Analysis of Power Flow In IEEE Five Bus Power System Based on PV Curve Assessment

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Abstract- *In this paper P-V curve analysis is use to determine stability of power system. P-V curve is drawn for different load power factor condition. Load flow analysis is helps in calculating loadability limit and critical voltage collapse point at candidate load bus. Results were obtained using MATLAB applications software and power world simulator.*

Keywords- PV Curve, Voltage Stability, Newton Raphson, loadability.

I. INTRODUCTION

The power system consists of various busses which are interconnected by means of the transmission lines. Power is injected to a bus with the help of generators, while loads are taped on it. The load flow study is very significant in a power system. By load flow analysis we can determine currents, voltage, active and reactive powers at various points of power system. This analysis is simplified by making a network model and its network equations. Thus resulting equations in terms of power, known as the power flow equation, become nonlinear and must be solved by iterative techniques. Power flow studies commonly referred as load flow are backbone of power system analysis and design[1].

P-V curve analysis is use to determine voltage stability of a radial system and also a large meshed network. 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 then curves for those particular buses will be plotted to determine the voltage stability of a system by static analysis approach.

II. THEORETICAL BACKGROUND

Newton Raphson Method is an iterative technique for solving a set of various nonlinear equations with an equal number of unknowns. In this paper polar coordinate form is used[7]. As shown in figure the current entering at bus i is given by equation

$$I_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \qquad j \neq i$$

This equation can be rewritten in terms of the bus admittance matrix as

$I_i = \sum_{j=1}^{n} Y_{ij} V_j$, expressing in polar form we have

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

Complex power at i^{th} bus is $P_i - j Q_i = V_i^* I_i$

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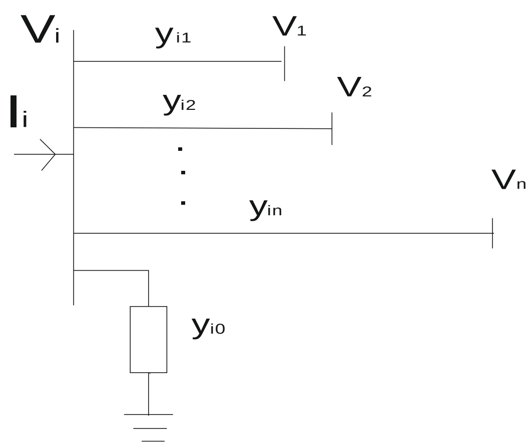


Figure 1 : i^{th} bus of the power system

Substituting the value of current in complex power equation we get

$P_i - j Q_i = |V_i| \angle -\delta_i \sum_{j=1}^{n} |Y_{ij}||V_j| \angle \theta_{ij} + \delta_j$, simplify and separating real and imaginary parts,

$$P_i = \sum_{j=1}^{n} |V_i||Y_{ij}||V_j| \cos(\theta_{ij} - \delta_i + \delta_j)$$

$$Q_i = -\sum_{j=1}^{n} |V_i||Y_{ij}||V_j| \sin(\theta_{ij} - \delta_i + \delta_j)$$

Elements of Jacobian matrix is obtained by taking partial derivatives of above equations with respect to magnitude and phase angle of voltages i.e., $|V|$ and δ. the jacobian matrix gives the linearised relationship between small changes in magnitude and phase angle of voltages i.e., $\Delta|V|$ and $\Delta\delta$ with the small changes in real and reactive power ΔP and ΔQ.

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix} = \begin{bmatrix}J_1 & J_2\\ J_3 & J_4\end{bmatrix}\begin{bmatrix}\Delta\delta\\ \Delta|V|\end{bmatrix}$$

