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# PV and QV Curve Analysis of IEEE 9 Bus System with Fact Devices

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*Abstract:-* **Voltage Stability investigation of voltage shakiness in electric power framework is extremely critical with a specific end goal to keep up the balance of the system. Voltage security is the capacity of the framework to keep up sufficient and controllable voltage levels at all framework stack buses. The primary concern is that voltage levels outside of a specified range can influence the task of the client's heaps. This paper exhibits the examination of voltage insecurity of electric power framework by utilizing power-voltage (PV) bend and receptive power-voltage (QV) bend.**

## I. INTRODUCTION

Voltage steadiness is a vital part of any power framework plan as it guarantees the framework has adequate energy to take care of the heap demand. Power framework voltage unsteadiness is identified with the absence of responsive power assets in the system and the voltage can fall when the power furthest reaches of a framework is surpassed. Voltage security in the power framework is characterized as the capacity of a power framework to keep up adequate voltages at all transport in the framework under ordinary condition and in the wake of being subjected to an unsettling influence. In the ordinary working condition the voltage of a power
Framework is steady, yet when the blame or unsettling influence happens in the framework, the voltage winds up temperamental this outcome in a dynamic and wild decrease in voltage. Voltage solidness is at times likewise called stack security.

## .CLASSIFICATION OF VOLTAGE STABILITY

Voltage stability may be classified into two categories. These are:

a. Large-disturbance Voltage Stability – It is worried about a framework soundness to control voltages following an expansive unsettling influence, for example, framework shortcomings, loss of load, or loss of age. For assurance of this type of dependability requires the examination of the dynamic execution of the framework over a period adequate to catch of such gadgets as under load tap evolving transformers, generator field, and current limiters. Expansive aggravation voltage studies can be examined by utilizing non-straight time space reproductions which incorporate appropriate demonstrating

b. Small-Disturbances Voltage Stability – The working condition of a power framework is said to have little aggravations voltage steadiness if the framework has little unsettling influences, a voltage close loads does not change or stay near the pre-aggravation esteems. The idea of little unsettling influence solidness is identified with enduring state and be investigated utilizing a little flag model of the framework.

## II. TEST SYSTEM

The Voltage soundness cutoff can be characterized as the constraining stage in a power framework past which no measure of receptive power infusion will raise the framework voltage to its ostensible state. The framework voltage must be balanced by receptive power infusions till the framework voltage steadiness is kept up. Test framework with 9 transports and 3 generators. This specific experiment likewise incorporates three 2 winding transformers, 6 lines and 3 loads. The base kV levels are 13.8 kV, 16.5 kV, 18 kV, and 230 kV. The single-line graph of the IEEE 9 bus case is demonstrated as follows

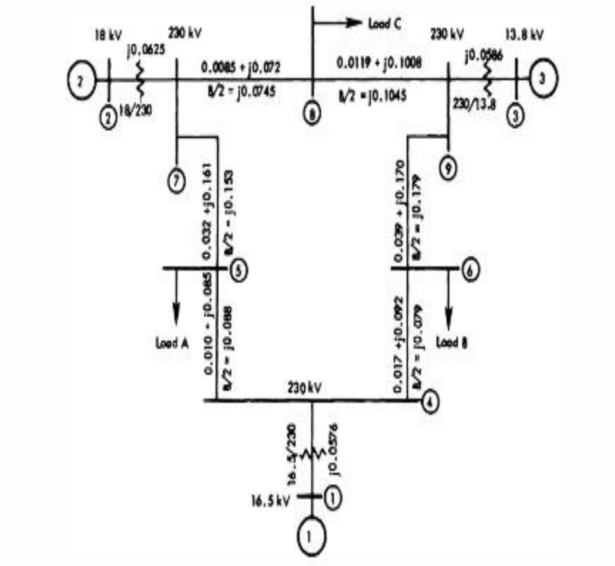


Fig 1: IEEE 9-Bus System

Here demonstrating of IEEE 9 transport framework is done in MATLAB/SIMULINK and researches the conduct of Power framework by Using PV and QV curves

