Power Quality (16%)

1. The phase current consumed by a three-phase non-linear load is given as follows (in RMS values):

| Fund. | $5^{th}$ | $7^{th}$ | $11^{th}$ | $13^{th}$ |
|---|---|---|---|---|
| 100 A | 20 A | 15 A | 10 A | 8 A |

Assume the fundamental current component is in-phase with the supply voltage (100 V, line-to-neutral).

(a) Calculate the average power of this load.

(b) Calculate the VAR of this load.

(c) Calculate the power factor of this load.

(d) Give two examples of non-linearity in the utility system.

Per Unit and Fault Analysis (24%)

2. A 10 kV generator is connected to a 10 kV (delta)-20 kV (grounded sye) 2 MVA transformer as given in the circuit diagram. The positive, negative and zero sequence impedance of the circuit are also given as follows:

| | Positive | Negative | Zero |
|---|---|---|---|
| Generator | 15Ω | 10Ω | 10Ω |
| Transformer | 20Ω | 20Ω | 20Ω |
| Line | 50Ω | 50Ω | 200Ω |

A single line-to-ground fault occurs at phase A of the line. Construct the sequence network in terms of per-unit values of the faulted system. (20%)

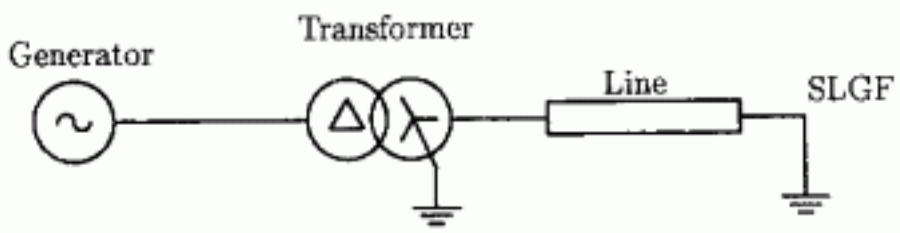


Figure 1

3. For the power system of Figure 1, if the occurred is a substation close-in fault rather than a remote failure (A close-in fault has its fault location at the substation exit or, for the power system of Figure 1, at the transformer output terminal).
How is the fault current magnitude for $3\phi$ fault ($I_{3\phi}$) in comparison with the same magnitude for phase-a-to-ground fault ($I_{1LG}$)? Answer by selecting one of the following: (4%)

(i) $|I_{3\phi}| > |I_{1LG}|$

(ii) $|I_{3\phi}| < |I_{1LG}|$

(iii) $|I_{3\phi}| = |I_{1LG}|$

(iv) No definite comparison result.

(Note: You are not requested to do any calculation or explanation for Problem 3).

Power Flow (16%)

4. Power flow analysis is a basic tool of the power system engineer.
(a) Describe how to classify the bus types and how to obtain the power flow equations.
(b) Newton-Raphson method is often used to solve the problem due to its fast convergence rate.
Will the number of iterations required for convergence increase with system size linearly or be independent of system size?

Voltage Control (8%)

5. Explain how to control a bus voltage of a power network,
(a) When it is overvoltage,
(b) When it is undervoltage.

Protection Relay (20%)

(Note: In your answer for Problems 6 ~ 8 , you are not requested to give any explanation.)

6. The power system of Figure 1 is comprised of three major components: h. v. distribution line, transformer and synchronous generator.

(a) Give two types of relay for primary protection of the line; also give two types of relay, one for primary and one for backup protection of the transformer. (4%)

(b) Figure 2 depicts three phase-CT's for the h. v. distribution line. How the CT's are connected to the relay for ground fault protection of the line? Answer by drawing the connection wires on Figure 2. (2%)

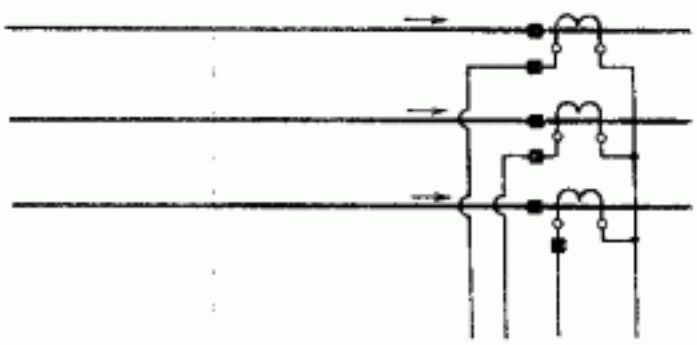

Figure 2

(c) Assume the line fault of Figure 1 has not been cleared by the line protection relay. Which is the backup relay to be tripped first? Answer by giving the relay type and location. (2%)

(d) If the following synchronous generator relays do not work, what effects will it occur on the generator? Select one answer from Table 1 for each relay (Note: One answer can be selected twice). (8%)

(1) Stator voltage unbalance relay,

(2) Loss of excitation relay,

(3) Overfrequency relay,

(4) Reverse power relay.

