# VOLTAGE STABILITY IMPROVEMENT IN POWER SYSTEM USING ON-LOAD TAP CHANGER

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## Abstract:

This work is about the study of long-term voltage stability in power system by viewing the on-load tap changers OLTCs at the vulnerable buses. Vulnerable buses are identified from P-V and Q-V curves often plotted by using the power flow analysis. Vulnerable buses are susceptible to voltage instability. This work attempts to enhance the voltage stability by operating the tapings of the OLTC under a stressed condition. However, a condition will be developed to block the tapings to avoid the reverse effects. OLTCs are included in the Newton Raphson (NR) power flow program in MATLAB environment.

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**Introduction:** Managing the modern power systems has become a challenging task due to the ever increase in load demand and financial pressures in the electricity sector due to deregulation. This enforcing the grid to operate at limits near to the stability limits [1]. One of the stability issues in the power system is the voltage stability problem [2]. Voltage stability is the ability of the system to maintain allowable voltages at all nodes in the system before and after the happening of a disturbance [2]. Reactive power reinforce at buses is the major requirement for maintaining voltage stability. Voltage stability leads to voltage collapse. Voltage collapse may cause a complete or partial blackout in the system [3]. US blackout in 2003, Indian grid blackout in 2012 is the prominent blackouts reported so far in the literature [4]. Though the occurrence of blackouts in the power system is rare, the effects are very severe.

Several factors can cause voltage instability. A continual increase in load demand in the system or a contingency under stressed condition may result in voltage instability. It is observed from the open literature that whenever the network characteristic does not have the intersection point with load characteristic it then results in voltage instability [5-7].

Voltage stability is assorted as large disturbance voltage stability and small disturbance voltage stability. Small disturbance voltage stability occurs due to small disturbance in the system like load variations etc. Large disturbance voltage stability occurs due to large disturbance such as system faults, loss of heavy loads, outage of major generator, etc[8]. Large disturbance voltage stability is affected by the dynamic performance of the system with OLTCs, over-excitation limiters of the generators [9]. Time domain simulations are useful for studying the large disturbance voltage stability. Small disturbance voltage stability is the power systems' ability to control voltages after small disturbance such as changes in loads. Small disturbance stability may be studied by considering the singularity condition of the power flow Jacobian matrix [10].

Voltage stability may be improved by placing suitable reactive power supporting devices. Voltage stability is a local problem and therefore placing the reactive power support devices at nodes prone to instability is sufficient. Voltage stability may be improved considerably by placing shunt capacitors, synchronous condensers, FACTS devices and, OLTCs at weak nodes.

## Methodology:

Power system stability is the most important phenomenon in power system operation. In power system stability, voltage stability is one importantclassification. Power system voltage stability study is essentially at transmission level and in a few cases the distribution effects may reflect on to the transmission side.In general, voltage stability analysis is done by performing the load flow studies [2]. A series of P-V and Q-V curves are plotted for analysis[11-13].The power flow analysis may give the active power margin accurately. Q-V method is also the most powerful tool to analyze the voltage stability [13-15]. This curve basically gives the amount of reactive power required to maintain a specified voltage level stably [12].

Before the advent of PMU measurements, load flow study is the only method for power system planning and operation. The load flow study gives the sinusoidal steady state solutions for the entire system of power flow equations. The obtained solutions are voltage magnitudes, real power, reactive power, and line losses [13]. By using these results real power and reactive power margins can be computed. The voltage magnitudes and power margins combinedly used for estimating the voltage stability of the system [16].

The steady state real and reactive power at a bus in a power network are expressed in terms of nonlinear algebraic equations. Non-linear equations does not contain an explicit solution and therefor an iterative method is required to solve algebraic equations [17]. The Newton RaphsonNR method is very accurate and promising technique for solving such non-linear algebraic equations. It is because of this reason NR method is most popular and accurate load flow method. In this paper NR load flow method is employed to implement the effects of OLTC [18-19].

In the power system, it is realized that there is an exponential growth in load from past two decades globally and system operators continually grappling to manage the system to meet the increased load demand. The limitation in generation and transmission expansion due to additional investments made the system operators and research communityfind ways to tackle the issue. The load characteristic and system characteristic actually determine the voltage stability. The existence of load and system characteristic intersection point guarantees voltage stability. As mentioned previously that several hindrances to generation and transmission expansion lead to the usage of devices which may guarantee voltage stability. One of such device is OLTC. In this work the OLTC is implemented in NR load flow method.

The OLTC changes voltage level at output side whenever needed. The tapings are provided to the primary side usually high voltage side, to reduce the switching problem. When output voltage changes, this changed voltage sensed by voltage sensing device and provides this data to comparator. Comparator is device which is connected in between the input supply to output voltage sensing devices. So, it is comparing voltages and acting as the isolating device which turn on the TRIAC semiconductor device and this semiconductor device adjust the taps according to the output voltage. This whole process happens automatically.This work attempts to improve the voltage stability by operating the tapings of the OLTC under a stressed condition.This work is done in MATLAB Environment.

