Performance Analysis of Solar system installation on load handling capability of Power system by using PSSE Simulator

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ABSTRACT

Continuation power flow (CPFLOW) is performed on the system without PV system and with gradually increasing the solar power penetration. The solar plant is installed at bus 9 and 14 as these are the weakest buses. The simulation analysis was performed by PSSE (Power System Simulator for Engineers). Results of this research show the benefits of introducing solar power to existing power grid. It increases the power handling capacity of the system and voltage instability was occurring at higher loading factor. Finally, the steady state bus voltages became higher than without PV penetration and at a certain point it exceeds the permissible upper voltage limit, and that's the maximum point up to which, the penetration can be done.

Keywords: Photovoltaic (PV), Irradiance, IEEE 14 bus test system, most sensitive bus, Voltage Stability Analysis, PSS/E.

1. INTRODUCTION

Solar power has an exceptionally good potential for providing electrical energy that is free & non-polluting. Its effectiveness as an electricity supply source has encouraged ambitious targets for solar PV system in many countries around the world. Its benefits include:

- No emissions of harmful gasses like CO_2
- Significant economically viable resource potential
- No impact on generation cost due to fuel supply price fluctuations
- Increased security of supply
- Can be used as distributed generation Source
- Cost-effective energy production
- Improves sustainability
- Reduces global warming
- Requires no waste storage

- The below table shows the installed capacity of various generation systems of India.

- Table 1.: Installed capacity of various generation system of India

Sr. No	Resources	Cumulative Achievements (in MW) till 31.03.2020
Grid connected renewable electricity		
1	Biomass Power	8701
2	Waste to energy	138
3	Solar PV power plants	21651
4	Wind Power	34046
Off-grid renewable energy		
5	Biomass Cogeneration	661.4
6	Solar PV system	539.13
7	Biomass Gasifiers	163.37
8	Waste to Energy	175.45
9	Hybrid Systems / Aero Generators	3.29

Solar power is one of the fastest growing industries in India. The solar generation capacity of India has increased nearly 8 times from 2016 to 2020. It was 2650 MW in 2016 and up to 31 January 2020 it has reached 25 GW.

1.1 VOLTAGE COLLAPSE

Following voltage instability, a power system undergoes voltage collapse if the post-disturbance equilibrium voltages near loads are below acceptable limits. Voltage collapse may be total (blackout) or partial. The absence of voltage stability leads to voltage instability and results in progressive decrease of voltages. When destabilizing controls (such as OLTC) reach limits or due to other control actions (under voltage load shedding), the voltages are stabilized (at acceptable or unacceptable levels). Thus abnormal voltage levels in steady state may be the result of voltage instability which is a dynamic phenomenon.

There are other concepts such as power controllability and maximum loadability which are elated to the voltage problem but should not be confused with voltage stability. The power uncontrollability is a steady state problem accompanied by low voltages, when switching in more load results in reduced load power.

1.2 QV CURVES FOR VOLTAGE STABILITY ANALYSIS

The loading margin is an index to roughly calculate the voltage stability of power system. The difference between critical loading point of the system and actual operating point of the system is called the loading margin. The voltage collapse points must be assessed to make sure secure operation at the normal operation point.

Under steady state conditions, as the reactive power Q is injected at a particular bus the voltage (V) of that same bus increases. No matter how, when voltage of any of the buses decreases with the increase in reactive power for that same bus, the system is said to be unstable. Voltage stability is dependent on how a slight difference in active and reactive power affect the voltages at different buses. It indicates how much bus voltages are sensitive with respect to reactive power operations.

A typical QV curve is shown in fig. 1 below. Voltage stability limit occurs at the point where the ratio of change in voltage magnitude to the change in reactive power equates to zero. The minimum requirement of reactive power for a stable operation is also found at this point. Under normal operating conditions, increase in reactive power injection results in improved voltage stability. The operating point of the system should lie on the right hand side of the QV curve in order to maintain the system stable. Whereas when operating points is in the left side of the graph system is considered to be unstable.

