Tutorial Solution 4 DG and Protection, Power Quality

1) What is the main protection for conventional distribution network without a distribution generation?

Answer:

Conventional Distribution Protection is based on overcurrent protection to ensure discrimination between upstream and downstream faults.

Traditional protection system for distribution networks assumes uni-directional power flow from the grid supply point to the downstream LV network.

2) Brief explain how the following DGs can affect the protection configuration of a distribution network:
   a) Synchronous generator
   b) Induction generator
   c) Power electronics based PV generation

Answer:

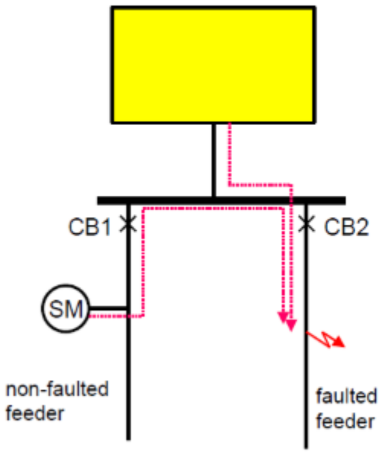
DGs can affect the effectiveness of protections by changing the fault current, which the protection system is meant to be based on. The change of the fault current may lead to undesirable operation of protective devices. The relay settings and switchgear may have to be modified accordingly if the change is significant.

a) Synchronous generator can provide sustained extra fault current.

b) Induction generator can provide an extra transient fault current but the extra fault current will not be sustained.

c) PV inverter is able to limit its fault current contribution during a fault within its rating. The behavior depends on the control strategy of the inverter.

3) A DG of a hydro generator is installed to the established conventional distribution network, which is indicated as the figure below. Briefly explain how the indicated fault can cause an undesirable trip after a DG is installed at the indicated location.



Answer:

When a fault occurs at the downstream of CB2, the DG may produce a fault current towards the fault point. If such fault current is sufficiently large, it may trip the upstream protective device CB1, which is undesirable. The rating of CB2 may have to be increased.

4) Explain how Rate of change of frequency (ROCOF) can be used as an anti-islanding protection technique.

Answer:

The frequency will change if there is a voltage variation, which will be caused the generation cannot does not completely meet the load.

For an island powered by a synchronous machine, this load change causes a change in the rotor speed which is proportional to a frequency change. The rate of change of frequency following an LOM event is directly proportional to the amount of active power imbalance between local load and the generator output.

This ROCOF relay will trip the generator in case the frequency changes more than a certain set point within a certain amount of time.

5) Briefly explain how Vector Shift (VS) relay can be used as an anti-islanding protection technique.

Answer:

This relay will trip the breaker in case it detects a phase shift in the generator voltage.

The phase shift is the integration of the change of the frequency. If this vector shift is larger than a certain set point the relay will trip

6) A synchronous generator is powering a 12kV feeder during an islanding operation. The power rating of the generator is 1.5 MVA and the total equivalent impedance between the emf to the feeder is 0.25 p.u. at a distance of 2 km. The distributed capacitance along the distribution line is 500 nF/km. Calculate the natural resonance frequency in such system. (assume the impedance is purely inductive)

Answer:

The generator inductance is: $L_{gen} = \frac{1}{2\pi f_0} z_{gen} \times \frac{V^2}{S_{gen}}$

L_{gen}=1/(2*pi*f)*Z_{gen} * V^2/S_{gen}= 1/(2*pi*50)*0.25* $(12kV)^2$/1.5MW=76.4 mH

The resonance frequency is thus:

f_{res}=1/(2*pi*sqrt(L*C))=1/(2*pi*sqrt(76.4mH*2km*500nF/km))=574.7 Hz

7) Explain how wind turbines can affect the power quality in terms of voltage variation.

Answer:

- Variations of several Hz: due to the mechanical dynamics: turbine dynamics, the tower resonance and the gearbox
- Variations of around 1 Hz: due to power pulsation caused by the blades passing the tower
- Variation of lower frequency: slower variation due to the changes in wind speed
- Caused by switching of DGs when operating at a certain power output
- Non-periodic fast voltage fluctuation caused by energy source conditions:
    - Wind speed variation close to the cut-in speed
    - System response to a fault and clearance
    - Reclosing operation

8) Consider a weak medium-voltage network, supplied by a 10 MVA, 10% transformer. A 2 MVA induction generator (magnetizing reactance 4 p.u.; total leakage reactance 0.2 p.u.; both based on 2MVA) is connected to this medium-voltage network through a 2 MVA, 5% generator transformer. A switched capacitor bank is installed at the medium-voltage feeder close to the point of connection to compensate for the reactive power consumption of the generator.

(i) Calculate the reactive power at no load

(ii) Calculate the reactive power at a load current of 1 p.u. (based on 2 MVA).

(iii) Calculate the range of capacitance connected to MV network and corresponding resonance frequencies.

(iv) For which harmonic order there is a risk of resonance? Calculate the size of capacitance for which the resonance will occur in the calculated harmonic.

Answer:

(i)Calculate the reactive power at no load

The reactive power at no load is 2/4 = 0.5 MVar

(ii)Calculate the reactive power at full load.

The reactive power at full load is 0.5+(0.2+0.05)X2 = 1 MVar

(iii)Calculate the desirable range of capacitance connected to MV network and corresponding resonance frequencies.

To compensate the full reactive power, the size of the reactive power compensation is between 0.5 and 1 MVar.

(iv) Calculate the size of capacitance in per unit for which the resonances may occur due to series resonance.

For 0.5 MVA

$f_{res} = f_0 \times \sqrt{\frac{S_{tr}}{X_{tr}Q}} = 50 \times \sqrt{\frac{1}{0.1\times 0.05}}$=707Hz (Q is based on the power rating of transformer 10 MVA here)

For 1 MVA

$f_{res} = f_0 \times \sqrt{\frac{S_{tr}}{X_{tr}Q}} = 50 \times \sqrt{\frac{1}{0.1\times 0.1}}$=500Hz

11th harmonics (at 550 Hz) and 13th harmonics are between 550 Hz and 650 Hz.

$$f_0 \times \sqrt{\frac{S_{tr}}{X_{tr}Q}} = 550\ Hz$$

$$\sqrt{\frac{S_{tr}}{X_{tr}Q}} = 11$$

$$Q = 0.083\ p.u.$$

The risky reactive compensation value is 10X0.083 =0.83 MVar.

13rd harmonics (at 550 Hz) and 13th harmonics are between 550 Hz and 650 Hz.

$$f_0 \times \sqrt{\frac{S_{tr}}{X_{tr}Q}} = 650\ Hz$$

$$\sqrt{\frac{S_{tr}}{X_{tr}Q}} = 13$$

$$Q = 0.059\ p.u.$$

The risky reactive compensation value is 10X0.059 =0.59 MVar.