International Journal of Engineering Research & Technology (IJERT)
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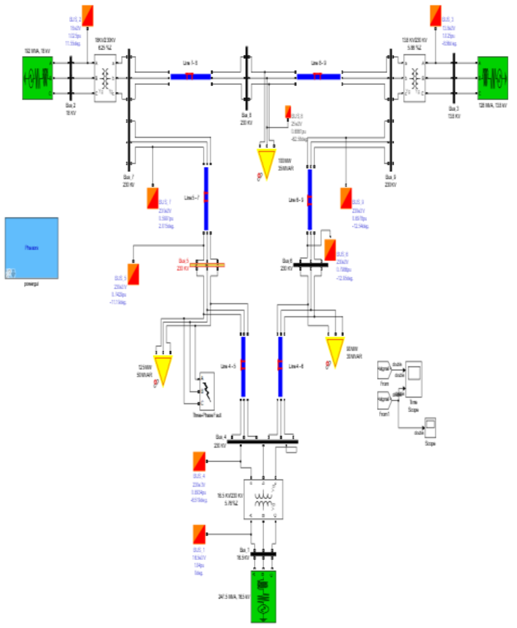

Fig 2: IEEE 9-Bus System Matlab Model

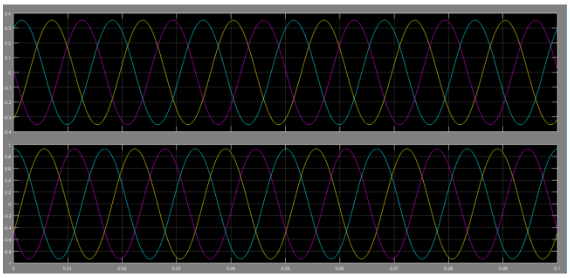

Fig 2: Voltage and current waveforms at bus 5

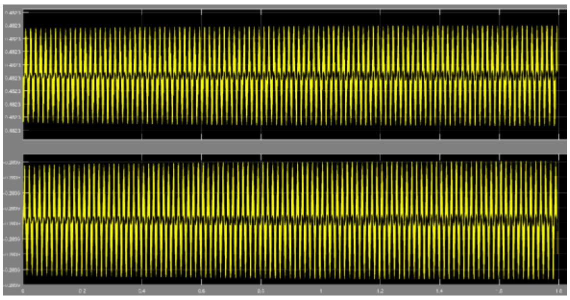

Fig 3: Active and reactive power at bus no 5

## III. P V CURVE ANALYSIS

P-V curve investigation is use to decide voltage dependability of an outspread framework and furthermore an expansive fit system. For this examination P i.e. control at a specific zone is expanded in steps and voltage (V) is seen at some basic load transports and afterward bends for those specific transports will be plotted to decide the voltage security of a framework by static investigation approach. To clarify P-V bend investigation let us accept two-transport framework with a solitary generator, single transmission line and a heap, as appeared in Figure.

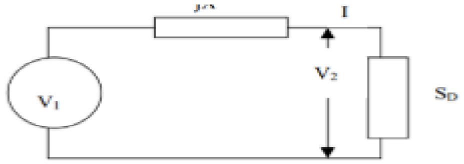


Fig 4: Two bus representation model

P-V bends are valuable in determining how much load shedding ought to be done to set up prefault organize conditions even with the most extreme increment of receptive power supply from different programmed exchanging of capacitors or condensers. Here, the intricate load expect is with V1 is the sending end voltage and V2 is getting end voltage and is stack control factor.

$$P_{12} = |V_1|^2 G - |V_1||V_2| G\cos(\theta_1-\theta_2) + |V_1||V_2| B\sin(\theta_1-\theta_2)$$

$$Q_{12} = |V_1|^2 B - |V_1||V_2| B\cos(\theta_1-\theta_2) - |V_1||V_2| G\sin(\theta_1-\theta_2)$$

Let G=0. Then….

$$P_{12} = |V_1||V_2| B\sin(\theta_1-\theta_2)$$

$$Q_{12} = |V_1|^2 B - |V_1||V_2| B\cos(\theta_1-\theta_2)$$

Now we can get SD=PD+jQD=-(P21+jQ21) by

- - exchanging the 1 and 2 subscripts in the previous equations.
- - negating

$$P_D = -P_{21} = -|V_1||V_2| B\sin(\theta_2-\theta_1) = |V_1||V_2| B\sin(\theta_1-\theta_2)$$

$$Q_D = -Q_{21} = -|V_2|^2 B + |V_1||V_2| B\cos(\theta_2-\theta_1) = -|V_2|^2 B + |V_1||V_2| B\cos(\theta_1-\theta_2)$$

