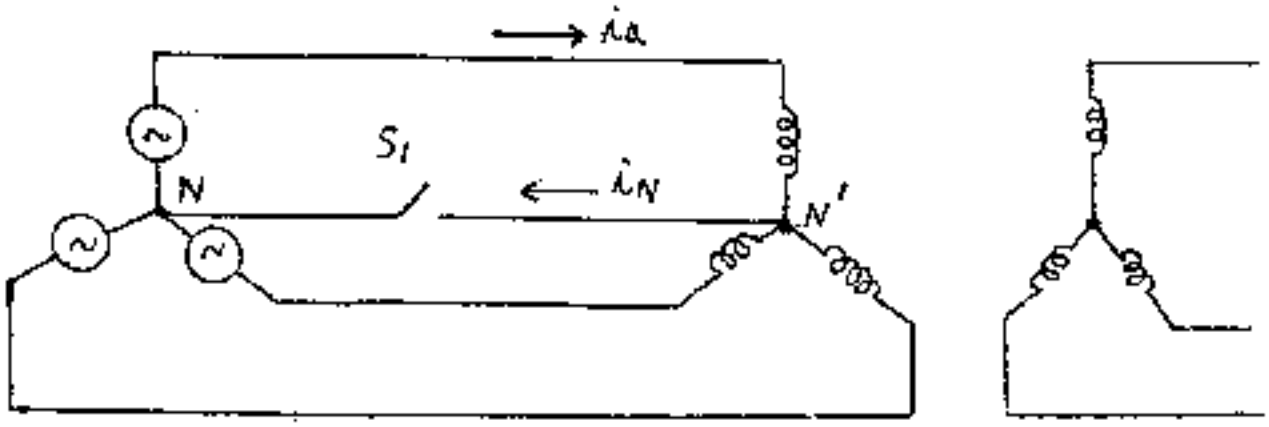
選擇題答對得分，不答零分，答錯倒扣該分。

**Transformer** (20%)

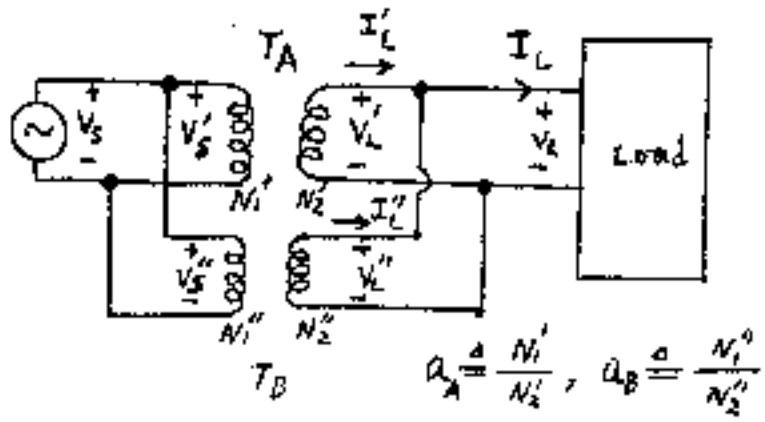



1. If the exciting current of a single-phase transformer can be expressed as $i_m(t) = I_{m1}\sin\omega t + I_{m3}\sin 3\omega t + I_{m5}\sin 5\omega t$, find the currents $i_a(t)$ and $i_N(t)$ in the circuit as shown when, (10%)

   (1) $S_1$ is opened;

   (2) $S_1$ is closed.

2. Assume that the core losses and magnetizing currents are neglected, the turn ratios of $T_A$ and $T_B$ are $a_A$ and $a_B$, the equivalent impadances of $T_A$ and $T_B$ referred to their secondaries are $Z_A$ and $Z_B$, and the load current and voltage are $I_L$ and $V_L$. Find the expressions of $I'_L$ and $I''_L$ using the given parameters. (10%)



3. Transmission Line (12%)

For a 345 KV transmission line, let $\Delta x$ denote the length of a line element, z $\Delta x$ denote the series impedance of this elemental length of the line, and y $\Delta x$ denote its shunt admittance. Also let

$$z = R + jwL$$
$$y = G + jwC$$

Assume R, L, G, C are known values, and the total length of this line is 100 km. Give a mathematical formula to calculate each of the following:

(1) Surge impendance ($Z_c$) of this line, (4%)

(2) Propagation speed (r) in meter per second of the lightning wave struck on this line, (4%)

(3) Surge impedance loading (SIL) of this line. (4%)

4. Per Unit and Fault Analysis (10%)

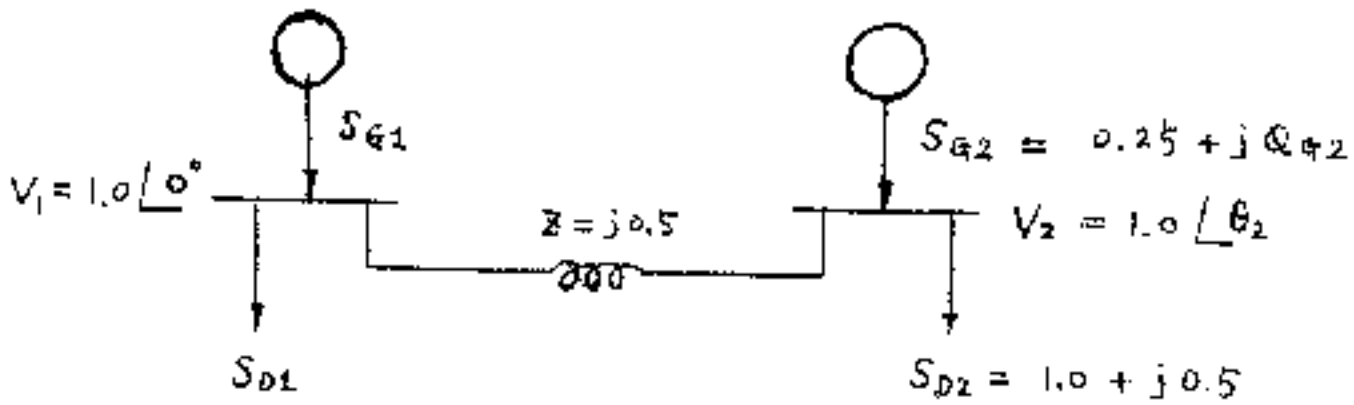
A three-phase synchronous generator is connected to a step-up three-phase transformer $T_1$, which is connected to a 60-km-long transmission line. At the far end of the line, a step-down transformer bank $T_2$ is connected. The secondary of $T_2$ supplies two motor loads $M_1$ and $M_2$. The ratings of the various types of equipment are

Generator: 10 MVA; 12 kV; X = 20%; wye
$T_1$: 5 MVA; 12/69 kV; X = 10%; delta-wye
$T_2$: 5 MVA; 69/4.16 kV; X = 10%; wye-delta
$M_1$: 2000 kVA; 4.16 kV; X = 20%; wye
$M_2$: 1000 kVA; 4.16 kV; X = 20%; wye
Transmission line: X = 0.32 Ω/km

(a) Draw the per-phase equivalent circuit of the system showing all reactances in per unit and the base voltages used at various parts of the network. Choose the generator ratings as bases in the generator circuit.

(b) For a three-phase fault on the low-voltage terminals of transformer $T_2$, calculate the short-circuit current in amperes supplied by the generator assuming that all internal voltages are $1.0 \angle 0°$ pu.

5. Power Flow (12%)




(1) Give the bus-admittance matrix for the above power system. (4%)

(2) Predict the power flow solution $(\theta_2, Q_{G2})$, by giving your choice among the following, which, you consider, is closest to the exact solution.

