Constrain Power Flow Solution and Enhancement of Voltage Stability Margin by OLTC

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Abstract- the voltage stability becomes the main concern in large interconnected system. With MATLAB application the N-R power flow solution and OLTC is applied to obtain voltage stability margin across weak bus of the system. This will prevent the system from voltage collapse by finding the voltage stability limit. Observation of voltage stability margin has been made on load bus by providing PV and QV curve on each bus. The observation has been made by the comparison of voltage drop at each bus and power loss in each transmission line. It also giverise to constrained power flow solutions. This paper discusses the effect of OLTC on the voltage stability via the calculation of the maximum power transmission.

Keywords:Newton raphson power flow solution, PV and QV curve, voltage stability margin (VSM), OLTC.

I. INTRODUCTION

The increase in power demand and limited sources for electric power is one of the major consideration has resulted in an interruption and instability in interconnected system. Under normal and contingent condition, stability is concern with the ability of power system to maintain acceptable voltage level at all node in the system. A power system comes under the concern of voltage instability when voltage level of a bus decreases due to disturbance of heavy load fluctuation. Due to change in operating condition or disturbance occur which can tends to voltage collapse. Since reactive power is sensitive to voltage, this will increase the demand of reactive power. The approach of this paper is to r maintain the voltage level by providing appropriate taping of OLTC. The increase in electric power demand (D.P. Papadopoulos et al. 1991, QuinmengMeng et al. 2017). Due to increase in electric power demand power system need to work on their limited condition. High load current, low voltage level and relatively high power angle differences which indicate that the system is operating under heavy loading condition which can cause loosing stability, islanding or voltage collapse. The main aim is to maintain adequate voltage level at busses. In large interconnected system, to control the reactive power margin for the system will become difficult. It’s very important to analyses this voltage fluctuation to prevent our system from voltage collapse.

II. LITERATURE REVIEW

Saurabhratra et al. (2017) has incorporated wind turbine in power system and study the effect of voltage profile and voltage stability. The voltage analysis can be controlled by using on-load tap changers (OLTC). Due to small disturbance in power system there may be the reduction in extra high voltage which affect the distribution system network. With the help of on-load tap changer(OLTC) this problem can be reduced and restore the voltage at prior levels. By each time tap changing operation, it would increase the line current and this results in increasing reactive power loss of the system. Due to gradual increase in reactive power the generators may reach to their reactive power capability limit and beyond this limit it does not support the system and voltage instability occurs. For the concerned of voltage stability and line loss of the system this paper has introduced the coordination operation of OLTC using Taguchi method.

Pyone Lai Swe et al.(2017) has introduced a method of voltage stability enhancement of transmission networks by the on-load tap changer and shunt capacitor. Voltage stability become a major problem to every power system all over the world, the reason is weak system and long transmission lines. So to find out the weak points and voltage stability limit in the power system a MATLAB load flow program has been introduced. In this method different values of shunt capacitors are incorporated for the improvement of voltage stability by analyzing the tap ratio by using tap changing transformer.

HajunFeng et al.(2017) has proposed a methodology of using local measurement for on-load tap changer control based on intelligent voltage stability margin. The methodology consist of three section comprises of HV-grid, HV/MV- transformer with OLTC and the ZIP model. The HV grid model is based on the thevenin theory in which the voltage source is connected with an impedance. A load flow equation will be made for the estimated parameter of the Thevenin equivalent, ZIP model and OLTC. This proposed approach gives idea for the operation and control of both, tap-changer and compensation equipment in the substation. Here the methodology uses the fluctuation of load which are connected to the substation and the switching process of OLTC for the estimation of TheveninEquivqlent and the load characteristic in the next grid.

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III. PROPOSED METHODOLOGY

A. System model

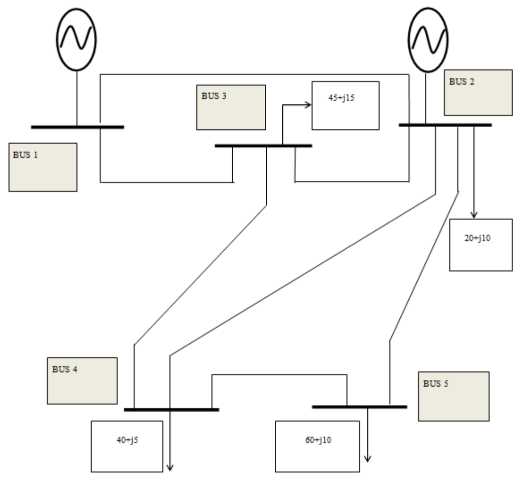

Fig.1 Bus system Diagram.