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

$$|V_2|^2 = \frac{1-\beta P_D \pm [1-P_D(P_D+2\beta)]^{1/2}}{2}$$

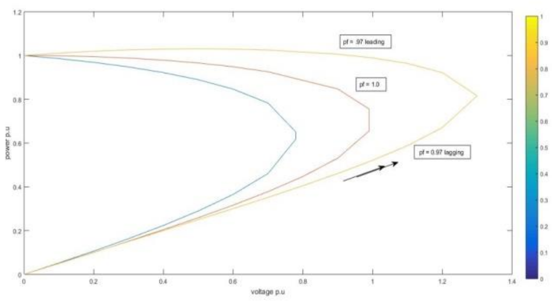

Fig 5 PV curve without SVC (bus no 5)

## IV. Q V CURVE

Q-V Curve is the connection between the responsive powers (Q) and accepting end voltage (V2) for various estimations of active power P [3]

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

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

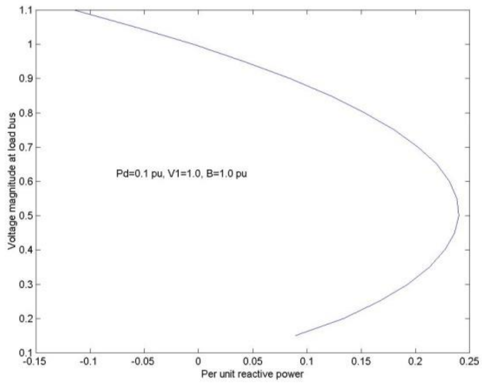


Fig 6 QV curve (bus no 5)

## V. SVC OPERATION

A static var compensator (SVC) is used to oversee voltage on a 500 kV, 3000 MVA system. Right when system voltage is low the SVC produces reactive power (SVC capacitive). Exactly when structure voltage is high it acclimatizes responsive power (SVC inductive). The SVC is evaluated +200 Mvar capacitive and 100 Mvar inductive. The Static Var Compensator piece is a phasor demonstrate addressing the SVC static and dynamic characteristics at the system real repeat

a. SVC dynamic response

The Three-Phase Programmable Voltage Source is utilized to fluctuate the framework voltage and watch the SVC execution. At first the source is creating ostensible voltage. At that point, voltage is progressively diminished (0.97 pu at t = 0.1 s), expanded (1.03 pu at t = 0.4 s) lastly came back to ostensible voltage (1 pu at t = 0.7 s)

The SVC reaction speed relies upon the voltage controller essential pick up Ki (Proportional pick up Kp is set to zero), framework quality (reactance Xn) and hang (reactance Xs). In the event that the voltage estimation time consistent and normal time postpone Td because of valve terminating are ignored, the framework can be approximated by a first request framework having a shut circle time steady :

Tc= 1/(Ki*(Xn+Xs))

With given framework parameters (Ki = 300; Xn = 0.0667 pu/200 MVA; Xs = 0.03 pu/200 MVA), Tc = 0.0345 s. In the event that you increment the controller pick up or diminish the framework quality, the estimation time consistent and the valve terminating defer Td will never again be unimportant and you will watch an oscillatory reaction and in the long run flimsiness.

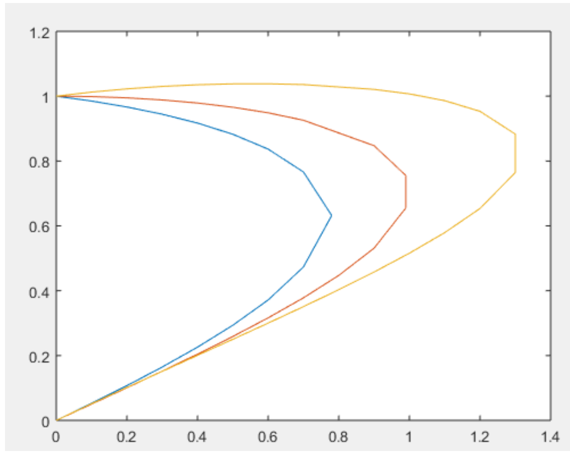

Fig 7: PV curve with SVC (5 bus)

