master control and other would be on follower control. Instead of operating tap changer manually it is proposed to operate tap changer automatically.

II. VOLTAGE STABILITY AND REACTIVE POWER

A. Voltage Stability

Present power system is now large, complex and interconnected systems, which consists of thousands of buses and hundreds of generators. New installations of power stations and other facilities are primarily determined based on environmental and economic reasons. In addition, new transmission lines are expensive and take considerable amount of time to construct. Given these conditions, in order to meet ever-increasing load demands, electric utilities have to rely on power export /import arrangements through the existing transmission system, deteriorating voltage profiles and system stability in some cases. This situation has resulted in an increased possibility of transient, oscillatory and voltage instability, which are now brought into concerns of many utilities in planning and operation. Moreover, the trend of the deregulated power system has led to some unexpected problems, such as voltage instability, etc. Voltage stability is concerned with the ability of the power system to maintain acceptable voltages at all nodes in system under normal operating conditions and after being subjected to a disturbances. The study of voltage stability has been analysed under different approaches that can be basically classified into dynamic and static analysis. The static voltage stability methods depend mainly on the steady state model in analysis, such as power flow model or a linear zed dynamic model described by the steady state operation. The dynamic analysis implies the use of a model characterized by nonlinear differential and algebraic equations which include generators dynamics, tap changing transformer, etc., through transients stability simulations.

B. Classification of Voltage Stability

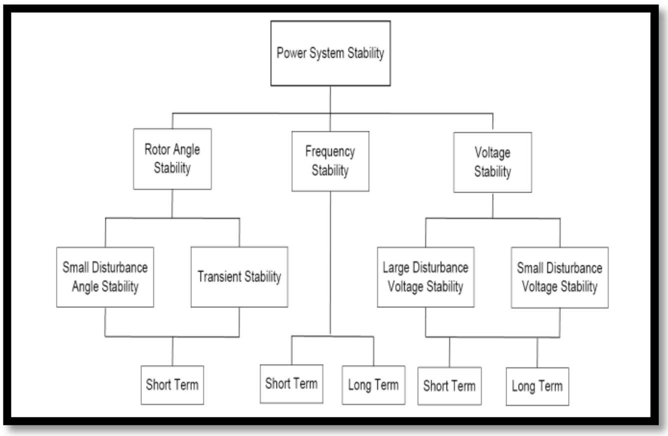

Figure-1 Types of Power System Stability

The time span of disturbances in a power system, causing a potential voltage instability problem can be classified into short term and long term. The corresponding voltage stability dynamics is called short term and long term dynamics respectively .Automatic voltage regulators ,excitation systems, turbine and governor dynamics fall in short term or "transients" time scale, which is typically a few seconds. If the system is stable short term disturbance dies out and the system enters a slow long term dynamics. Components operating in the long term time frame are transformer tap changers, limiters, boilers etc. Typically this time frame is for a few minutes to ten of minutes. A voltage stability problem in the long term time frame is mainly due to the large electrical distances between the generators and the load, and thus depends topology of the power system. The instability may be triggered by high imports from remote generating stations, sudden large disturbances, or large load build up. Operator intervention may be possible if the time scale is long enough. It is often useful to categorize the problem into small disturbance and large disturbance voltage stability. The first one deals with the situations when system is subjected to a small perturbation and last one deals with larger disturbance such as loss of generation, line etc.

B. Causes of Voltage instability

In last two decades power system has operated under much more stressed conditions than they usually had in the past. There are number of factors responsible for this: continuing growth in interconnections; the use of new technologies, bulk power transmission over long transmission lines. Environmental pressure on transmission expansion: increase electricity consumption in heavy load areas, new system loading patterns due to the opening of electricity markets; growing the use of induction machines: and large penetration of wind generators and local coordinated controls in the systems. Under these stressed conditions a power system can exhibits a new type of unstable behaviour namely Voltage Instability.

