Impacts of PV penetration on the performance of Power Network

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ABSTRACT

The performance of a power system can be improved by integrating renewable energy sources into the grid. In this paper the various impacts of PV entry into the operation of the IEEE 14 bus system are studied. Continuous power flow (CPFLOW) is generated in a system outside the PV system and with a gradual increase in solar energy input. The solar plant is installed on buses 9 and 14 as these are weak buses. Simulation analysis is performed by PSSE (Developer Power System Model).

Key words- Irradiance, IEEE 14 bus test system, most sensitive bus, PSS/E.

1. INTRODUCTION

Increased commodity production per capita, growing prosperity and urbanization, increased per capita consumption, and ease of access to energy are factors that contribute to the increase in total electricity demand on a large scale. If we seem at the variation in demand and provide of electricity, great amount of coal and furnace oil are worn. These use require to be compact, as this lead to better costs in the form of grants and an augment in the country’s reliance on exports. Renewable power sources have the possible to make a important payment to these areas. Because of every one of this, renewable power needs to be erudite and used to a great degree. Then, the employ of solar power units on the alive grid creates trouble such as, bus break over the grid limits, power excess, abnormal system losses and power outages.

1.1 VOLTAGE STABILITY

Voltage stability is defined as ability of power grid to sustain fixed tolerable voltage at every single bus of the network under standard operating conditions likewise as after being subjected to an interruption. The power system in a particular operating condition has an electrical potential of minor disturbances when, after any minor error, the voltage near the loads is the same or near the pre-fault values. The concept of electrical stability for small disturbances is said to be stable and can be analyzed using a small (line) signal model system.

1.2 VOLTAGE STABILITY LIMIT

Voltage stability limit is defined as the limit of the reactive power injection into the system after which the voltage level of the system fails to increase. Voltage level of the system can be adjusted upto voltage stability limit only by injecting reactive power.

The equation for transfer of power for a lossless transmission line is expressed as:

$$P = \frac{V_s V_r}{X} sin\delta$$

where,

V_s = rms value of sending end voltage

V_r = rms value of receiving end voltage

P = transferred power/phase

δ = phase difference between sending end and receiving end voltages

X = transfer reactance/phase

1.3 OPTIMAL POWER FLOW

An indicator called the L -indicator is based on Kirchhoff's law to detect power outages. This power indication indicator predicts the voltage stability of the operating current. Lower the value of L - indicator greater is the stability margin. By using the L indicator it is used to determine the impact of loads, location and power transactions. High power flow is done using the Newton-Raphson method in PSS / E. This Indicator predicts the voltage problem accurately and accurately.

1.4 PV CURVE AND VOLTAGE STABILITY

Power voltage curve is used to examine the system stability. For plotting the PV curve, the active power absorption of a load bus is increased gradually and the corresponding changes in the bus voltage is monitored. The resulting plot gives the PV curve. Sometimes it is also called as “nose curve”.

To understand the relationship between power and voltage, the system’s equivalent Thevenin circuit is shown in Figure 1. The circuit consists of a load supplied by an equivalent voltage source (E), the line has an equivalent reactance of X .

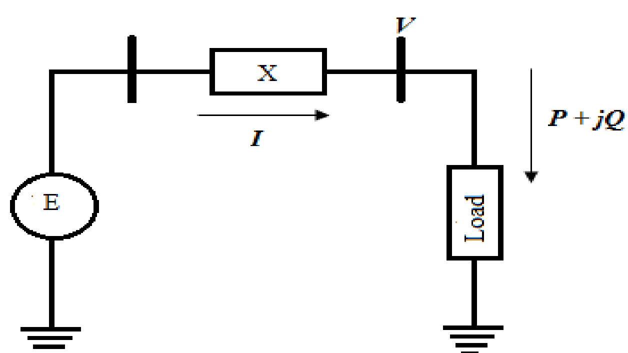

Fig. 1: Thevenin equivalent circuit

The stability can be determined from Figure 2, which shows the P-V curve for certain system. The bending point of this curve is called as the critical point. At this point voltage collapse would occur if the active power is kept increasing. The relation between the voltage and power is given according to equation.