Results and discussions:

In this work an IEEE 14- bus test system is considered for simulation. IEEE 14- bus test system consists of 5 Synchronous generators. Bus 1 is a slack bus/Reference bus. Eleven buses contains loads. To understand the effect of OLTC and its significance it is essential that the system has to undergo a transformation from stable state to unstable state. To achieve this a load increment of 0.2pu/sec at all the load busses are considered as per IEEE standards, which states that for voltage stability studies all the load buses are to be simultaneously loaded. Here, to show the simulated results only the vulnerable buses are considered. These vulnerable buses are obtained from PV curves.Initially without operating the OLTC the instability occurred at 26s as per the fig1. Then, simulation is run for the case with OLTC and the instability occurred at 44s as depicted in fig 2. This simulation results evince that the operation of OLTC is very significant for improving the voltage stability. The tap position with time are shown in fig 3. The details of the simulated results with and without OLTC are tabulated in table1.

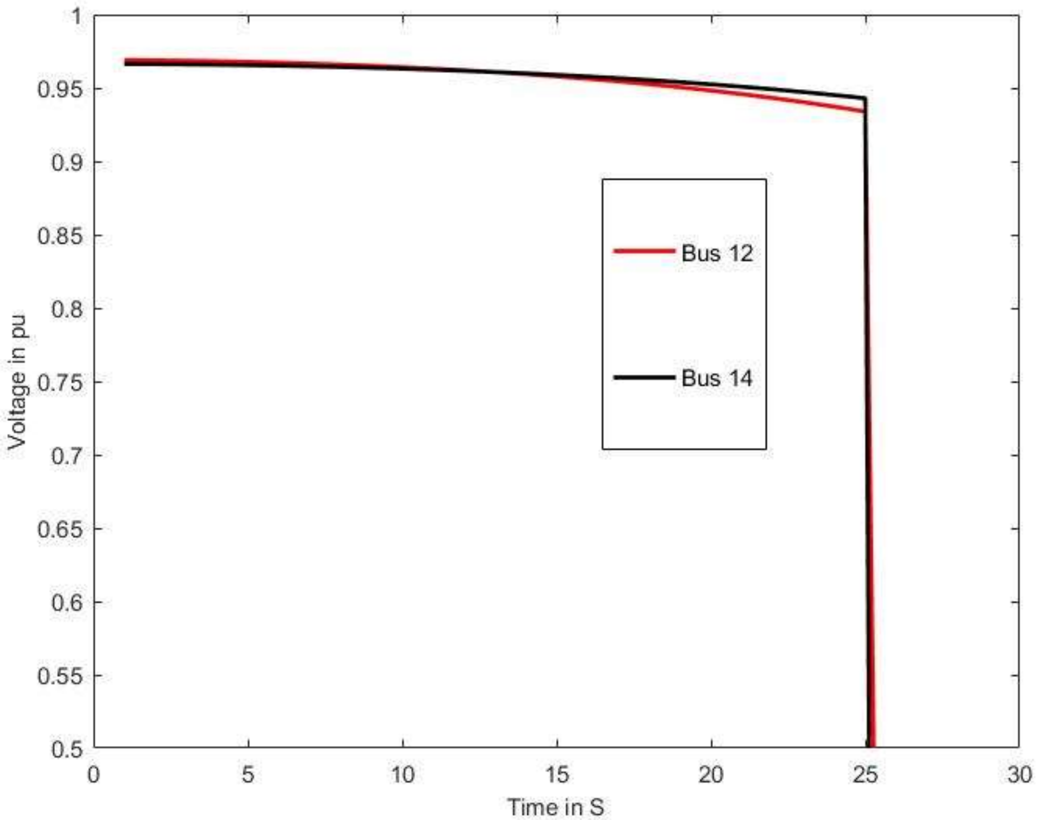

FIG 1: WITHOUT-OLTC Voltage(pu) to Time(sec)