(a) (-10° , 0.65)

(b) (-15° , 0.65)

(c) (-20° , 0.65)

(d) (-10° , 0.50)

(e) (-15° , 0.50)

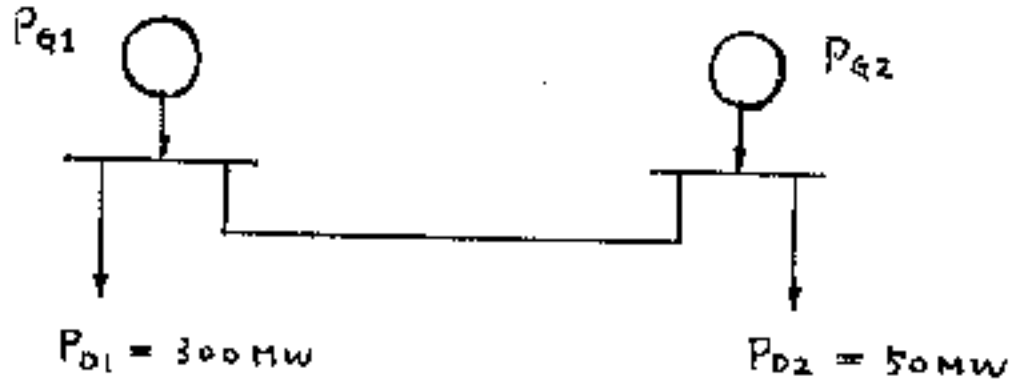
(f) (-20° , 0.50) (8%)

Remark :

| $\theta$ | $\sin\theta$ | $\cos\theta$ |
|---|---|---|
| 5° | 0.087 | 0.996 |
| 10° | 0.174 | 0.985 |
| 15° | 0.259 | 0.966 |
| 20° | 0.342 | 0.940 |
| 25° | 0.423 | 0.906 |

6. Economic Operation (10%)

Consider a system of two generators as follows




The incremental cost and the line loss are given:

$$\frac{dC_1}{dP_{G1}} = 0.007\ P_{G1} + 4.1 \text{ dollars/MWh}$$

$$\frac{dC_2}{dP_{G2}} = 0.007\ P_{G2} + 4.1 \text{ dollars/MWh}$$

$$P_{loss} = 0.001\ (P_{G2} - 50)^2 \text{ MW}$$

Assume the penalty factor of $P_{G1}$ is 1.0,

(a) find the penalty factor expression of $P_{G2}$ in terms of $P_{G2}$. (3%)

(b) find the optimal $P_{G1}$, $P_{G2}$, and $P_{loss}$ without considering generator output limits. (7%)

7. Voltage Control (12%)

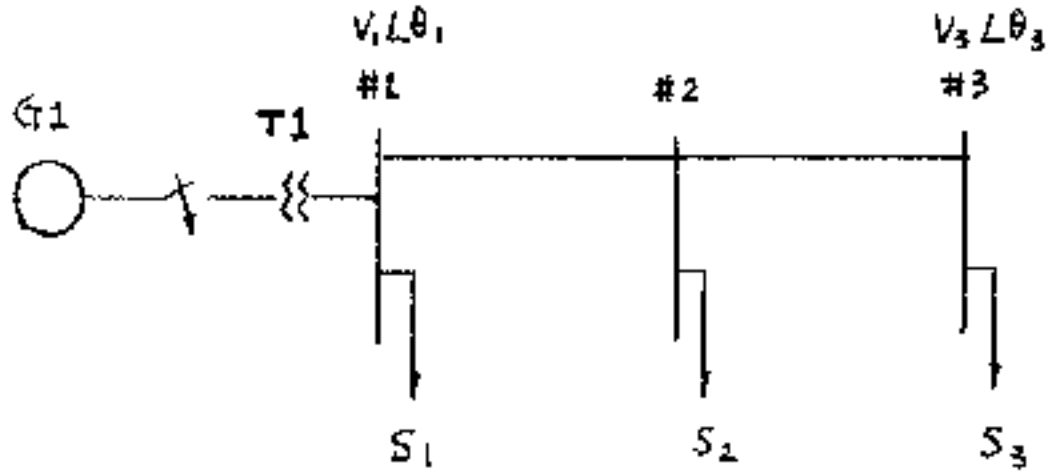



Figure 1

Complex power: $S_1 = S_2 = S_3$
Capacity and voltage ratings of G1: 1000 KW at 380V
Voltage rating of T1: 380V/22KV

Figure 1 depicts the artificial power system of Tansui Line of Taipei Mass Rapid Transit (MRT). As shown, under the emergency condition (e.g. under the power cut of Taipower), the MRT emergency generator is switched into the above system to pick up the railway load. To simplify our discussion, the system load were evenly lumped into 3 bus loads: $S_1$, $S_2$ and $S_3$. The 22KV line is an underground cable with a length of 10 km. After the generator is swiched into the system, the system steady state voltage arc:

$$V_3 > V_1 > 25KV > 22KV$$

which violates the voltage limitation.

