Power Quality

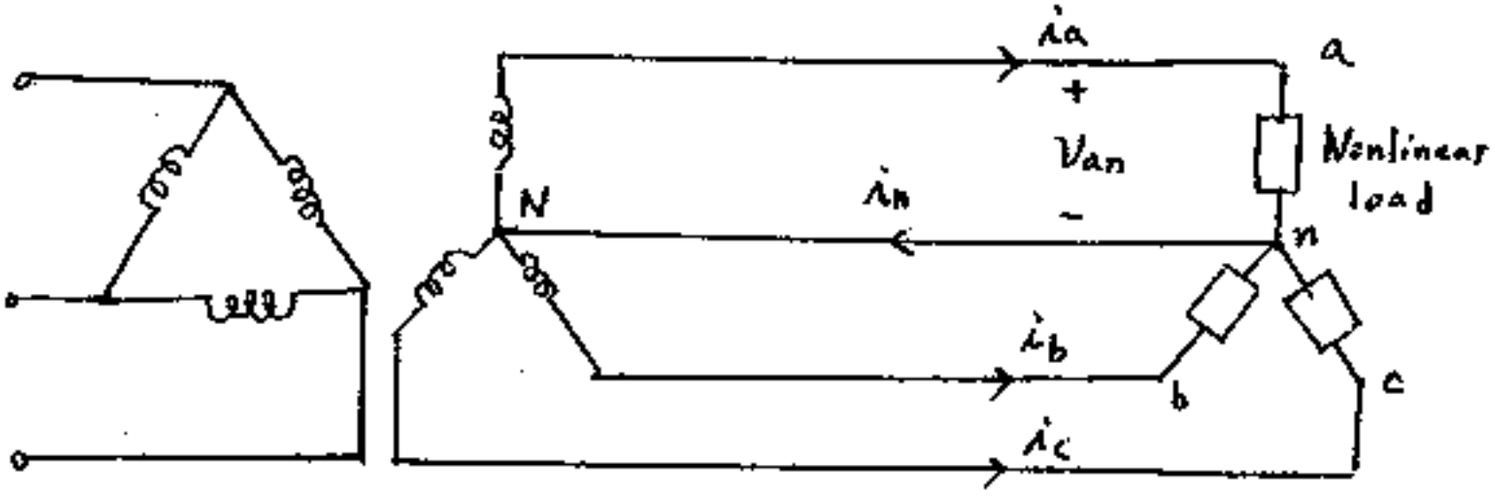
1. Three identical single-phase nonlinear loads are placed on the secondary side of a three-phase four-wire, Y-connected system as shown. If the load voltage and current of phase a are: (15%)

$$v_{an} = 120\sqrt{2}\sin 2\pi 60t \ldots\ldots\ldots\ldots (V)$$

$$i_a = 50\sqrt{2}\sin(2\pi 60t - 30^\circ) + 40\sqrt{2}\sin(2\pi 180t - 40^\circ) +$$
$$\ldots\ldots 30\sqrt{2}\sin(2\pi 300t - 50^\circ) + 20\sqrt{2}\sin(2\pi 420t - 60^\circ) +$$
$$\ldots\ldots 10\sqrt{2}\sin(2\pi 540t - 70^\circ)\ldots\ldots\ldots (A)$$

(1) Calculate the rms currents in each phase conductor and in the neutral conductor.

(2) Calculate the average three-phase load power.



Dynamics

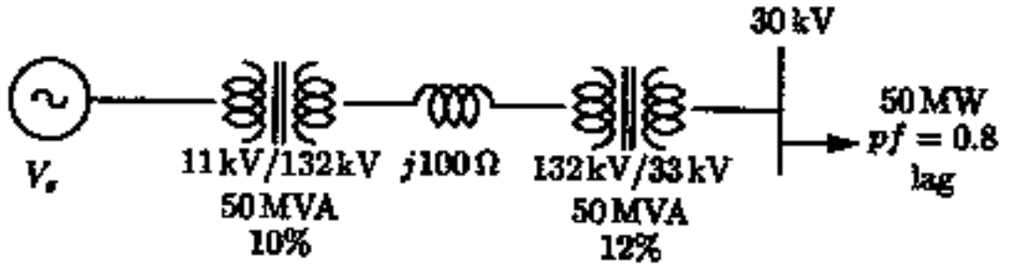
2. (1) The reservoir of a pumped-storage facility is separated by 400m in altitude, and it is 1.0km square and 5.0m deep. Find its stored energy.

(2) Assuming the generation process is 80% efficient, how long would the stored water operate the six 400,000kva generators? Assume they are operated at the rated load with unity power factor.

