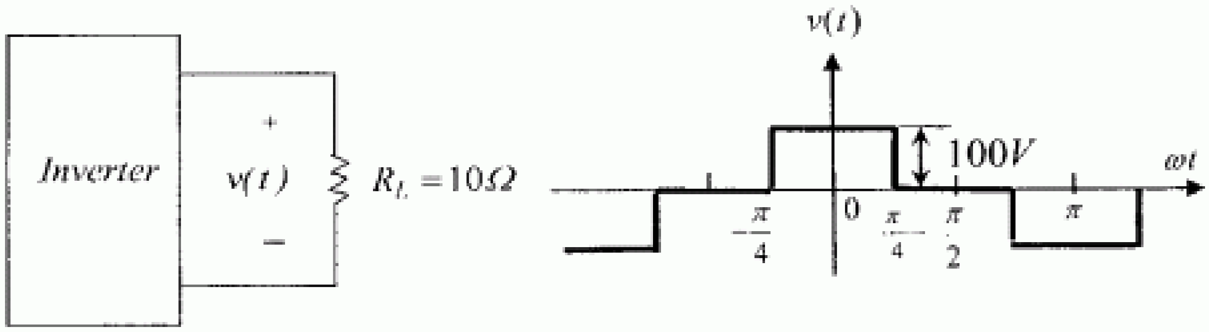
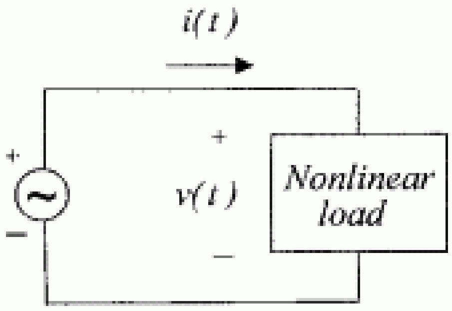
Power quality: (25%)

1. (a) A resistive load is powered by an inverter with its terminal voltage waveform as shown. Find: (a) the rms value of $v(t)$; (b) the average load power.



(b) The harmonic components of a nonlinear load current $i(t)$ are listed as follows:

Order	Amplitudes
1	10A
3	8A
5	6A
7	5A



Find: (a) the rms value of $i(t)$; (b) the total harmonic distortion (THD) of $i(t)$.

(c) The ratings of two motors used in a factory are:

Induction motor: 60kW, 80kVAR;

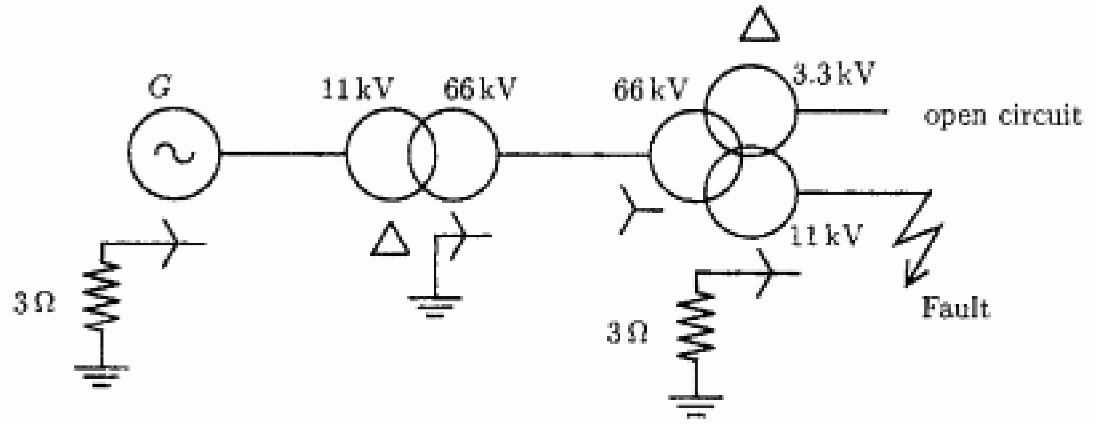
Synchronous motor: 100kVA, 60kW.

If the excitation of synchronous motor is adjustable and its rotational losses are negligible. Find the best and worst power factors of this factory.