With a specific end goal to gauge the SVC consistent state V-I trademark, you will now program a moderate variety of the source voltage. Open the Programmable Voltage Source menu and change the "Kind of Variation" parameter to "Tweak". The regulation parameters are set to apply a sinusoidal variety of the positive-grouping voltage in the vicinity of 0.75 and 1.25 pu in 20 seconds. In the Simulation->Configuration Parameters menu change the stop time to 20 s and restart reenactment. At the point when reproduction is finished, double tap the blue square. The hypothetical V-I trademark is shown (in red) together with the deliberate trademark (in blue).

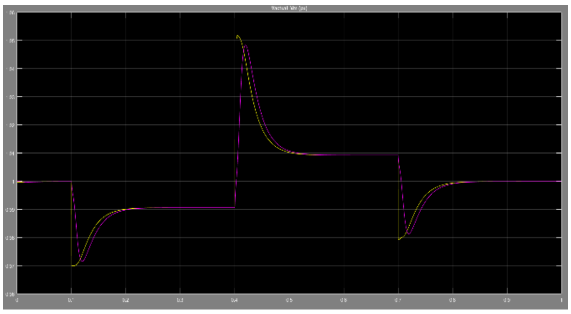

Fig 8 Effect of SVC on Voltage

## VI. METHODS OF IMPROVING VOLTAGE STABILITY

The power framework voltage insecurity can be enhanced utilizing the accompanying strategies

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1. Generator AVRs
2. Under-Load Tap Changers
3. Load shedding amid possibilities
4. Receptive Power Compensation

## VII. CONCLUSION

SVC Plays exceptionally foreign made part in Power framework. In voltage Stability the attributes with SVC can be enhanced to wanted level. In Modern Power framework we locate the feeble transport and SVC enhances easily. Voltage profiles can be enhanced by SVC by extraordinary surviving appeared in above outcomes.

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# Appendix
## PV AND QV CURVES ANALYSIS

Frequency (Hz): 60.0 | Base power (VA): 1e+08 | Max iterations: 50 | PQ tolerance (pu): 1e-05

| | type | Bus ID | Vbase (kV) | Vref (pu) | Vangle (deg) | P (MW) | Q (Mv... | Qmin (Mvar) | Qmax (Mvar) | V_LF (pu) | Vangle_LF (deg) | P_LF (MW) | Q_LF (Mvar) | Block Name |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ng | BUS_1 | 16.50 | 1.0400 | 0.00 | 0.00 | 0.00 | -Inf | Inf | 0 | 0.00 | 0.00 | 0.00 | 247.5 MVA, 16.5 kV |
| 2 | | BUS_4 | 230.00 | 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | Load Flow Bus1 |
| 3 | | BUS_5 | 230.00 | 1 | 0.00 | 125.00 | 50.00 | -Inf | Inf | 0 | 0.00 | 0.00 | 0.00 | 125 MW 50 MVAR/Three-Phase Par... |
| 4 | | BUS_6 | 230.00 | 1 | 0.00 | 90.00 | 30.00 | -Inf | Inf | 0 | 0.00 | 0.00 | 0.00 | 90 MW 30 MVAR/Three-Phase Para... |
| 5 | | BUS_7 | 230.00 | 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | Load Flow Bus4 |
| 6 | | BUS_9 | 230.00 | 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0.00 | Load Flow Bus5 |
| 7 | | BUS_2 | 18.00 | 1.0250 | 0.00 | 163.00 | 0.00 | -Inf | Inf | 0 | 0.00 | 0.00 | 0.00 | 192 MVA, 18 kV |
| 8 | | BUS_3 | 13.80 | 1.0250 | 0.00 | 85.00 | 0.00 | -Inf | Inf | 0 | 0.00 | 0.00 | 0.00 | 128 MVA, 13.8 kV |
| 9 | | BUS_8 | 25.00 | 1 | 0.00 | 100.00 | 35.00 | -Inf | Inf | 0 | 0.00 | 0.00 | 0.00 | 100 MW 35 MVAR/Three-Phase Par... |

Summary for IEEE_9bus : The load flow converged in 5 iterations !