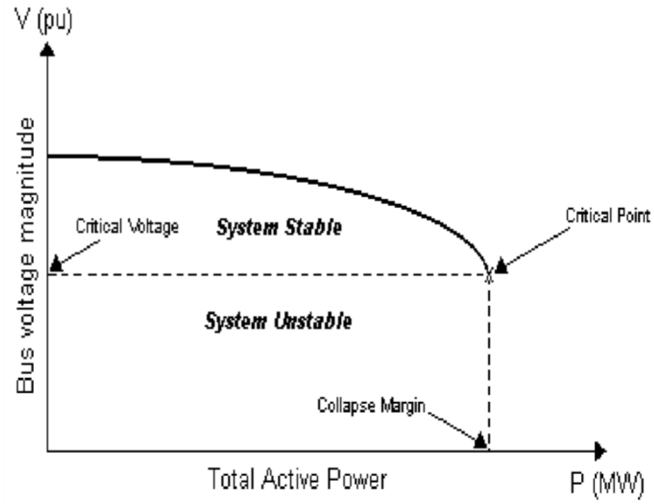

Fig 2: P-V curve

2. OVERVIEW ON THE MODELLED COMPONENTS

The analysis of voltage stability will be done on the standard IEEE 14 bus test system. In the considered base case, the power generators models and the tap changers are remain present in the system. The dynamic VAr compensating devices and solar PV models will be added as the research goes on. The input parameters of the models will be mainly based on and. Even though the parameters can be changed sometime in order to avoid the software going into unstable condition. PSS/E documentation provides useful information on how to use the software efficiently.

2.1 GENERATOR MODELS

There will be two generator models which will be used in the system namely solar PV model and synchronous generator model. It will represent the effects of large scale integration of renewable sources which is PV generator in our case on the IEEE 14 bus test system.

2.2 SOLAR PV MODELS

As the research begins, the network will contain only synchronous generators. Then we will gradually introduce solar PV units so that they represent a large integration. A general block diagram of solar PV plant and its components is shown here in Figure 1.

PSS/E has many built in wind turbine model models. These wind turbine models can be configured to behave as a solar PV generator. Wind model WT4 is best suited for this purpose. It has four sub modules:

- IRRAD: for solar irradiance.
- PANEL: PV panel output curve optimization.

- PVEU: Module of electrical control.
- PVGU: Module of Inverter.

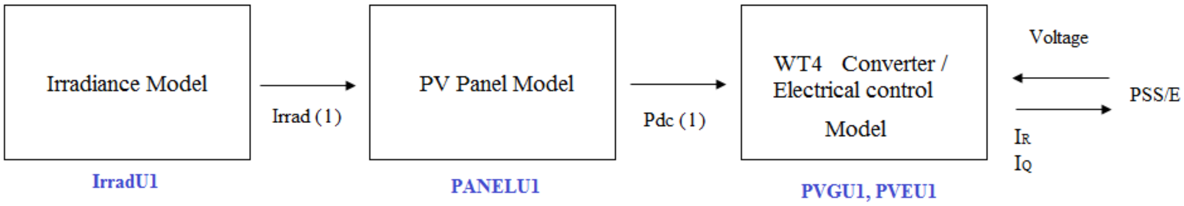

Figure 3: The interaction between PV modules in PSS/E

The electrical control module gives the command to inverter module for calculation of active and reactive power injection into the grid. The amount of output DC power of the solar panel is taken as a reference. The reference power is calculated by the panel module at different irradiances. The active power that is needed to supply to the grid is compared with the reference power and gets adjusted accordingly. The interaction between the modules in shown in figure 3. Further information can be found in PSS/E documentations.

3. RESULTS

3.1 IDENTIFICATION OF THE WEAK BUSES IN THE SYSTEM

Following standard test data was used to find the weakest bus.