Per Unit and Fault Analysis (25%)

2. As given in the circuit diagram, an 11kV synchronous generator is connected to a 11kV/66kV transformer which feeds a 66kV/11kV/3.3kV three-winding transformer through a short feeder of negligible impedance. A phase A-to-earth fault occurs on a terminal of the 11kV winding of the three-winding transformer. The relevant data are given as follows:

- Generator: $X_1=j0.15$pu, $X_2=j0.1$pu, $X_0=j0.03$pu, all on a 10 MVA basis. The neutral of the Y-connected windings is earthed through a 3Ω resistor.
- 11kV/66kV transformer: $X_1=X_2=X_0=j0.1$pu on a 10 MVA basis. 11kV winding is delta-connected. 66kV winding is Y-connected with solidly-earthed neutral.
- Three-winding transformer: The impedances are all on a 10 MVA basis. 66kV winding: Y-connected with solidly-earthed neutral. $X_1=X_2=X_0=j0.04$pu; 11kV winding: Y-connected, neutral is earthed through a 3Ω resistor. $X_1=X_2=X_0=j0.03$pu; 3.3kV winding: delta-connected. $X_1=X_2=X_0=j0.05$pu



(a) Draw the positive, negative, and the zero sequence network of the system respectively.
(b) Calculate the fault current due to the phase A-to-earth fault.

Power Flow (20%)

3. The power system depicted in figure A is an artificial power system. At the load bus, the static capacitor is not paralled to the bus (i.e., switch S is open).
   (a) Let $[J]\begin{bmatrix}\Delta\delta \\ \Delta V\end{bmatrix} = -\begin{bmatrix}\Delta P \\ \Delta Q\end{bmatrix}$ represent the mismatch equations, where $[J]$ is the Jacobian matrix, $[\Delta\delta\ \ \Delta V]^T$ and $[\Delta P\ \ \Delta Q]^T$ are both column vectors. Give dimensions for $[J]$, $[\Delta\delta\ \ \Delta V]^T$ and $[\Delta P\ \ \Delta Q]^T$. Also give the elements for the matrix and vectors (Note: when you give elements, you are requested to follow the notations given in Figure A, but you are not requested to give any calculation formula or numerical values for the elements.)
   (b) Is the Q loss for line 1-3 higher than Q loss for line2-3, or is $Q_{\ell 1\text{-}3} > Q_{\ell 2\text{-}3}$? Answer yes or no and give the key reason (by writing down a key phase, not a statement).

(c) Is the power flow for line 1-3 (P_{l1-3}) higher than the power flow for line 2-3, or is $P_{l1-3} > P_{l2-3}$? Also answer yes or no and give the key reason in the same way as (b).

(d) Assume switch S is closed and bus 3 becomes a PV bus. Repeat (a) for the new power system.

(e) After closing switch S, what will happen? Answer by giving your multiple selection among the following (but you are not requested to explain):

(1) Q_l for both line 1-3 and line2-3 decrease, but $Q_{l1-3} > Q_{l2-3}$ still exists.

(2) Both Q1and Q2 for generators at buses 1 and 2 become negative values.

(3) The voltage angle at bus 2 (δ_2) becomes positive, or δ_2 leads δ_1 .

(4) None is correct.