C. Ways of Improving Voltage Stability and Control

Reactive power compensation is often most effective way to improve both power transfer capability and voltage stability. The control of voltage levels is accomplished by controlling the production, absorption and flow of reactive power. The generating units provide the basic means of voltage control, because the automatic voltage regulators control field excitation to maintain scheduled voltage level at the terminals of the generators. To control voltage throughout the system we have to use addition devices to compensate reactive power. Reactive compensation can be divided into series and shunt compensation. It can be also divided into active and passive compensation. But mostly consideration will be focused on shunt capacitor banks, static VAR compensator (SVC) and Static Synchronous Compensators (STATCOM), which are the part of group of active compensators called Flexible AC Transmission Systems (FACTS). The devices used for these purposes may be classified as follows:

- Shunt capacitors
- Series capacitors
- Shunt reactors
- Synchronous condensers
- SVC
- STATCOM

D. Shunt Capacitors

Shunt capacitors and reactors and series capacitors provide passive compensation. They are either permanently connected to the transmission and distribution system or switched. Synchronous condensers, SVC and STATCOM provide active compensation. Together with the generating units, they establish voltages at specific points in the system. The primary purposes of transmission system shunt compensation near load areas are voltage control and load stabilization. Mechanically switched shunt capacitor banks are installed at major substations in load areas for producing reactive power and keeping voltage within required limits.

E. Shunt reactors

Shunt reactors are mainly used to keep the voltage down, by absorbing the reactive power, in the case of light load and load rejection, and to compensate the capacitive load of the line. Other equipment can be involved in the provision of reactive power and energy, such as:

- Unified Power Flow Controllers (UPFC) and other advanced FACTS (flexible ac transmission system) devices;
- Tap staggering of transformers connected in parallel;
- Disconnection of transmission lines;
- Load shedding

F. Synchronous condensers

Synchronous machines that are designed exclusively to provide reactive support are called synchronous condensers. Synchronous condensers have all of the response speed and controllability advantages of generators without the need to construct the rest of the power plant (e.g., fuel-handling equipment and boilers). Because they are rotating machines with moving parts and auxiliary systems, they require significantly more maintenance than static compensators. They also consume real power equal to about 3% of the machine's reactive-power rating.

G. Static VAR compensators

An SVC combines conventional capacitors and inductors with fast switching capability. Switching takes place in the sub cycle time frame (i.e. in less than 1/50 of a second), providing a continuous range of control. The range can be designed to span from absorbing to generating reactive power. Advantages include fast, precise regulation of voltage and unrestricted, largely transient-free, capacitor bank switching. Voltage is regulated according to a slope (droop) characteristic. Static VAR compensator could be made up from:

- TCR (thyristor controlled reactor);
- TSC (thyristor switched capacitor) ;
- TSR (thyristor switched reactor);
- FC (fixed capacitor);

H. Static synchronous compensator (STATCOM)

The STATCOM is a solid-state shunt device that generates or absorbs reactive power and is one member of a family of devices known as flexible AC transmission system (FACTS) devices. The STATCOM is similar to the SVC in response speed, control capabilities, and the use of power electronics. Rather than using conventional capacitors and inductors combined with Thyristors, the STATCOM uses self-commutated power electronics to synthesize the reactive power output.

III. LITERATURE REVIEW

Paper [1] Bob Mc Fetridge from Beckwith Electric company, "How to reduce operations on load tap changers at distribution substation transformers. " , IEEE 2014 Focuses on the main purpose of this paper is to present the methods and setting changes in LTC that will allow to reduce the operations on LTC. From this paper, we can understand the historical meaning of reducing operation, methods to reduce the operations on LTC, types of time delay and why it is provided and smart voltage reduction. The conclusion of this paper is that LTC operations can be reduced decreasing the maintenance cost and increasing the life of LTC asset.

Paper [2] Zoran Gajic and Samir Aganovic, " Advanced tap changer control to counteract power system voltage instability",ABB AB,Substation Automation Products,SE-721 59 Vasteras, SWEDEN Focuses on the possibilities to improve traditional load tap changer control in order to perform properly also during stressed situation in the power system.

Paper [3] Akwukwaegbu I. O, Okwe Gerald Ibe, " concepts of reactive power control and voltage stability methods in power system network" ,www.iosrjournals.org,volume 11 ,May – June 2013. Focuses on the purpose of this paper is to present an analysis of reactive power control and voltage stability in power system. This paper defines the concepts for voltage instabilities and discussed a number of issues related to this. The importance of reactive power is explained.

Paper [4] Mahemood Reza Shakarami,Reza Sedaghati " A study on integrated performance of tap changing transformer and SVC In association with power system voltage stability", international journal of Electrical ,Robotics ,Electronics and communication engineering, volume 8,2014. Focuses on voltage stability assessment with appropriate representations of tap changer transformers and SVC is investigated.

