**Voltage Stability Analysis: PV Curve and Critical Point**

**Overview of Voltage Stability**

Voltage stability refers to the ability of a power system to maintain steady voltage levels at all buses in the network under normal operating conditions, as well as after being subjected to disturbances. In other words, it is the system's ability to maintain a balance between the voltage at each bus and the power being delivered.

The issue of voltage stability becomes critical when the system is pushed close to its operational limits, particularly when load increases or the generation capacity decreases. Voltage instability can lead to voltage collapse, where the system's voltage falls to a point where it is no longer able to recover.

Voltage stability is typically assessed using **voltage stability curves**, such as the **PV curve** (Power-Voltage curve) and **QV curve** (Reactive Power-Voltage curve), which provide insight into how changes in power injections (active and reactive) affect the voltage profile of the system.

**The PV Curve**

The **PV curve** is a key tool in analyzing voltage stability. It shows the relationship between **active power (P)** injected into the system and the **voltage (V)** at a specific bus (typically a slack or generator bus). This curve is generated by increasing the active power load and observing how the voltage at the bus changes.

**Steps for Creating the PV Curve**

1. **Vary Active Power (P)**: The active power injected into the system is gradually increased from a starting value (e.g., zero) up to a maximum value (e.g., the maximum generation limit). At each step, a **power flow** calculation is performed to determine the voltage at the bus of interest.
2. **Record Voltage (V)**: For each value of active power, the corresponding voltage at the bus is recorded.
3. **Plot the PV Curve**: The active power (P) values are plotted on the x-axis, and the corresponding voltage (V) values are plotted on the y-axis. The resulting curve typically starts with a stable voltage, and as the active power increases, the voltage drops. The curve will reach a point where voltage drops rapidly, indicating the onset of instability.

**Voltage Stability and Critical Point**

The **critical point** on the PV curve is the point at which the system is most vulnerable to voltage collapse. It is defined as the point where the slope of the PV curve, dP/dV, approaches zero. In practical terms, this represents the maximum power that can be injected into the system before voltage instability occurs. Beyond this point, even small increases in active power may result in a sharp drop in voltage, leading to a voltage collapse.

**How to Identify the Critical Point**

The critical point is identified as the point where the **derivative of active power with respect to voltage (dP/dV)** is closest to zero. This point is significant because it represents the system's limit in terms of active power injection. If the power increases further, the voltage will no longer be able to support the system, leading to instability.

* **Derivative dP/dV**: The derivative dP/dV quantifies how sensitive the active power is to changes in voltage. A large positive or negative value indicates a stable operating point, while a value close to zero indicates the approach of instability.

**Formula for dP/dV:**

We compute the derivative using finite differences:

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Automatiskt genererad beskrivning

Where:

* P is the active power.
* V is the voltage.
* ΔP and ΔV represent the differences in active power and voltage between two consecutive points on the curve.

**Method: Voltage Stability Analysis using PSS®E**

In this method, we simulate the PV curve for a system using PSS®E (Power System Simulator for Engineering), which involves the following steps:

1. **Load the system data**: The system case file is loaded into PSS®E, which contains the necessary information about the buses, generators, and loads.
2. **Solve the power flow**: For each active power value, the system's power flow is solved to obtain the voltage at the generator bus.
3. **Compute the PV curve**: The active power is varied, and corresponding voltage values are recorded to create the PV curve.
4. **Calculate dP/dV**: Using the finite difference method, the derivative of active power with respect to voltage is computed at each point.
5. **Find the critical point**: The critical point is identified as the point where **dP/dV** is closest to zero.
6. **Visualization**: The PV curve is plotted, and the critical point is highlighted. The plot also includes a red dashed line at the critical point, indicating the maximum power injection before instability.

**Conclusion**

This method helps in performing voltage stability analysis by generating PV curves and identifying the critical point, where the system becomes unstable. By understanding the relationship between power injections and voltage levels, we can predict the stability limits of a power system and take corrective actions before voltage collapse occurs.