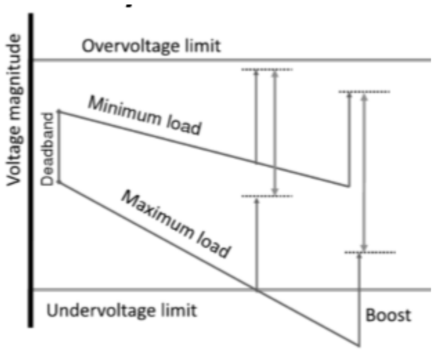
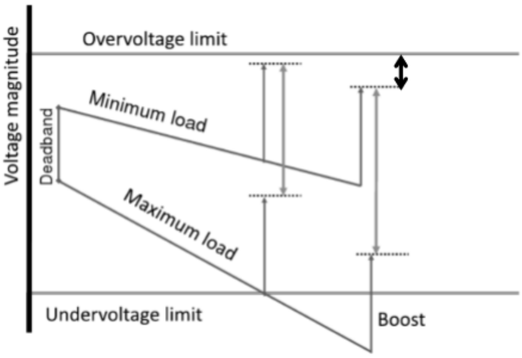
Tutorial 3 Solutions

1) Define the "Overvoltage margin". Show the overvoltage margin on the voltage profile below and how it is relevant to the hosting capacity of distributed renewable generation.



Answer:
The difference between the highest voltage magnitude and the overvoltage limit.



DG can give rise to voltage rise. There has to be sufficient overvoltage margin to ensure such voltage rise will not lead to an overvoltage.

2) A renewable DG is connected to an 11-kV feeder. The resistance between the DG source and the feeder bus is 5 ohms and the overvoltage limit is 105%. Assuming the bus voltage is nominal and constant, estimate the maximum power rating of the DG in terms of overvoltage limit. (when there is no reactive power generation or consumption)

Answer:
The connection of a generator to the distribution network will result in a voltage rise at the terminals of the generator.
The relative voltage rise is approximately equal to:

$$\Delta U/U = R*P_{gen}/U^2$$

Hence

$$P_{max} = U^2/R*\delta_{max} = (11\text{ kV})^2/5*5\% = 1.21\text{ MW}$$

3) Based on the table and conditions shown below, calculate the Hosting Capacity (HP) determined by the overvoltage margin when:

The connection is through a feeder of 1 km at a cross-section area of 50 mm^2.
Using tap change, the distribution transformer has boosted the voltage by 5%.
The overvoltage limit is 108%.

The voltage drop caused by the minimum-load condition is 1%.

The deadband for voltage regulation is between 101% and 102%.

Hosting Capacity for 10 kV Feeders with 1% Overvoltage Margin

Cross section (mm^2)	Hosting capacity for feeder length: 200 m	1 km	5 km	20 km	Loadability
25	7.4 MW	1.5 MW	300 kW	75 kW	2.5 MW
50	15 MW	3.0 MW	600 kW	150 kW	3.6 MW
120	36 MW	7.1 MW	1.4 MW	360 kW	6.0 MW
240	71 MW	14 MW	2.9 MW	710 kW	8.9 MW

Answer:

The maximum voltage in the low-voltage network is

102%-1%+5%=106%

The Overvoltage margin will be

108%-106%=2%

Considering the hosting capacity for a 1-km feeder 50mm^2 with 1% overvoltage margin is 3 MW according to the table provided, the hosting Capacity for 2 % overvoltage margin will be

2*3MW=6 MW.

(which is larger than the loadability 3.6 MW. This means for a relatively short feeder, the loadability/thermal limit could be more of a concern.)

4) Briefly explain how the following cable specifications affect the hosting capacity in terms of voltage magnitude (ignore the internal impedance of the DG):

the nominal voltage level

the cross-section area of the cable

over-voltage margin

the length of the cable

Answer:

Considering

$$P_{\max} = \frac{U^2}{R} \times \delta_{\max} \qquad R = \rho \times \frac{\ell}{A} \qquad \frac{\Delta U}{U} = \frac{R \times P_{\text{gen}}}{U^2}$$

HC is Proportional to the square of the voltage level.

Proportional to the cross-section area of the cable

Proportional to the overvoltage margin

Inversely proportional to the cable length

5) Outline the methods to increase the host capacity determined by constraints of voltage magnitudes.

Answer:

• New or stronger feeders: reduce the resistance to the DGs

• Applying power electronics technology on the DG side to regulate the voltage

• Timely and Accurate measurement of the voltage magnitude variations for the network operator to allow more DG power integration in a dynamic manner

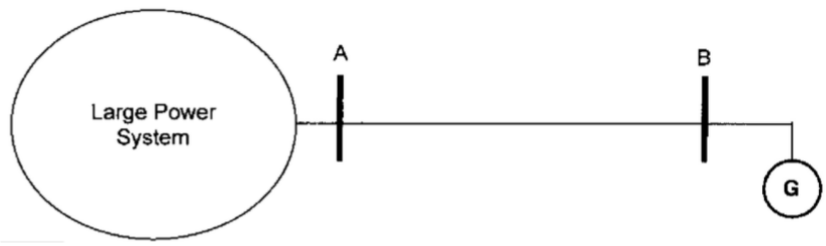
• Allowing higher overvoltage,

• Overvoltage protection,
Tripping EG when the terminal voltage comes too close to the overvoltage limit is a very effective way to prevent overvoltages.
• Overvoltage Curtailment,
A curtailment scheme in which the production is continuously reduced when the voltage gets closer to the limit is a very efficient scheme. It will result in less loss of production the overvoltage protection, but some stability concerns remain.
• DG with voltage control via reactive power regulation,
• Increasing the minimum load.

