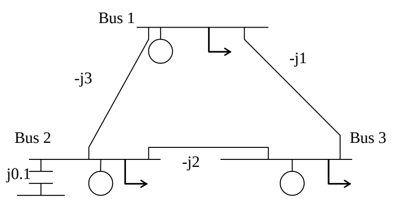
EE 303 Sample Final Exam. Time: 2 hrs. Open book, open notes. Calculator allowed. **Write all answers on a separate sheet. Indicate the problem and part clearly. Number your pages.**

1. (24) 3 phase circuits, synchronous generators, and power factor correction: Two three-phase balanced loads are connected in parallel directly to a balanced synchronous generator with positive (a-b-c) phase sequence. Load #1 is Y-connected with impedance 100+j50 ohms/phase. Load #2 is Δ-connected with impedance 300-j180 ohms/phase. The line-to-neutral voltage of the supply is 277 volts. Assume V_{an} is the reference, i.e., $\mathbf{V}_{an}=277\angle 0°$. Denote $\mathbf{E}_{an}$ as the line-to-neutral internal voltage of the synchronous generator, and δ is its angle.
   a. What is $\mathbf{V}_{ab}$ (magnitude and angle)?
   b. Compute $\mathbf{I}_{an}$ for the Y-connected load (magnitude & angle) and its power factor (leading/lagging).
   c. Compute $\mathbf{I}_{ab}$ for the Δ-connected load (magnitude & angle) and its power factor (leading/lagging).
   d. Compute the supply current from the synchronous generator $\mathbf{I}_a$ (magnitude and angle).
   e. What is the power factor of the composite load (leading/lagging)?
   f. How much complex power is produced by the synchronous generator?
   g. Under this condition, which quantity is larger, $|\mathbf{E}_{an}|\cos\delta$ or $|\mathbf{V}_{an}|$?
   h. How many vars need to be provided at the load to bring the power factor to 1.0?
2. (23) Power flow: A 3-bus system has a generator and load at each bus. The numbers given beside each branch are admittances. There is no line charging represented. Denote the injections as P_k, Q_k, the corresponding power flow equations as $P_k(\underline{x})$, $Q_k(\underline{x})$, and the voltage phasors at each bus as $V_k\angle\delta_k$, where k=1,2,3. Assume $\delta_1=0°$.



   a. (6) Write down the Y-bus matrix.
   b. (5) Identify the variables in the solution vector.
   c. (6) It is possible to write a power flow equation for real and reactive injections at buses 1, 2, and 3 (giving a total of 6 equations). From these six equations, write down the mismatch equation(s) that are required in the solution procedure. Express each equation symbolically (no numbers) in terms of P_k, Q_k, $P_k(\underline{x})$, $Q_k(\underline{x})$, k=1,2,3. Denote each equation by $g_i(\underline{x})$.
   d. (6) Write down the Jacobian matrix $\underline{J}$ used in the solution procedure. Indicate elements in the matrix using partial derivative notation; you need not differentiate anything or provide numerical values.
3. (18) Optimization: (18 pts) A small power system has only two generation units. The derivatives of the cost-rate functions for the two units are as follows:

   $dC_1/dP_1=2P_1+2$, $dC_2/dP_2=3P_2+4$ (in \$/MWhr for both derivative functions)

   Unit 1 can supply from 0 to 9 MW and unit 2 can supply from 0 to 11 MW.
   a. (2) When the load is 10 MW, the output at the two plants is set at 5 MW for both unit 1 and unit 2. What is the incremental cost of each unit at this dispatch?
   b. When the load is 10 MW, the units are dispatched optimally (so as to minimize the total cost rate).
      i. (2) What is the optimal dispatch?
      ii. (2) What is the incremental cost of each unit at this dispatch?
      iii. (2) What is the system lambda at this dispatch?
   c. (4) How much would the objective function change if the load increased from 10 MW to 11 MW, assuming the dispatch was kept optimal.
   d. (6) When the load is 20 MW, the optimal solution in the first step of the solution procedure (ignoring inequality constraints) is P_1=12.4MW, P_2=7.6MW, λ=26.8\$/MWhr. In the second step, the solution is found to be P_1=9MW, P_2=11MW, λ=37\$/MWhr, μ_1=-17\$/MWhr.
      i. Only one inequality constraint is "mathematically" binding. Which one is it?
      ii. For this 20 MW load, how much would the objective function change if the unit 1 upper limit was increased to 10 MW, assuming the dispatch was kept optimal?
      iii. For this 20 MW load, how much would the objective function change if the upper limit of unit 2 was increased to 12 MW, assuming the dispatch was kept optimal?
4. (21 pts) Short answer:
   a. What is the essential control parameter in using a BJT as a controlled switch?
   b. What two regions does a BJT operate in when serving as a controlled switch?
   c. What is the essential control parameter in using a naturally commutated thyristor as a controlled switch?
   d. What is the main operational difference between a thyristor and a diode?
   e. Why is energy dissipation used in controlled switching a motor?
   f. What is the advantage of energy recovery over energy dissipation?
   g. What are the three control parameters for performing speed control for a DC motor?
5. (14 pts) True-false:
   a. An induction motor is like a transformer in that the voltage of one of the windings is induced.
   b. Induction motors are like synchronous machines in that both have externally supplied field windings.
   c. An induction motor is like a DC motor in that both devices have AC applied to 3 stator windings.
   d. Rotor speed for an induction motor is fixed whereas rotor speed for a synchronous machine varies.
   e. A slip of 0 corresponds to a stationary rotor.
   f. A DC motor is like a synchronous machine in that both may utilize slip rings and brushes.
   g. It is common to perform power factor correction by controlling field current of an induction motor.