IV. OLTC (ON LOAD TAP CHANGER)

A. Introduction of OLTC

Historically, utilities have used LTCs on distribution substation transformers to step the voltage down from a transmission, typically 69 kV or higher, to a lower distribution voltage, typically 12 or 25 kV. On the distribution system, as load changes, the voltage will fluctuate due to the impedance of the system and the load. ANSI requires utilities to maintain a consistent voltage of 114-126 V at every customer meter. As the voltage fluctuates under varying load conditions, the utility may need to take corrective actions to keep the voltage within limits to all customers. The LTC control allows the utility to keep the voltage within predetermined limits by monitoring the voltage and then issuing lower or raise commands to the LTC, as needed. The LTC is a variable winding used on the output or low side of the transformer allowing voltage to be adjusted by +/- 10% in granular steps. A typical LTC has 16 lower taps, 16 raise taps and one neutral tap for a total of 33 taps. Some LTCs may have multiple neutral taps or may only have 8 lower and 8 raise taps, however, the majority of the LTCs found in the U.S. operate with 33 taps and a central neutral. When in the neutral position, the incoming voltage I transformed to the lower outgoing voltage without raising or lowering the voltage. When in a tap raise position, the output voltage will be higher than the rated output voltage with the

LTC in the neutral position. When in a lower tap position, the output voltage will be lower than the rated output voltage in the neutral position. As an example, if the transformer is rated as 115 kV/25 KV and the transformer high-side voltage is exactly at the rated 115 kV, then the low-side voltage leaving the transformer would be 25 kV if at the neutral tap, higher than 25 kV if on a raise tap and lower than 25 kV if on a lower tap.

B. Methods to Reduce the Operations of OLTC

There are two methods to reduce the operations on LTC. Enlarged LTC control Band width allowing the voltage to vary more before action is taken. This will reduce the operations but allow for large variation of voltage, being acceptable for some customers but may have negative impact on others. Expand the time delay setting on the LTC control. First: LTC mechanism motor draws more current as they start but will draw less current once running. The voltage drop cause by increased current will correct itself as the motor gets to full speed. The current is reduced. Therefore if the LTC raised the voltage while motor was accelerating from the locked rotor condition, when motor is up to speed, the current drop to full load ampere and voltage will rise, now LTC will have to lower the voltage. The other reason for time delay is that of coordination.