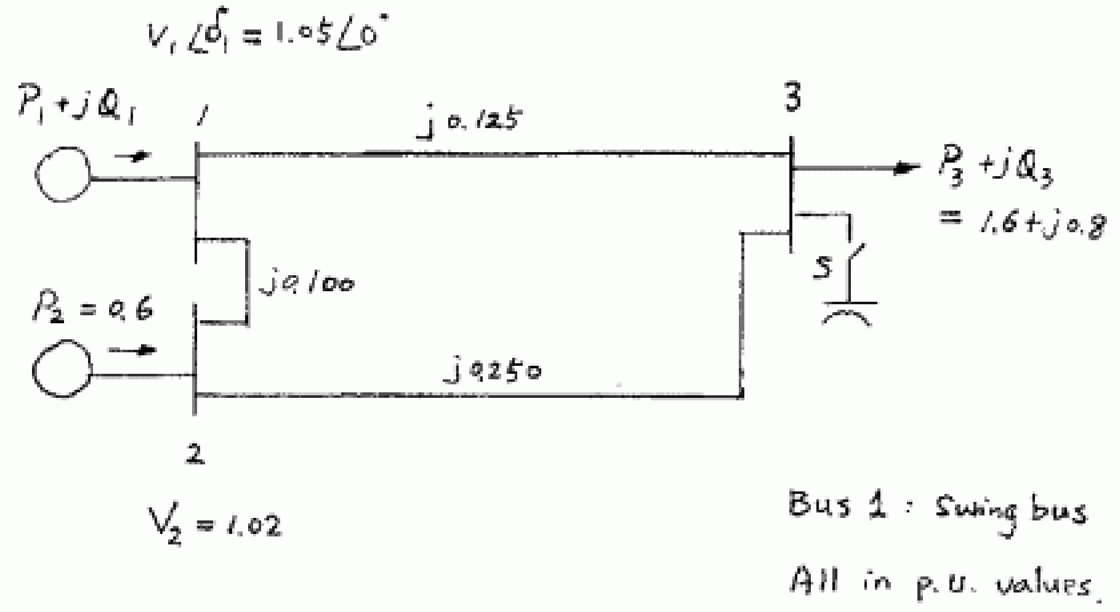


Figure A

Protection (15%)

4. For the power system in Figure A (with switch S in the open status), suppose a single-line-to-ground fault (which is a direct ground fault)occurs at phase A of bus 3.

(a) What will be the relaying scheme operated to trip circuit breakers for the fault clearing at bus 3? Select the correct operation sequence among the following (not requested to explain):

(1) Bus differential at bus 3 → Distance relaying at buses 2 and 1 →Directional overcurrent at buses 2 and 1.

(2) Bus differential at bus 3 → Directional overcurrent at buses 2 and 1 → Distance relaying at buses 2 and 1.

(3) Others.

If you select (3), give your answer (Note: A→B means A is primary and B is backup).

(b) To avoid CT saturation, what do you suggest? Answer by selecting the correct statement or statements, among the following (not requested to explain):

(1) Reduce the CT burden.

(2) Increase the CT turn ratio.

(3) Replace CT with linear coupler for the bus differential relay.

(4) None is correct.

(c) Describe the faulted power system by selecting the correct statements, among the following (not requested to explain):

(1) Both generators 1 and 2 provide negative-sequence current (I_{2g1} and I_{2g2}) flowing into the faulted bus, and $I_{2g1} > I_{2g2}$ (Assume: G1 and G2 are both thermal units of the same type).

(2) The negative-sequence current could overheat stator winding.

(3) If both generators are resistively grounded, the bus voltage at the unfaulted phases (i.e., phase B or C) of bus 3 could be higher than 1.0p.u.

(4) None is correct.

Transient Stability (15%)

Figure B

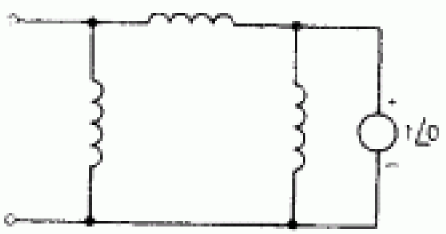


Figure C

5. (a) What are the underlying assumptions for transient stability analysis of power system? Answer by giving "correct" or "wrong" for each statement of the following. For those selected as wrong statement or statements, write down one key phrase within the statement you don't agree and correct it, e.g., "positive-sequence" for statement (1), "remains unchanged" for statement (2), if you consider (1) and (2) are wrong statements. As to your correction, e.g., write down "positive-sequence"→ "negative-sequence", "remains unchanged"→ "is changed", etc.

(1) The analysis accounts for the positive-sequence model only, or the three-phase disturbance (such as three-phase fault) only, because most substations' main-transformers for the primary transmission system are reactively grounded.

(2) Assume machine's internal voltage remains unchanged due to the voltage regulator design of generation machine.

(3) Assume the mechanical power inputted to the machine remains unchanged because machine's governor can effectively work during the faulted condition.

(4) Take machine's damper winding into account because the winding's time constant is much longer than the fault duration.

(b) Consider the system in Figure B.

$X_1=0.4$ $X_2=0.2$ $X_3=0.2$

$E_q'=1.2$ $P_m=1.5$ $X_d'=0.2$

Where X1, X2 and X3 are line reactances, E_q' and X_d' are generator's internal voltage and transient reactance, and Pm is generator's turbine mechanical power. Suppose a balanced three-phase fault occurs at point (or location) F. The fault at F reconfigures the external system positive-sequence network into that shown in Figure C. The three reactances of Figure C refer to the three transmission lines or line segments in Figure B. Give the reactance values.

(c) If the fault is not removed, will the generator be stable? Answer yes or no, but do not explain.

(d) If one more transmission line having the same rating as the existing is additionally installed between buses 1 and 2, is the stability improved or worsened?

(e) If an isolation transformer (with turn ration 1:1) is additionally installed between bus 1 and the generator, is the stability improved?

For (d) and (e), answer "improved" or "worsened" only; do not explain.