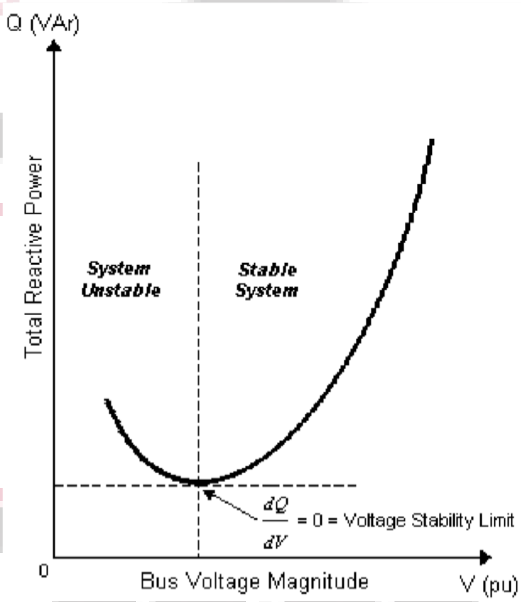

Fig 1: QV Curve

1.3 OPTIMAL POWER FLOW

An indicator termed as L –indicator which is derived from Kirchhoff's law to determine voltage instability. This voltage stability indicator predicts the voltage stability margin of current operating point. Lower the value of L - indicator greater is the stability margin. By using L-indicator it is used to find the impact of loads, area and power transaction. Optimal power flow is carried out by using Newton-Raphson method in PSS/E. This Indicator predicts the voltage stability problem accurately and properly.

1.4 CONTINUATION POWER FLOW

Singularity of the Jacobian matrix of power flow equation occurs at voltage stability limit. Continuation power flow takes control of this problem. CPFLOW executes successful load flow solutions in accordance to a load scenario.

It comprises of prediction and correction steps. From a known base solution, a tangent (known as predictor) is employed so as to estimate next solution for an outlined pattern of load increase. The corrector step then determines the precise solution using Newton-Raphson technique employed by a traditional power flow. Afterward a brand new prediction is formed for an outlined increase in load based upon the new predictor. Then corrector step is applied. This process goes until sensitivity is reached. The sensitive point is that the point where the tangent vector is zero. The flow chart of predictor-corrector scheme is illustrated in Figure.2.

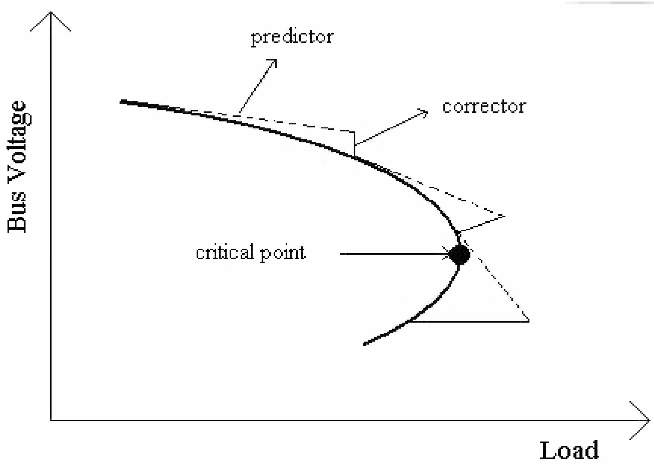

Fig. 2: Illustration of prediction-correction steps

2. SYNCHRONOUS GENERATORS MODELS

In the standard IEEE 14 bus system, either thermal generators or hydro generators are used. They both have their own unique characteristics. Salient pole generator models have been used for representing the hydro electric generators whereas wound rotor machine models have been used for representing the thermal electric generators.

2.1 LOAD CHARACTERISTICS AND MODELS

In the beginning of the simulation, all the loads are modelled as static loads with constant MVA loads. In PSS/E, any kind of loads can be adjusted to be either constant, constant current impedance or constant power (ZIP loads). Some loads consist of dynamic motors and transformer such types of loads are also available in the library. The voltage stability of the system and the recovery time of the system after a disturbance is greatly influenced by the composition of the load present in the system.

After a certain fault occurs on the system and system tries to recover, during this time tap changing transformers try to restore the power consumption of the loads. Because of this torque-speed characteristics of the induction motor would change and as a result will draw very high current from the grid. Ultimately, it will force the generators and compensators to work at their highest reactive power limit. This will increase the danger of voltage instability.