C. Smart OLTC Voltage Control Scheme

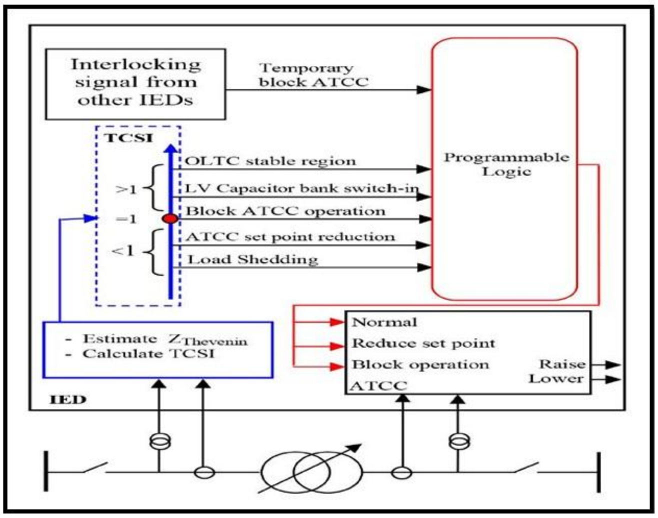

Figure -2 Smart OLTC Automatic Control

The above OLTC stability monitoring method may be included in the new developed IEDs to develop a smart tap changer automatic control by providing additional inputs to ATCC from stability monitoring system Fig.2, shows the principals of a typical scheme. Thevenin impedance and to calculate tap change stability index. When OLTC is in its stable region (i.e., TCSI > 1) and there is no temporary block signal from other IEDs a "Normal" signal is sent from programmable logic board to ATCC for its normal action. This signal is intentionally included in the scheme to make sure that TCSI block is healthy and OLTC is in its secure situation. The ATCC will raise and / or lower the tap if the secondary side voltage is out of the predetermined dead band. In the case the stability limit is reached: i.e. TCSI = 1, the ATCC is blocked to avoid the voltage collapse. When OLTC is in its unstable state; i.e. TCSI < 1, ATCC set point is reduce to improve the OLTS stability by a reverse control action. This is in fact a soft load shedding applied by OLTC to improve the HV side voltage stability. The system instability can be counteracted by a direct load shedding scheme. The TCSI block Fig. 2 Principals of a smart OLTC control scheme. Output can also be used o improve the ATCC stability by switching the LV side capacitor bank interlocking signal from other IEDs is used to coordinate the tap changers in series and or in parallel and to minimize the number of operations and to improve the system stability. Programmable logic block consists AND, OR gates, timers and other logical elements. The estimated Thevenin impedance can also be sent to a control room to be used for other purpose. The secondary side current transformer is used by IED for other purpose such as active and reactive power measurement. Overall, including tap changer stability monitoring block in its automatic control process will improve the system self-healing feature which is one of the most important requirements in the smart grid context.

V. PROPOSED WORK

Flow-chart (OLTC)