Table 1

| |
|---|
| (i) Overvoltage at stator terminal, |
| (ii) Rotor overheated, |
| (iii) Overcurrent in stator winding, |
| (iv) Stator terminal voltage dropped, |
| (v) Overspeed of rotor, |
| (vi) Turbine blade overheated for a steam generator, |
| (vii) None is correct. |

7. Let Xe denote the magnetization reactance of CT, and $V_L$ denote the voltage at CT output terminal. Compare the magnitude for Xe and $V_L$ under CT saturation (denoted by Xe, sat and $V_L$, sat) with their unsaturated values (denoted by Xe, uns and $V_L$, uns), by selecting one correct answer among the following: (4%)

(i) Xe, sat $<$ Xe, uns , and $V_L$, sat $<$ $V_L$, uns.

(ii) Xe, sat $>$ Xe, uns , and $V_L$, sat $>$ $V_L$, uns.

(iii) Xe, sat $<$ Xe, uns , and $V_L$, sat $>$ $V_L$, uns.

(iv) Xe, sat $>$ Xe, uns , and $V_L$, sat $<$ $V_L$, uns.

(v) None is correct.

Electromagnetic Transients (16%)

8. Assume a $3\phi$ capacitor bank with grounded neutral, rated at $S_{3\phi}$ = $MVA_1$ and $V_L$ = $KV_1$, is being switched; the voltage source is also grounded and has an inductance of L = $mH_1$. Figure 3 shows the reactance diagram for the $3\phi$ power system. Now open the CB which interrupts the current at t = $t_0$. Suppose an inadvertent restrike occurs at t = $t_1$ after the opening of CB. Oscillation current occurs in the circuit under the restrike. Figure 4 depicts the source voltage ($e_s$). Let Vrsk and Vc denote the restrike voltage and capacitor voltage respectively. Then Vrsk refers to Vc during the restrike.

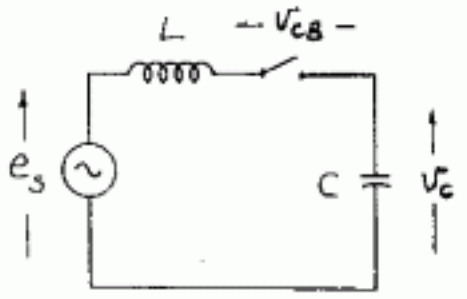


Figure 3

(a) Draw Vrsk waveform on Figure 4; mark $t_o$ and $t_1$, and indicate the peak value for Vrsk on the same diagram. (6%)

(b) Give a formula to calculate the $3\phi$ capacitance for the bank. (2%)

(c) Give a formula to calculate the surge impedance under oscillation. (2%)

(d) Assume CB interrupts the restrike current at t = $t_2$ after the first breakdown. Mark $t_2$ on Vrsk waveform of Figure 4. (2%)

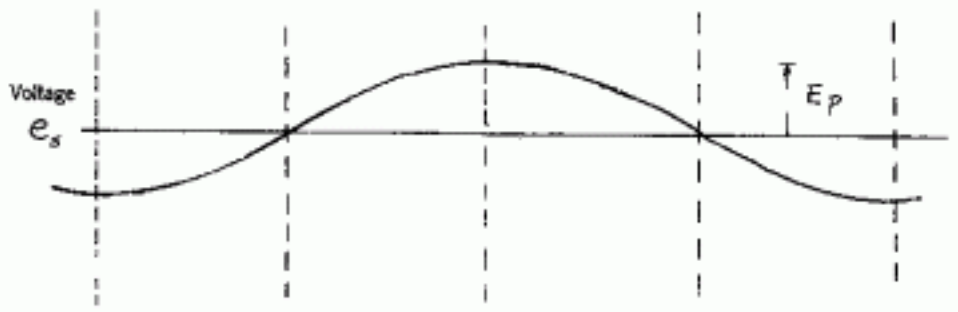


Figure 4

(e) What is the basis for derivation of the surge impedance calculation formula? Answer by selecting one of the following: (4%)

(i) Long transmission line model,

(ii) Short transmission line model,

(iii) Bewley lattice diagram,

(iv) None is correct.