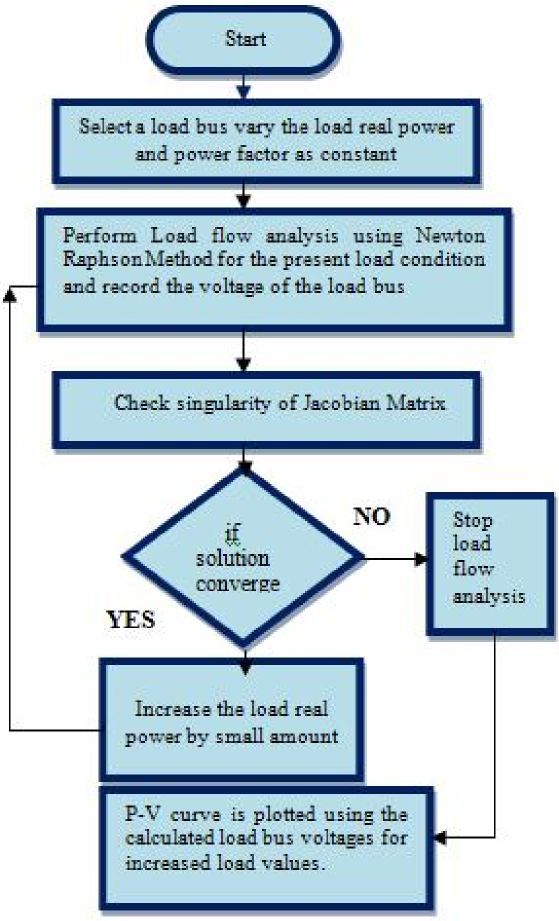
The term ΔP and ΔQ known as power residue or mismatch, given by

$\Delta P = P_{schedule} - P$

$\Delta Q = Q_{schedule} - Q$

$$\begin{bmatrix}\Delta\delta\\ \Delta|V|\end{bmatrix} = \begin{bmatrix}J_1 & J_2\\ J_3 & J_4\end{bmatrix}^{-1}\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix}$$

The new estimate for bus voltages are $\delta^{k+1} = \delta^k + \Delta\delta$ and $V^{k+1} = V^k + \Delta|V|$.



III. CASE STUDY

Power systems analysis is a critical part of any transmission or distribution system. In this paper load flow calculations from provided data on a 5-bus system and the results were obtained using MATLAB and power world simulator [16] [11]. Figure below represent 5 bus power system network and related information on 5 bus systems are shown in tables.

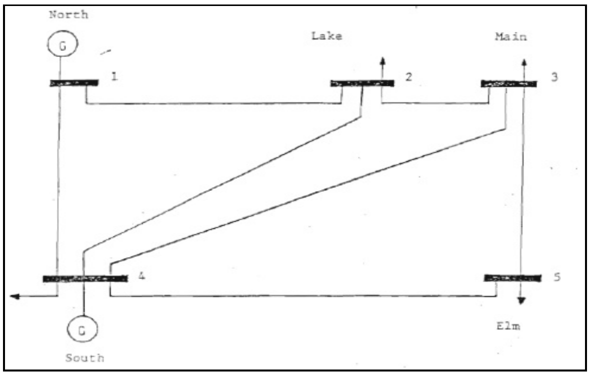


Figure 2 : Line diagram of the 5 bus system

TABLE I : Given operating condition of 5 bus system

Bus .no.	Voltage p.u.	Angle (δ) degree	Generation Active power MW	Load	
				MW	MVar
1	1.06	0	0	0	0
2	1.00	0	0	45	15
3	1.00	0	0	40	5
4	1.047	0	45.00	20	-20
5	1.00	0	0	60	10

Bus no. 4 have Mvar capability between -40 and 50 Mvar

TABLE II : Line Data for 5 bus system

Send Bus	End Bus	Resistance	Reactance	Line charging (B/2)
1	4	.0600	.0600	.0300
1	2	.0800	.2400	.025
4	2	.0600	.1800	.0200
4	3	.0600	.1800	.0200
4	5	.0400	.1200	.0150
2	3	.0100	.0300	.0100
3	5	.0800	.2400	.0250

Using same data simulation is done with Power world simulator and Better results were obtained. Below figure shows 5 bus system in power world simulator and using above given data load flow analysis is done using Newton Raphson method. Line power flows, voltage magnitude and angle at each bus and losses in line can be calculated for various loading level.