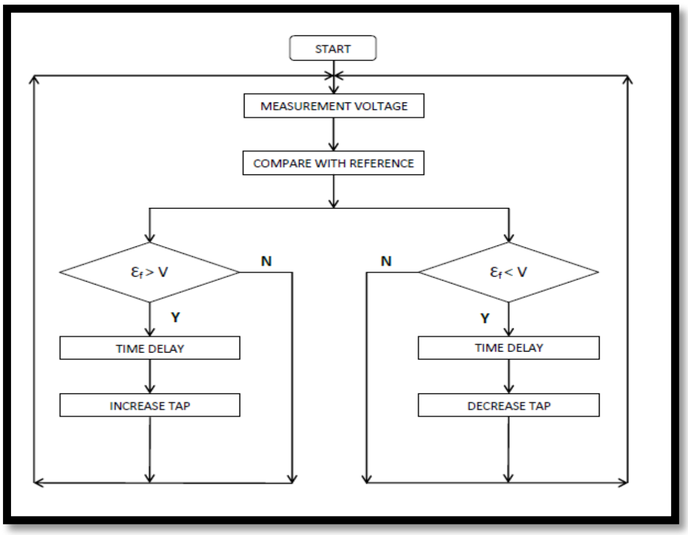

Figure 3 Flow chart for OLTC

Three phase Three bus System

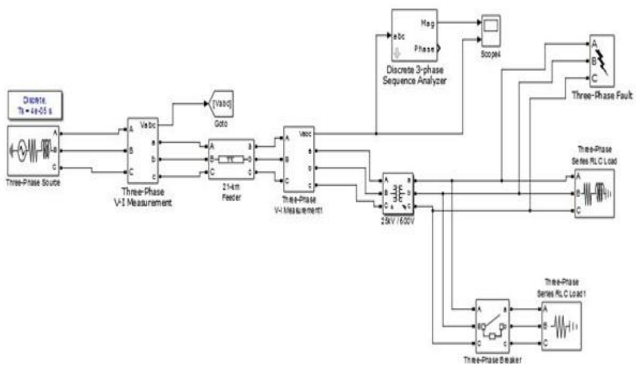

Figure 4 Three phase Three bus System

Simulation Using OLTC

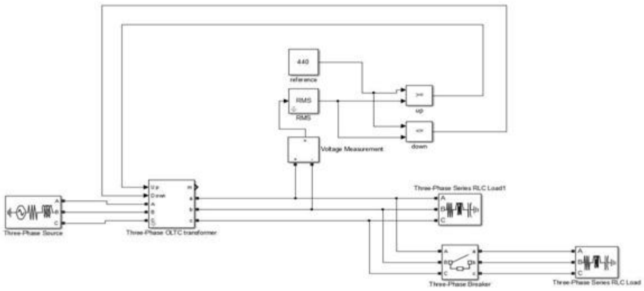

Figure 5 Simulation Using OLTC

VI. SIMULATION RESULTS

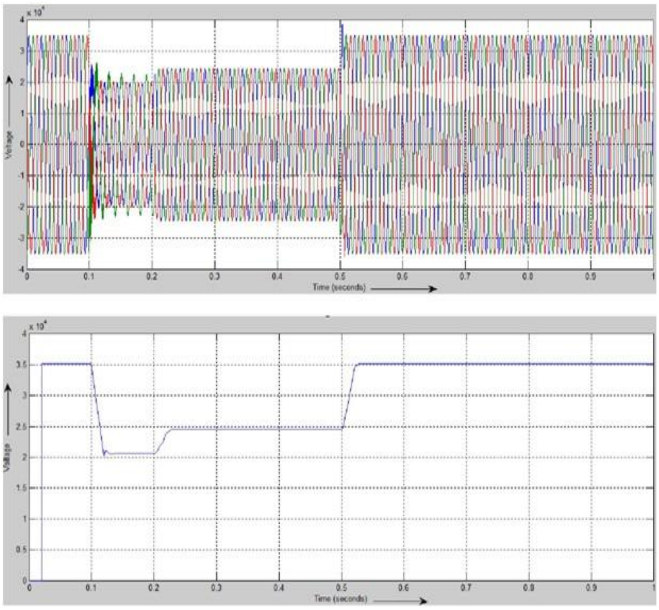

Figure 6 Simulation Result for 50 MW Load

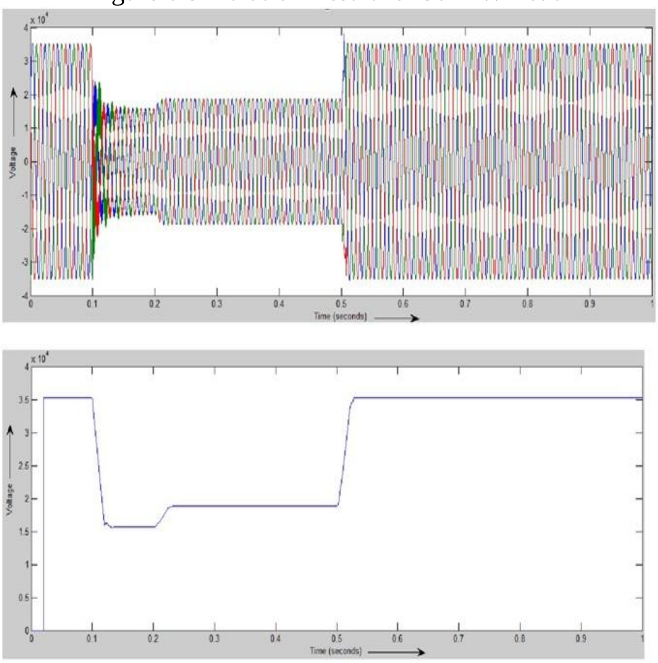

Figure 7 Simulation Result for three phase fault

One line diagram for IEEE 6 bus system:

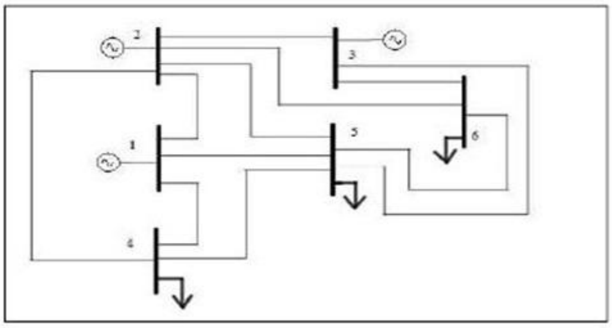

Figure 8 one line diagram for IEEE 6 bus system

Data for IEEE 6 bus system:

DEMAND DATA FOR IEEE 6 BUS SYSTEM						
bus no	type	real power (pu)	reactive power (pu)	base KV	Vmax (pu)	Vmin (pu)
1	slack	0	0	230	1.05	1.05
2	PV	0	0	230	1.05	1.05
3	PV	0	0	230	1.07	1.07
4	PQ	0.7	0.7	230	1.05	0.95
5	PQ	0.7	0.7	230	1.05	0.95
6	PQ	0.7	0.7	230	1.05	0.95

VII. CONCLUSION

In power system, the voltage control and reactive power control are two main problems due to which the system cannot be operated satisfactorily. To avoid the problem related to voltage control transformer tap changer is used .Nowadays the manual operation is done .But the automatic control of tap changer is beneficial for voltage stability and contributes to increased load ability margins. From the proposed methodology in this paper we can analyse that tap changer has not more effect on voltage control.

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