(Note: $1.0\,m^3$ of water has a mass of 1000kg, gravitational acceleration $g=9.81\,m/s^2$, 1.0kwh=3.6MJ) (10%)

Per Unit

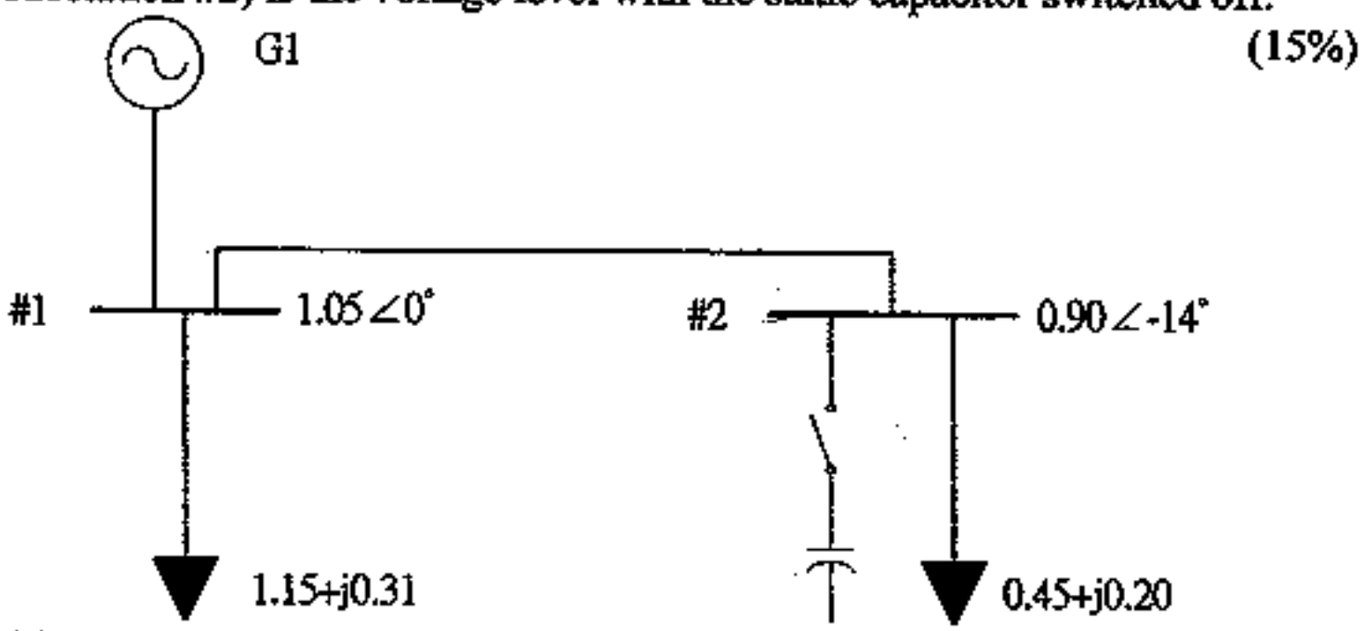
3. For the given transmission system, the load draws 50MW at pf=0.8(lag) from the voltage bus which is maintained at 30kV. Find V_s in volt. (15%)



Circuit Theory

4. A synchronous generator, modeled by a voltage source with an inductive reactance X_1 connected in series, is connected to a load consisting of inductive reactance X_2 and a variable resistor R in parallel. Find R (in terms of X_1 and X_2) so that the output power of the generator is maximum. (10%)

5. For an artificial power system below. Assume the line between substation #1 and #2 is a medium-distance line. The figure, 0.90 P.U., for bus #2 (or substation #2) is the voltage level with the static capacitor switched off. (15%)



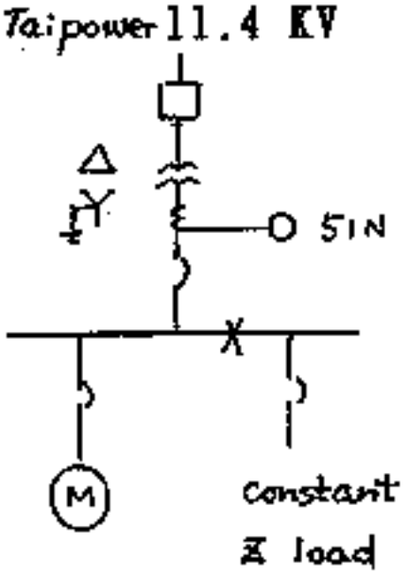
(1) Compare the power flow results before and after the static capacitor switched on. That is, indicate how the following will be changed after the static capacitor switched on.
(a) The reactive power output for generator G1.
(b) Line loss.
(c) Line charge.
(d) Voltage magnitute for bus 2.
(e) Voltage angle for bus 2.

(2) Simulate the above power flow problem by the Newton-Raphson (N-R) method. In the N-R model formulation, let m*n represent the dimension of Jacobian matrix. Give m*n in the following conditions:
(a) With the static capacitor off.
(b) With the static capacitor on.

Fault Analysis and Protection

6. For an industrial power system, assume a phase-A-to ground fault occurs at the system main bus as shown below. (25%)
(a) Draw the sequence diagram for this faulted power system. In that diagram, indicate:
- the system reactance of Taipower (or the system reactance at duty point), X_{S1}, X_{S2}, X_{S0};
- the leakage reactance of 11.4kV main transformer (X_{t1}, X_{t2}, X_{t0});
- the reactance of induction motor (X_{m1}, X_{m2}, X_{m0}).

(b) Compare the relative magnitute among X_{m1}, X_{m2}, X_{m0}. Also give reasons for your comparison results.
(c) Write a formula to calculate the fault current I_f in terms of the above system parameters.
(d) Explain how X_{S1} is derived. Give the derivation procedure.
(e) Draw the CT connection for 51N.
In your drawing, indicate how the ground fault can be detected.



Stability

7. Power system transmission system (T/S) requires high-speed protection, mainly to meet the critical clearing time (CCT) requirement. In contrast, the distribution system (D/S) does not have such requirement. (10%)
(a) Define CCT.
(b) Why does T/S have CCT requirement, but not D/S?