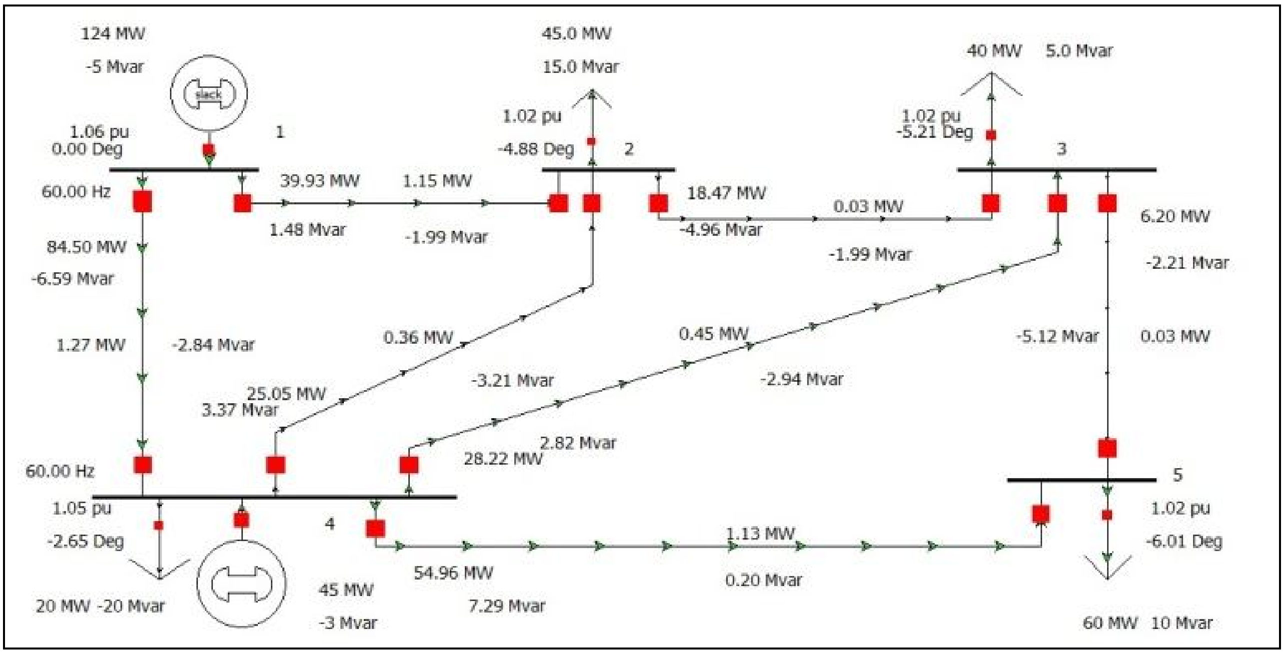


Figure 3 : Five bus system at Loading level LL=1

Case study

PV Curve Analysis of 5 Bus System is done by varying load power P_2 and $Q_2 = P_2 \tan\phi$ and constant generator real power $P_4 = 45\ MW$, $Q_{Mvar\ limit} = -40\ \&\ 50$ at generator bus 4, and PV curve is drawn.

TABLE III : Bus Voltage at Selected Bus =2 and Power Factor $\phi = 45°\ lag$.

P_2 MW	Q_2 $MVar$	V_2 $p.u.$	V_3 $p.u.$	V_4 $p.u.$	V_5 $p.u.$
0	0	1.04	1.04	1.05	1.05
100	100	.94	.95	1.03	.98
150	150	.84	.87	.99	.92
200	200	.70	.73	.92	.83
210	210	.63	.68	.89	.79
215	215	.56	.61	.86	.74
Blackout occur					

TABLE IV : Complex Power at Selected bus =2 and Power Factor $\phi = 45°\ lag$.

P_2 MW	Q_2 $MVar$	*Slack bus*		*Generator bus*
		P_{GEN}	Q_{GEN}	Q_4
0	0	77	0	-30
100	100	187	52	50
150	150	251	147	50
200	200	336	306	50
210	210	364	373	50
215	215	395	456	50
Blackout occur				

TABLE V : Bus Voltage at Selected bus =2 and Power Factor $\phi = 0^{\circ}$.

P_2 MW	Q_2 $MVar$	V_2 $p.u.$	V_3 $p.u.$	V_4 $p.u.$	V_5 $p.u.$
0	0	1.04	1.04	1.05	1.05
100	0	1.02	1.02	1.05	1.02
200	0	.99	.99	1.04	1
300	0	.92	.93	1.01	.95
400	0	.79	.80	.94	.86
420	0	.72	.74	.90	.81
430	0	.67	.69	.87	.77
Blackout occur					

TABLE VI : Complex Power at Selected bus =2 and Power Factor $\phi = 0^{\circ}$.