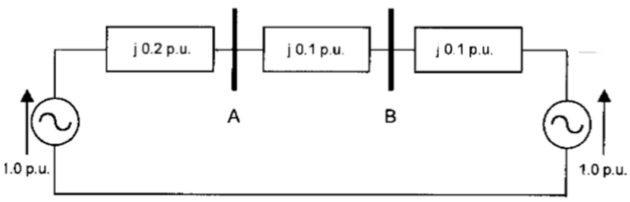
6) What is a “fault” in power system?
Answer:
A short circuit creates a low-impedance path through which the currents greater than normal condition can flow.

7) Why the fault current needs to be calculated when designing a power system?
Answer:
- appropriately selecting the equipment rating
- adjusting the settings of protection devices
- sizing the circuit breaker interrupting current capability.

8) The diagram below shows an embedded synchronous generator plant connected to a large power system through a distribution network. Assuming the lines are purely inductive for simplicity, the impedances of the large power system, between A and B, DG are is j0.2 p.u., j0.1 p.u. and j0.1 p.u. respectively. Using an equivalent circuit, compare the fault levels of Points A and B.



Answer:
The equivalent circuit is as follows:

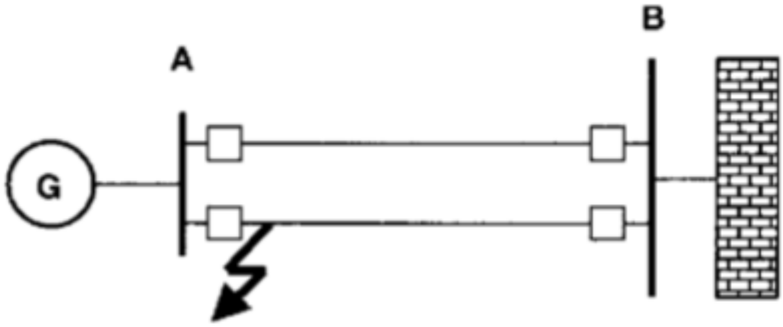


$For\ Point\ B\ I_{f,B} = \left\|\frac{1}{j0.1}\right\| + \left\|\frac{1}{j0.3}\right\|$=13.1 p.u.

$For\ PointA\ \ I_{f,B} = \left\|\frac{1}{j0.2}\right\| + \left\|\frac{1}{j0.2}\right\|$=10 p.u.

The fault level of Point B is higher.

9) A DG of hydro generator is connected to an infinitive bus as shown below. The internal impedance of the DG is X_s = j0.25 p.u. and the line impedance are both X_L j0.8 p.u..



① Sketch the equivalent circuit.

② Find out the equivalent impedance between the DG source and the infinitive bus during normal operation.

③ Determine the power angle between the source and the infinitive bus during normal operation when the input mechanical power to the DG is 1 p.u.. (assuming both voltage sources at 1p.u.)

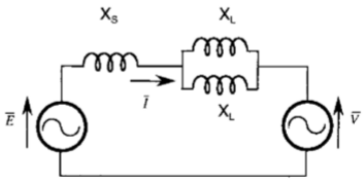
④ If a 3-phase bolt fault happens on one end of the cable as shown, find out the voltage magnitude of Point A during the fault and the power delivery from the DG to the grid.

⑤ Determine the post-fault equivalent impedance between the DG source and the infinitive bus.

⑥ If the input mechanical power to the DG is maintained at 1 p.u. after the fault clearance, briefly explain if the stability can be maintained.

Answer:

①



② The equivalent impedance in total:

$X_0 = X_S + \frac{1}{2}X_L$ =0.25+0.8/2=0.65 p.u.

③ Considering

$$P_e = \frac{EV}{X}\sin\delta = P_{e,\max}\sin\delta$$

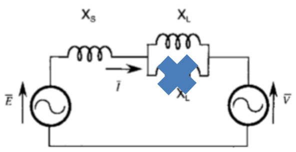
Therefore

$$\sin\delta = \frac{P_e X_0}{EV} = \frac{1 \times 0.65}{1 \times 1} = 0.65$$

the power angle δ =40.5°

④ If a three phase fault happens at point A, the voltage at Point A will be 0. No power can be delivered from the generator to the grid.

⑤



$X_1 = X_S + X_L$=0.25+0.8=1.05 p.u.

⑥ The maximum power is

$$\frac{EV}{X_1} = \frac{1\times1}{1.05} = 0.95 < 1$$

The maximum electrical power can be delivered is less than the input mechanical power. This means that the electrical torque will not be decelerate the rotor after the clearance so the frequency or the power angle will not be able to maintain. The system will lose synchronization and become unstable.