The simplified system model is shown in fig 1. This test system consist of 5busbar, 7 transmission line, 2 machine and 4 load. The OLTC transformer is placed after determination of weak bus of the system and it should be considered as bus no 6.

B. Newton raphson method.

The most widely used method is thenewton raphson method for solving simultaneous nonlinear algebraic equations. Newton's method is found to bemore efficient and practical. The number of iterations required to obtain a solution is independent of the system size, but more functional evaluations are required at every iteration (sabaakramet al. 2015). Since in the power flow problem real power and voltage magnitude are specified for the voltage-controlled buses, the power flow equation is formulated in polar form. This equation can be rewritten in admittance matrix as

$$I_i = \sum_{j=1}^{m} Y_{ij} V_j$$

In the above equation, j includes bus i. expressing this equation in polar form, we have

$$I_i = \sum_{j=1}^{m} |V_j||Y_{ij}| \angle \theta_{ij} + \alpha_j$$

The complex power at bus i is

$$P_i + jQ_i = V_i^* I_i$$

Separating the real and imaginary parts

$$P_i = \sum_{j=1}^{m} |V_i||V_j||Y_{ij}| cos(\theta_{ij} - \alpha_i + \alpha_j)$$

$$Q_i = -\sum_{j=1}^{m} |V_i||V_j||Y_{ij}| sin(\theta_{ij} - \alpha_i + \alpha_j)$$

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} j1 & j2 \\ j3 & j4 \end{bmatrix} \begin{bmatrix} \Delta \alpha \\ \Delta |V| \end{bmatrix}$$

By running the load flow analysis using NR-method we can fine the Power flows in individual lines and loss.

C. Analysis of PV and QV curve.

P-V curve analysis is use to determine voltage stability of a radial system and also a largemeshednetwork (KabirChakrabortyet al. 2007) (Penggaoet al. 2009) For this analysis P i.e. power at a particular area is increased in steps and voltage (V) is observed at some critical load buses and thencurves for those particular buses will be plotted to determine the voltage stability of a system by static analysis approach. To explain P-V curve analysis let us assume two-bus system with a singlegenerator, single transmission line and a load, as shown in Figure 2.

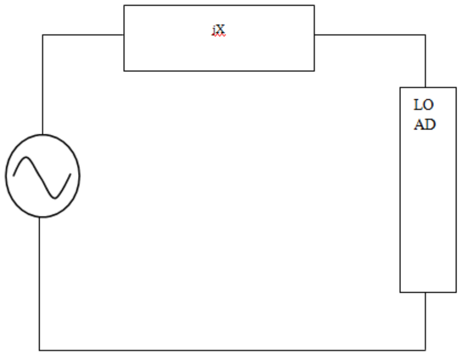

Fig. 2 Single Transmission line.

P-V curves are useful in deriving how much load shedding should be done to establishprefaultnetwork conditions even with the maximum increase of reactivepower supply from various automatic switching of capacitors or condensers. Here, the complex load assume is S_{12} with V= P+ jQ$_1$ is the sending end voltage and $V_2$is receiving end voltage and cosθ is load power factor

$$S_{12} = P_{12} + jQ_{12}$$

$$S_D = P_D + jQ_D = -(P_{21} + jQ_{21})$$

Taking $P_D = -P_{21}$ and $Q_D = -Q_{21}$, theactivepower and reactivepowerdemand can bewritten as

$$P_D = |V_1||V_2|B \sin \theta_{12}$$

$$Q_D = -|V_1|^2 B + |V_1||V_2| B \cos \theta_{12}$$

$$\beta = tan\emptyset,$$

$$Q_D = P_D \beta$$

Equating the expression for P_D and Q_D, We have

$$(|V|^2)^2 + \left[\frac{2P_D\beta}{B} - |V|^2 + \frac{P_D}{B^2}[1+\beta^2]\right] = 0$$

This is a quadratic equation in $|V_2|^2$, Eliminating θ_{12} and solving the secondorderequation, we get

$$|V^2|^2 = \frac{1 - \beta P_D \pm \sqrt{1 - P_D(P_D + 2\beta)}}{2}$$

As seen from equation, the voltage at the load point is influenced by the powerdelivered to the load, the reactance of the line, and the power factor of the load. The voltage has two solutions; the higher one is the stable solution. The load at which the two solutions have one valueindicates the steadystatevoltagecollapse point. Using this equation we haveplotted PV curve using MATLAB program for various power factors, lagging as well as leading as shown in figure3.