(1) Suggest your approaches to solve this voltage violation problem, by giving your multiple choices among the following:

(a) Install a synchronous condenser at bus 3,
(b) Install a capacitor bank in series with T1,
(c) Install a series reactor at bus 2,
(d) Replace T1 with a transformer having ULTC,
(e) Replace T1 with a regulating transformer,
(f) Adjust AVR of G1,
(g) Operate G1 into the under-excitation mode. (8%)

(2) Give the technical limitations of your approaches (i.e., for each approach you suggested, list one technical limitation). (4%)

Protective Relay (24%)

8. The following are devices commonly applied to the implementation of complex relaying schemes (which will be specified later):

(a) Potential transformer
(b) Current transformer
(c) Impedance relay (to detect $|\overline{Z}|$)
(d) Directional relay
(e) Sensor to detect capacitive $\overline{Z}$
(f) Undervoltage relay
(g) Overcurrent relay
(h) Harmonic filter
(i) L-C voltage divider
(j) Line trap
(k) Transmitter
(l) Receiver

Select the devices among (a) ~ (l), which are applicable to implementation of the following complex relaying schemes (i.e., give your multiple choices among (a) ~ (l) for each of the following schemes):

(1) Pilot relaying with microwave as the the communication medium,
(2) MHO relay,
(3) Generator loss-of-excitation relay,
(4) Transformer differential relay. (16%)

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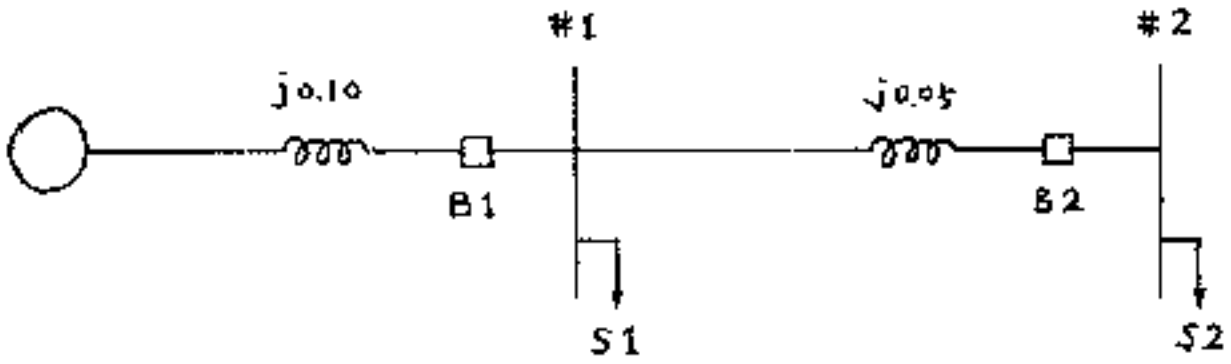
9.




$S_{3\phi base}$ = 10 MVA

Load:

$S_1$ = 8.5 MVA

$S_2$ = 8.0 MVA

Figure 2

Figure 2 depicts the single-line diagram of a 13.8 KV system. The line impedance in P.U. values (with 10 MVA as the system base) are also given in the diagram. The protective relays for breakers B1 and B2 are both CO-7 relays. The relay settings for breaker B2 are:

For B2: CTS = 10A
TDS = 1.1

Decide the relay settings for B1 by giving your multiple choices among the following ( Note: CT ratio for CO-7 at B1 is 800:5 ):

(a) CTS = 12A, TDS = 0.5

(b) CTS = 12A, TDS = 1.3

(c) CTS = 8A, TDS = 0.5

(d) CTS = 8A, TDS = 1.3

(8%)