Table 1: row information for IEEE 14 bus examination scheme

Between Buses	Line Impedance	
	Resistance (Ω)	Reactance (Ω)
1-2	0.9228	2.8708
2-3	2.2719	9.4535
2-4	2.7662	8.396
1-5	2.5727	10.619
2-5	2.7139	8.2843
3-4	3.2557	8.1474
4-5	0.6559	2.0086
5-6	0	0
4-7	0	0
7-8	0	0
4-9	0	0
7-9	0	5.2358
9-10	1.5147	4.005

6-11	4.52	9.4663
6-12	5.8575	12.171
6-13	3.144	6.2015
9-14	6.0571	12.878
10-11	3.964	9.445
12-13	10.51	9.519

Table .2: valve location principles used for transformers

Transformers	Tap Ratio	Between Buses
1	0.92	5-6
2	0.99	4-9
3	0.98	4-7

Table 3: Bus information for IEEE 14 bus examination scheme

Bus No.	Generation		Load	
	Real Power (MW)	Reactive Power (MVAr)	Real Power (MW)	Reactive Power (MVAr)
1	22.4	-16.9	0	0
2	40	4.4	2.7	2.7
3	0	3.4	4.2	19
4	0	0	7.8	2.9
5	0	0	7.6	1.6
6	0	0	1.2	7.5
7	0	0	0	0
8	0	0	0	0
9	0	0	9.5	16.6
10	0	0	9	5.8
11	0	0	3.5	1.82
12	0	0	6.1	1.6
13	0	0	3.5	5.84
14	0	0	14.98	5.00

After feeding these data to the IEEE 14 bus model, we simulated the base case and by Newton-Rapshon method got a power flow result. In doing so we increased the load in fixed steps of 5%up-to 40%.The table shown below shows the results obtained. Then average of each change was taken. After calculating the average, we have taken a difference between average power flow value and original power flow result value. The bus having the highest difference value is considered as the most sensitive bus (as shown by Table 4).

Table 4: Calculation of most sensitive bus

Bus No.	Voltage Change in p.u.										
	0%	5%	10%	15%	20%	25%	30%	35%	40%	Avg	Difference
1	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0
2	1.045	1.045	1.045	1.045	1.045	1.045	1.045	1.045	1.045	1.045	0
3	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	0
4	0.9960	0.9958	0.9957	0.9955	0.9959	0.9953	0.9951	0.9950	0.9948	0.995	0.0005
5	1.0012	1.0011	1.001	1.0009	1.0008	1.0007	1.0006	1.0005	1.0004	1.008	0.0004
6	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	0
7	1.029	1.0290	1.0286	1.0282	1.0278	1.0274	1.0269	1.0265	1.0261	1.031	0.0016
8	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	0
9	1.007	0.9999	0.9991	0.9983	0.9975	0.9966	0.9958	0.9950	0.9941	0.924	0.0765
10	1.0019	1.0012	1.0005	0.9998	0.9991	0.9966	0.9958	0.9950	0.9941	1.000	0.0010
11	1.0301	1.0297	1.0294	1.0291	1.0287	1.0284	1.028	1.0277	1.027	1.028	0.0014
12	1.043	1.042	1.0417	1.0413	1.0410	1.0407	1.0404	1.0404	1.0398	1.041	0.0012
13	1.0289	1.0284	1.0278	1.0272	1.0266	1.0261	1.0255	1.0249	1.0248	1.026	0.0026
14	0.9639	0.9614	0.9589	0.9564	0.9539	0.9514	0.9488	0.9462	0.9437	0.953	0.0100

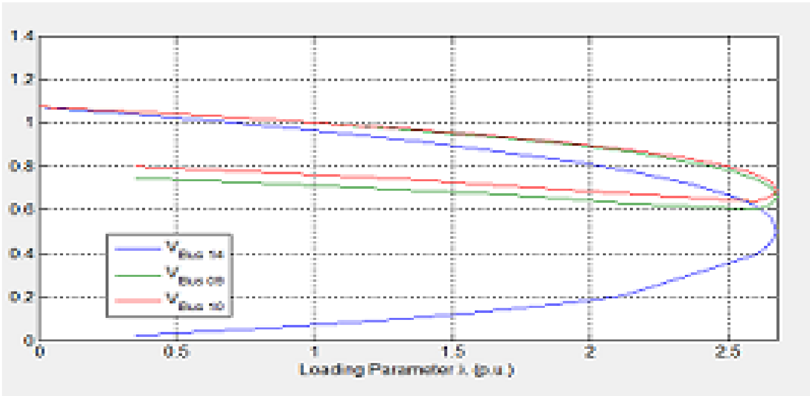

Fig. 4: Voltage against loading parameter

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