2.2 ZIP STATIC LOADS

ZIP load consist of constant power loads, constant current, and constant impedance characteristics. A constant power load is a kind of load that does not change its power consumption even after the voltage gets changed whereas the constant impedance and constant current loads change their power consumption with the alteration of the voltage.

3 RESULTS

P-V CURVE ANALYSIS WITH DIFFERENT SOLAR PV PENETRATION LEVELS

Continuation power flow has been performed to observe the effects of large scale solar PV integration on the voltage stability. Figures below show the P-V curve for different solar PV penetration levels. The results are also tabulated. It can be seen from the figure 3 and 4 that for small penetration, the critical point is nearly identical to the base case. However, as we go on increasing the solar PV penetration levels, the voltage stability critical point increases more and more. This indicates that by integrating more distributed photovoltaic power plants, we can improve voltage stability of the system. But, on the other hand, as we increase the penetration level, the voltage level of the buses goes on increasing and it breaches the upper voltage limit at a certain point. Voltage profile of buses with different penetration is also shown in figure 5 and 6.

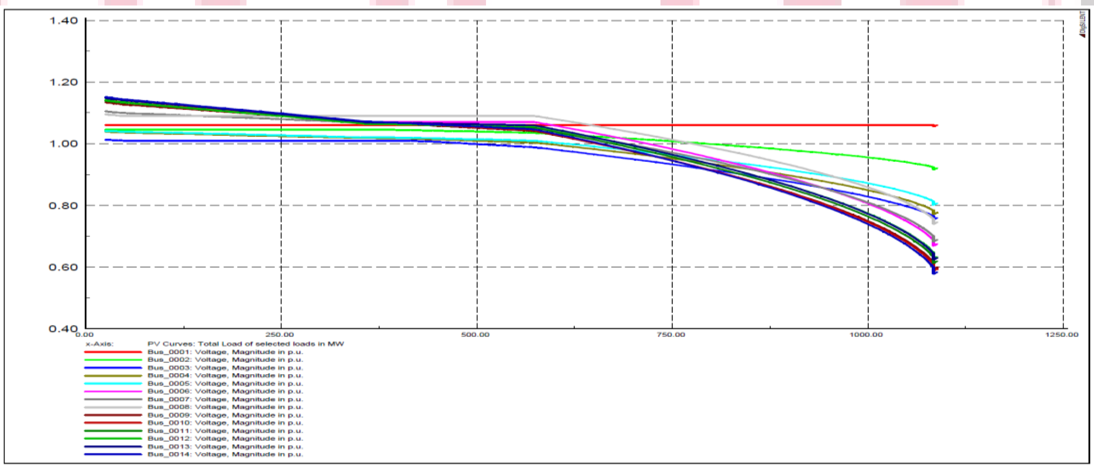

Figure 3: Power-voltage (P-V) curves for IEEE 14 bus systems with 20% PV penetration