P_2 MW	Q_2 $MVar$	Slack bus		Generator bus
		P_{GEN}	Q_{GEN}	Q_4
0	0	77	0	-30
100	0	184	-18	8
200	0	297	-19	50
300	0	422	57	50
400	0	575	221	50
420	0	622	305	50
430	0	658	383	50
Blackout occur				

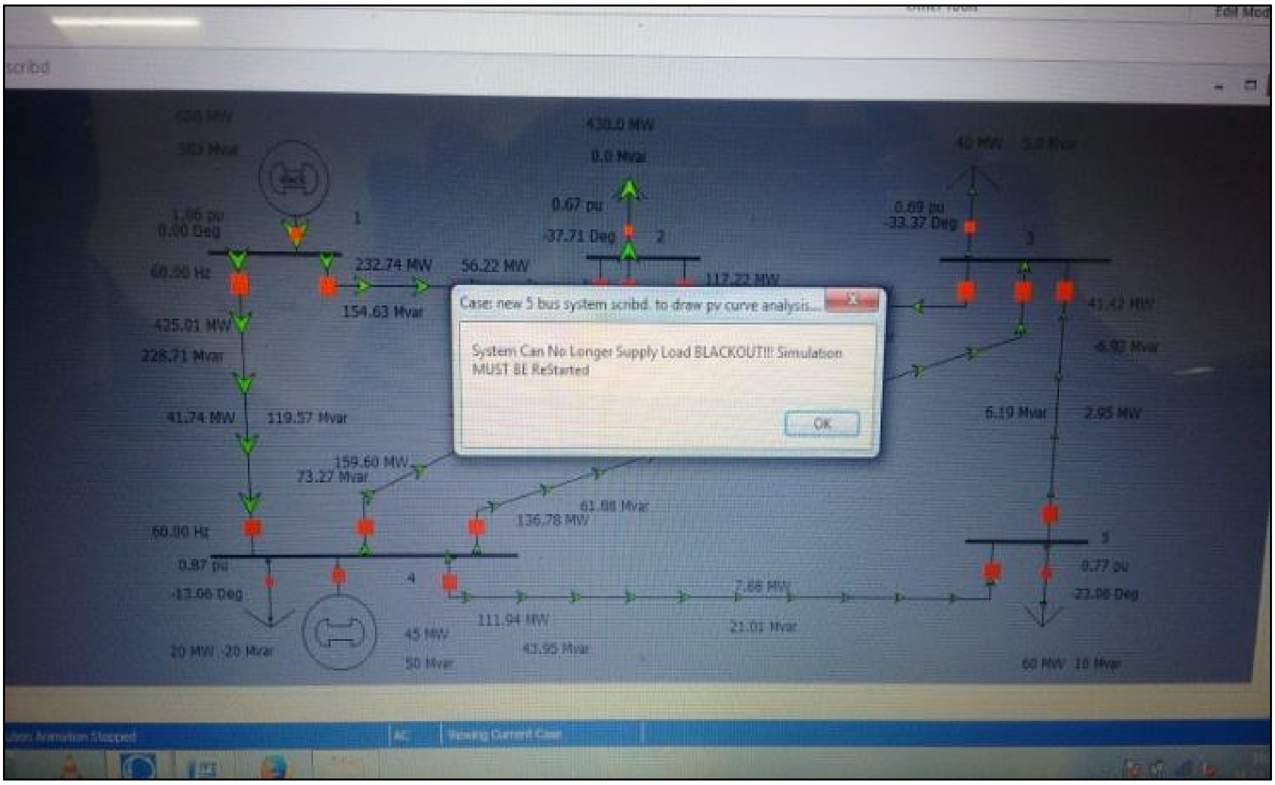


Figure 4 : PV curve for load bus 2 from lagging to leading condition

TABLE VII: Bus Voltage at Selected bus =2 and Power Factor $\phi = 45° \ lead$.