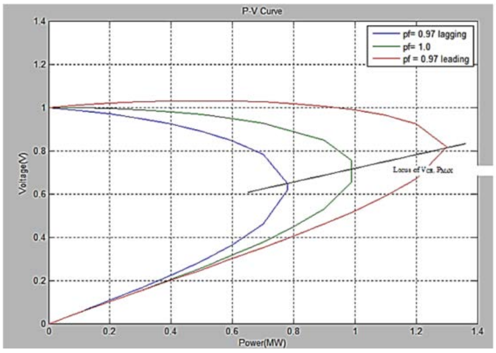

FIGURE3. P-V curve using MATLAB program

The dotted line can be shown by connecting nose points of the P-V curve. Only the operating points above the critical points represent satisfactory operating condition. At the knee of the P-V curve, the voltage drops rapidly with the increase in loads. P-V curves are useful for conceptualanalysis of voltage stabilityespecially for radial systems. Q-V curve is the relationshipbetween the reactive power support (Q) andreceiving end voltage (V_2) for different values of activepower P. We consider our simple (lossless) system again, with the equations P_D and Q_DNow, again assume that V_1=1.0, and for a givenvalue ofP_D and V_2, compute θ_{12} from the first equation, and thenQ from thesecondequation.Repeat for various values of V_2 to obtain a Q-V curvefor the specified real load P_D. The Q-V curve can beobtained from the P-V curve as shown in figure 4.

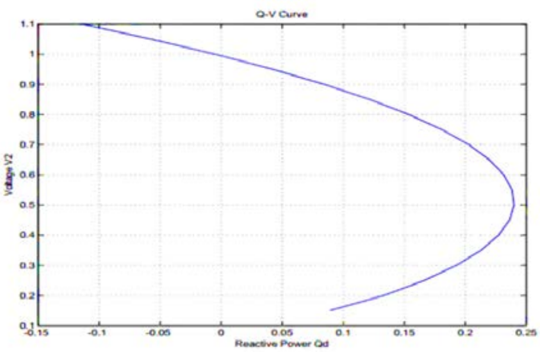

FIGURE4. Q-V curve analysis using MATLAB program.

One of the information that can be accessed from the curves is the sensitivity of the loads to the reactivepowersources. Thus P-V curve play a measurerole in understanding and explainingvoltage stability. However, it is not necessarily the most efficient way of studying voltage stability since it requires a lot of computations for largecomplexnetworks (Snehal B. Bhaladhareet al. 2013).

D. *Assessment of voltage stability margin*

"Voltage Stability Margin" of a powersystem is a measure to estimate the availablepowertransfer capacity, net powertransfer capacity or total powertransfer capacity. Voltage stability margin (VSM) is the measure of the securitylevel of the bus, if the value VSM is high then the bus is moresecured and viceversa. Voltage stability margin (VSM) is a straightforward, widelyaccepted and easilyunderstoodindex of voltagecollapse. This is a difference or a ratio between the operation and voltagecollapse points according to a key parameter (loading, line flow, etc).So, voltage stability margin can be calculated in the following manner-In equation, $V_{b\,(base)}$ = bus voltage of the weakest bus of the system at normal operating condition. $V_{b\,(critical)}$ = bus voltage of the weakest bus of the system at voltagecollapse point (Shantasree Royet al. 2013).

$$VSM = \frac{V_{b(base)} - V_{b(critical)}}{V_{b(critical)}}$$

E. *On load Tap changing*

In order to improve the voltage stability, tap changing transformer is known that have ability to control the voltage in transmission system within the limit (SudheerMokkapatyet al. 2017). This method also identifies critical load tap changing transformers to be made manual under peak load conditions to prevent possible voltage instability. The best tap ratio that produce output result within voltage stability limit at all 5buses was selected at corresponding transformer (P.W. Sauer et al. 1990).Variation of tap changer of transformer is doing by adjust tap ratio with step size 0.025from minimum tap ratio until maximum tap ratio. The voltage variation as varying the tap ratio at corresponding transformer is indicated in table2. Comparison of bus voltage magnitude describes as shown in Fig. 7. The results of 5buses system after varying tap ratio are described in Table 2.

IV. SIMULATION/EXPERIMENTAL RESULTS

In normal condition, the voltage at all busses in 5 bus system are not in acceptable range. The voltage in per unit is shown in figure 5 for all the bus. From PV and QV curve analysis critical maximum loading point is analyzed.