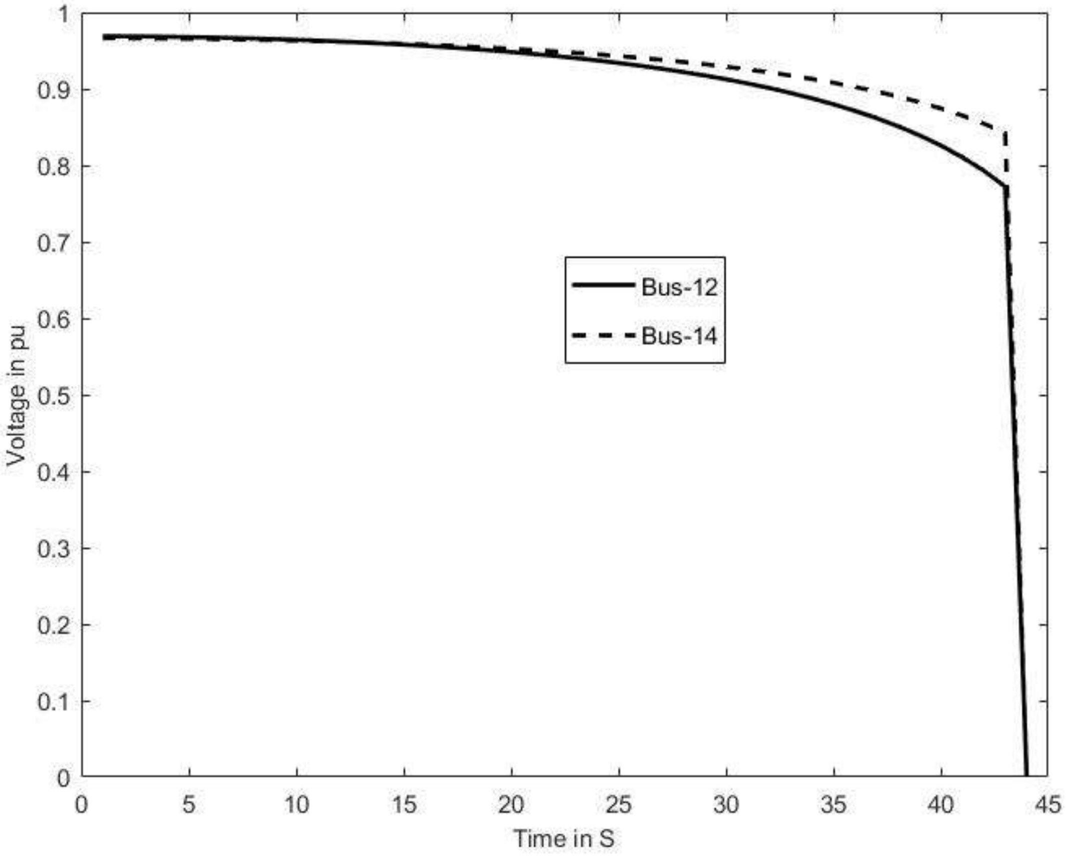

FIG 2: WITH-OLTC Voltage(pu) to Time(sec)

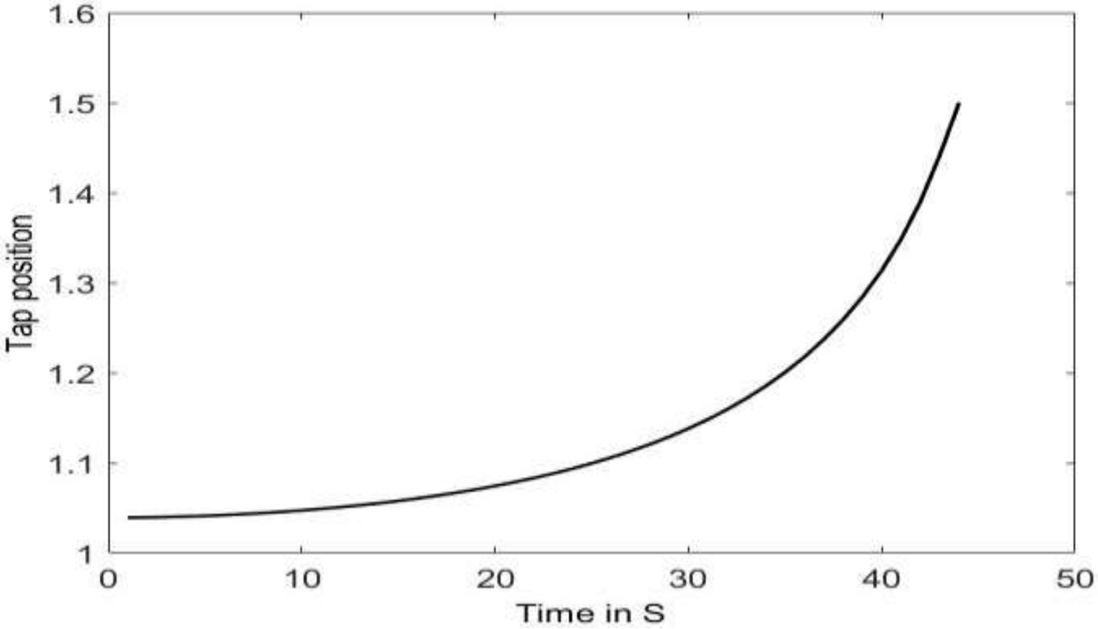

FIG 3: Tap position to Time(sec)

Table-1

| TERMS | WITHOUT-OLTC | WITH-OLTC |
|---|---|---|
| TIME (Sec) | 26 Sec | 44 Sec |
| Voltage Magnitude (pu) | 0.949 | 0.968 |

CONCLUSION:

This paper implements an on-line tap changing transformer in IEEE 14 bus test system using Newton Raphson power flow method for voltage stability enhancement. The simulation results show that the OLTC has potential to improve the stability margin. Without OLTC voltage instability occurred at about 29 s and with OLTC the instability occurred at 44s. This gives a reasonable time margin for system operators to activate additional voltage support devices.

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