Subnetwork 1

| | P(MW) | Q(Mvar) |
|---|---|---|
| Total generation | 431.3758 | 1563.048 |
| Total PQ load | 315 | 115 |
| Total Z shunt | 0.636575 | 0.636565 |
| Total ASM | 0 | 0 |
| Total losses | 115.7392 | 1447.411 |

1 : BUS_1 V= 1.040 pu/16.5kV 0.00 deg ; Swing bus

| | P(MW) | Q(Mvar) |
|---|---|---|
| Generation | 183.3758 | 275.2691 |
| PQ Load | 0 | 0 |
| Z shunt | 0.216324 | 0.216316 |
| BUS_4 | 183.1595 | 275.0528 |

2 : BUS_2 V= 1.025 pu/18kV 11.55 deg

| | P(MW) | Q(Mvar) |
|---|---|---|
| Generation | 163 | 712.3214 |
| PQ Load | 0 | 0 |
| Z shunt | 0.210128 | 0.210122 |
| BUS_7 | 162.7899 | 712.1112 |

3 : BUS_3 V= 1.025 pu/13.8kV -8.56 deg

| | P(MW) | Q(Mvar) |
|---|---|---|
| Generation | 85 | 575.4573 |
| PQ Load | 0 | 0 |
| Z shunt | 0.210129 | 0.210121 |
| BUS_9 | 84.78987 | 575.2472 |

4 : BUS_4 V= 0.893 pu/230kV -6.52 deg

| | P(MW) | Q(Mvar) |
|---|---|---|
| Generation | 0 | 0 |
| PQ Load | 2.34E-09 | -3.7E-10 |
| Z shunt | -2.8E-06 | 2.77E-06 |

International Journal of Engineering Research & Technology (IJERT)
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Vol. 7 Issue 05, May-2018

| | | |
|---|---|---|
| BUS_1 | -183.157 | -216.898 |
| BUS_5 | 81.53728 | 144.6962 |
| BUS_6 | 101.6202 | 72.20193 |

5 : BUS_5 V= 0.743 pu/230kV -11.19 deg

| | P(MW) | Q(Mvar) |
|---|---|---|
| Generation | 0 | 0 |
| PQ Load | 125 | 50 |
| Z shunt | 1.88E-12 | -1E-12 |
| BUS_4 | -77.8389 | -125.089 |
| BUS_7 | -47.1611 | 75.08909 |

6 : BUS_6 V= 0.799 pu/230kV -12.95 deg

| | P(MW) | Q(Mvar) |
|---|---|---|
| Generation | 0 | 0 |
| PQ Load | 90 | 30 |
| Z shunt | 2.11E-12 | -3.9E-12 |
| BUS_4 | -98.125 | -64.6108 |
| BUS_9 | 8.124995 | 34.61077 |

7 : BUS_7 V= 0.599 pu/230kV 2.01 deg

| | P(MW) | Q(Mvar) |
|---|---|---|
| Generation | 0 | 0 |
| PQ Load | 1.18E-08 | -1.9E-08 |
| Z shunt | -1.1E-06 | 1.15E-06 |
| BUS_2 | -162.78 | -394.679 |
| BUS_5 | 52.41219 | -62.4325 |
| BUS_8 | 110.3675 | 457.1119 |

8 : BUS_8 V= 0.686 pu/25kV -62.58 deg

| | P(MW) | Q(Mvar) |
|---|---|---|
| Generation | 0 | 0 |
| PQ Load | 100 | 35 |
| Z shunt | 1.55E-13 | -1.2E-13 |
| BUS_7 | -57.6 | -12.1851 |
| BUS_9 | -42.4 | -22.8149 |

9 : BUS_9 V= 0.698 pu/230kV -12.54 deg

| | P(MW) | Q(Mvar) |
|---|---|---|
| Generation | 0 | 0 |
| PQ Load | 1.2E-09 | 4.56E-10 |
| Z shunt | -1.7E-06 | 1.66E-06 |
| BUS_3 | -84.7834 | -386.668 |
| BUS_6 | -6.81295 | -49.0767 |
| BUS_8 | 91.59638 | 435.7449 |