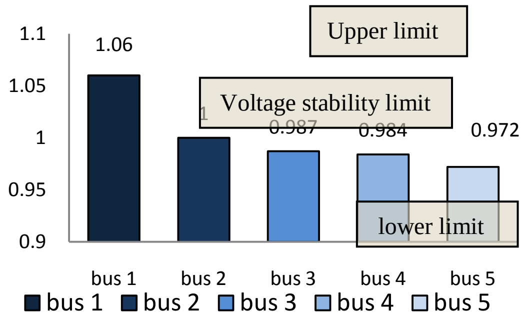

FIGURE5.voltage forbase case condition

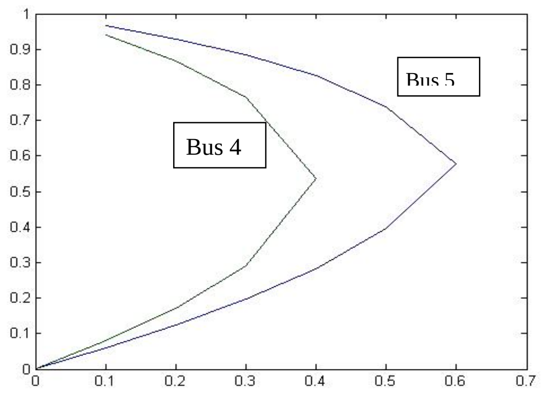

FIGURE 6.PV curve of bus 4 and bus 5

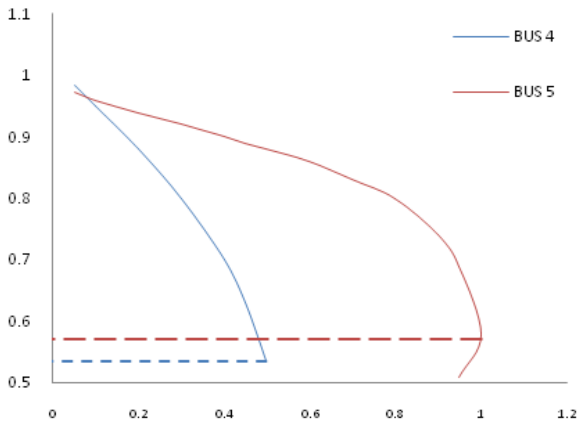

FIGURE 7. QV Curvefor Bus 4 and 5

Weak bus summary and voltage stability margin is shown in table 1

TABLE 1.voltage stability margin for base case

Bus no	Voltage in p.u	Critical voltage in p.u	Voltage stability margin
4	0.984	0.5373	0.831
5	0.972	0.5787	0.680

Aim is to maintain thevoltage level at bus no 4 and 5 above lower limit. For this transformer tapping is used between buses. The OLTC data is provided with line data and the following result is obtained on MATLAB.

TABLE 2.voltage at bus 4 and 5 with different tapping

Bus no	T_1=1.025 T_2=0.975	T_1=1.05 T_2=0.95	T_1=1.05 T_2=0.925
4	0.9862	1.0396	1.0396
5	0.97	0.9727	0.9787

TABLE 3.voltage stability margin with different tapping

bus no	voltage stability margin		
	T_1=1.025 T_2=0.975	T_1=1.05 T_2=0.95	T_1=1.05 T_2=0.925
4	0.8354	0.9348	0.9348
5	0.676	0.6808	0.6912

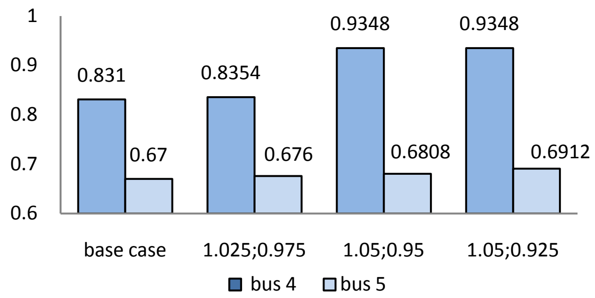

FIGURE 8.comparison of VSM with tapping T1 and T2

Voltage at bus no 4 and 5 has been improved and maintained within voltage stability limit. Thevoltage with different tapping provide different voltage level. At T_1= 1.05 and T_2= 0.925,gives better result as shown in table 3. The comparison of VSM with different tapping is shown in figure 6.

V. CONCLUSION

Power flow study determines the bestoperating condition of a PowerSystemNetwork. Newton- Raphson load flow method has beenused for solving the power-flow equation. To study the effect of OLTC on powersystem, a modifiedpower flow model of the OLTC is attempted. OLTC is placed at the weak bus locations in 5 bus systems and the modified load flow program is used to access the effect of OLTC on the system. The simulation is done using MATLAB. Load flow study of 5 bus system is considered and it is shown that the voltageprofile of the system is improved and it is shown using plots.The voltage stability margin of OLTC is greater than basecase.

VI. FUTURE SCOPE

The completion of one researchprojectopens the avenues for work in many otherrelatedareas. The following areasareidentified for future work:

- The load flow study can be done on largerinterconnectedpowersystemlike IEEE 118 bus and evenlarger

- Optimal location of weak bus can be found out using Genetic Algorithm and fuzzy logic
- Economic Assessment of FACTS devices against othermethods can be studied.

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