P_2 MW	Q_2 MVar	V_2 p.u.	V_3 p.u.	V_4 p.u.	V_5 p.u.
0	0	1.04	1.04	1.05	1.05
100	-100	1.09	1.07	1.06	1.04
200	-200	1.12	1.10	1.07	1.06
300	-300	1.14	1.12	1.07	1.06
400	-400	1.15	1.12	1.06	1.05
600	-600	1.15	1.11	1.05	1.04
650	-650	1.13	1.09	1.03	1.01
690	-690	1.09	1.05	1	.97
700	-700	1.08	1.03	.98	.96
750	-750	1.03	.98	.93	.90
Blackout occur					

TABLE VIII: Complex Power at Selected bus =2 and Power Factor $\phi = 45° \ lead$.

P_2 MW	Q_2 MVar	Slack bus		Generator bus
		P_{GEN}	Q_{GEN}	Q_4
0	0	77	0	-30
100	-100	185	-67	-40
200	-200	302	-117	-40
300	-300	428	-142	-40
400	-400	562	-139	-40
600	-600	865	-103	35
650	-650	954	-52	50
690	-690	1037	41	50
700	-700	1063	78	50
750	-750	1176	221	50
Blackout occur				

Here curve is drawn between real load power and bus voltage of candidate bus 2 for different power factor from lagging to leading conditions.

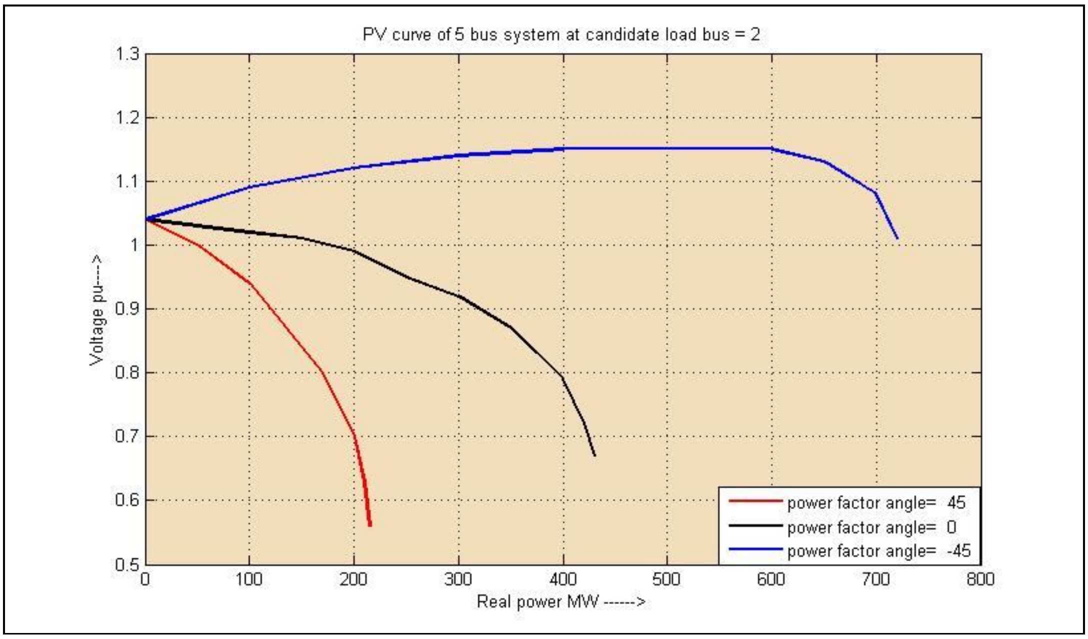


Figure 5 : PV curve for load bus 2 from lagging to leading condition

It is also evident from tables that as the load on system increases not only candidate bus but also other connected bus voltage profile get depressed with low voltage level. Also role of reactive power support at candidate bus is also important.

By observing above results it has been noted that for 5 bus test system loadability of the system increases and voltage stability improves as shown in PV curve from lagging to leading condition.

IV. CONCLUSION

In this paper PV curve analysis shows that with increasing load, voltage profile of line dropped. Power flow program is developed using Matlab software and simulation in power world simulator to analyze power system network. It is shown that reactive power compensation at load side has significant effect on loadability, critical voltage point of the system.

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