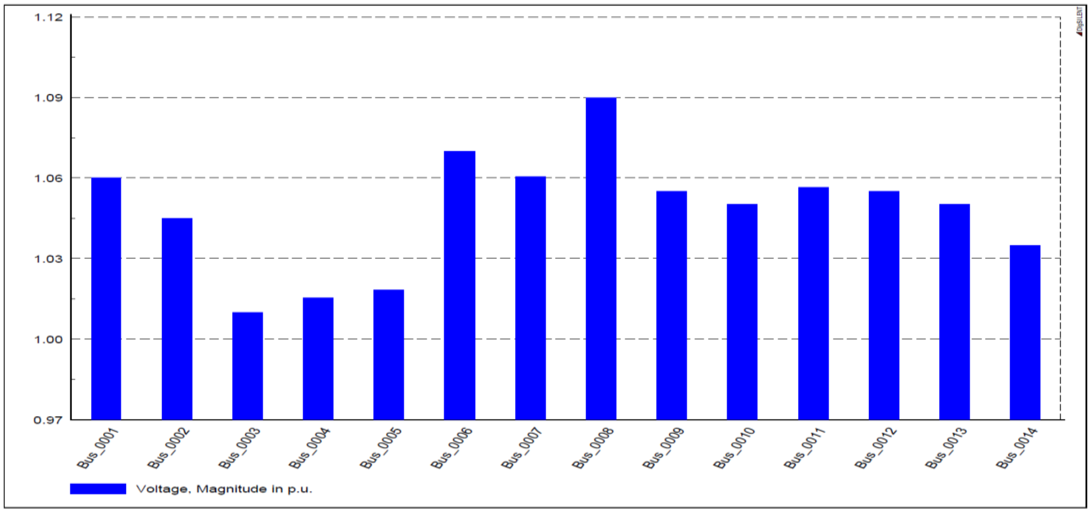

Figure 4: Voltage profile of buses without solar plants

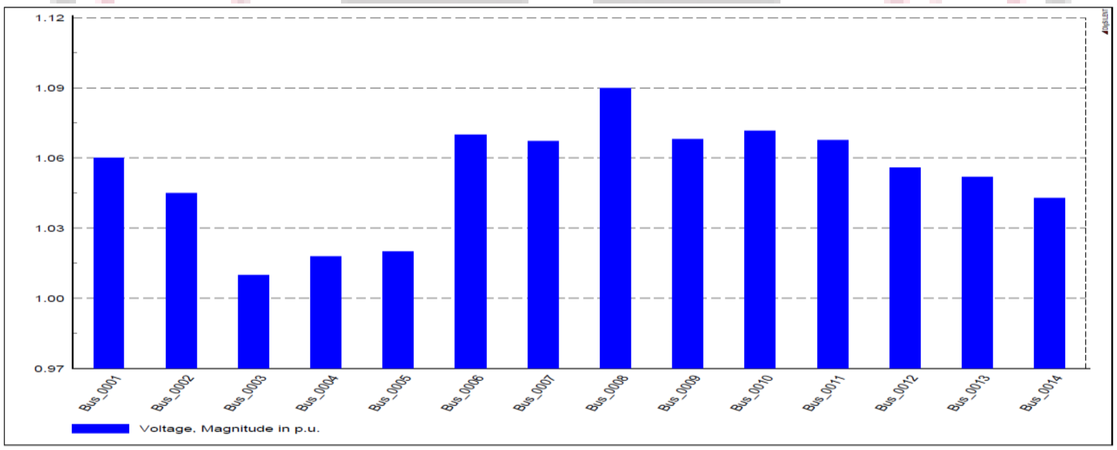

Figure 5: Voltage profile of buses with 5% penetration

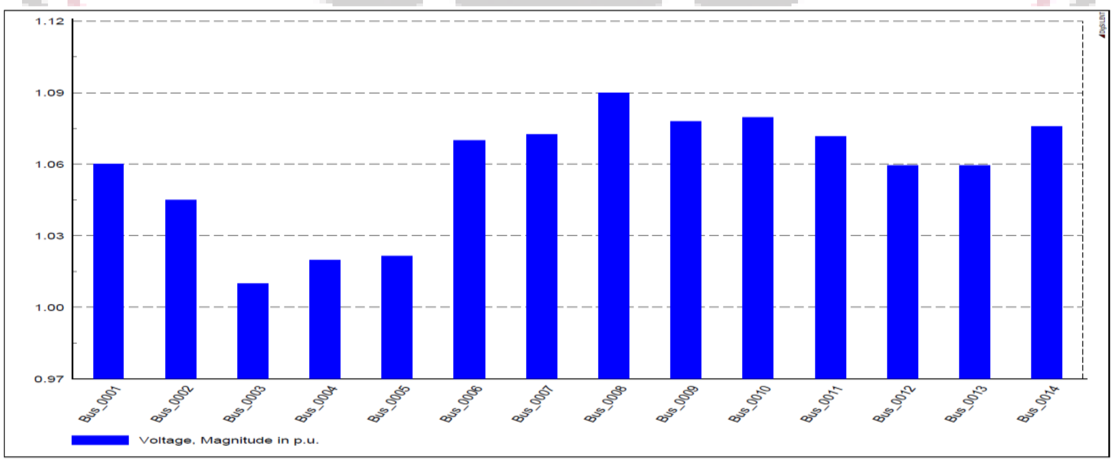

Figure 6: Voltage profile of buses with 10% penetration

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