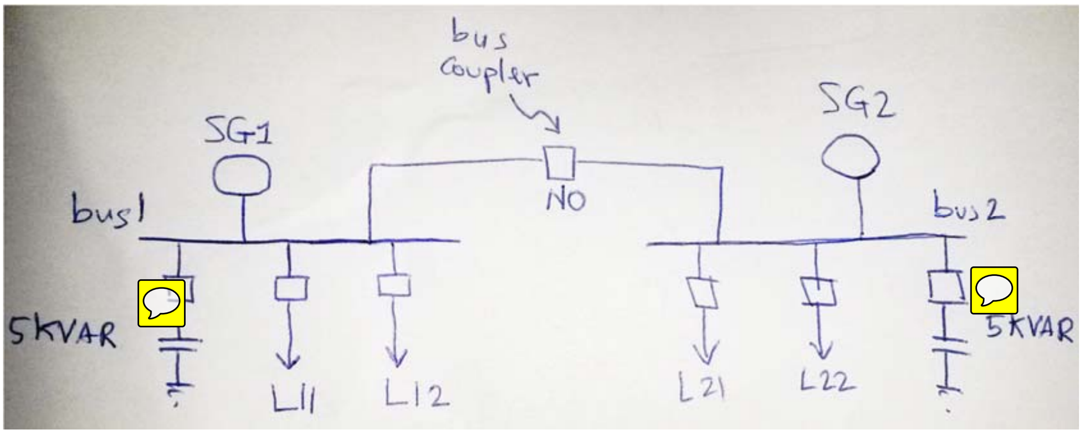
KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

ELECTRICAL ENGINEERING DEPARTMENT

EE 360 (Semester 152)

Voltage Control of an Industrial Facility

This project concerns voltage control of an industrial facility. This facility has four major loads fed from two synchronous generators. The system layout is shown in the figure below. As shown in the figure, loads L11 and L12 are fed by unit SG1 located at bus 1; loads L21 and L22 are fed by unit SG2 located at bus 2. In normal conditions, the bus coupler between bus 1 and bus 2 is left open (i.e. this breaker is a normally-open (NO) breaker). Loads L11 and L21 are critical loads. However, loads L12 and L22 are non-critical. Non-critical loads can be shed (i.e. turns off) if absolutely necessary. The load profiles are given in the table below.



	Hour 1	Hour 2	Hour 3	Hour 4	Hour 5	Hour 6	Hours 7-24
L11 (kW)	15	30	39	55	65	65	0
L11 (kVar)	10	19	23	13	23	23	0
L12 (kW)	5	5	5	5	5	5	0
L12 (kVar)	5	5	5	5	5	5	0
L21 (kW)	30	35	40	45	35	39	0
L21 (kVar)	19	15	19	22	15	25	0
L22 (kW)	5	5	5	5	5	5	0
L22 (kVar)	5	5	5	5	5	5	0

SG1 and SG2 are both 65-kW, 480-V, 60-Hz, three phase synchronous generators with synchronous reactances of 1 Ohm each and negligible armature resistances. The open-circuit characteristics of each generator is nonlinear. An approximate version of these characteristics are as follows:

$$E_A = \begin{cases} 100 I_f, & I_f \leq 5 \\ 500 + 40(I_f - 5), & 5 \leq I_f \leq 6 \end{cases}$$

The maximum value of I_f is 6A.

The operating costs of SG1 and SG2 are

$$C_1(P_1) = 20 + 5P_1 + 0.01P_1^2$$
$$C_2(P_2) = 20 + 4P_2 + 0.01P_2^2$$

where P_i is in kW and C_i is in \$/h.

The CO2 emissions of SG1 and SG2 are given by

$$E_1(P_1) = 10 + 5P_1 + 0.01P_1^2 \quad (\times 10^{-3})$$
$$E_2(P_2) = 10 + 6P_2 + 0.01P_2^2 \quad (\times 10^{-3})$$

where P_i is in kW and C_i is in tons/h.

The loads require strict line voltages of 480 V at their terminals. This can be achieved by controlling one or more of the following:

1- Adjusting the field current of each of the generators
2- Switching on or off each of the 5-kVar capacitors located at each bus
3- Closing the bus coupler
4- Shedding non-critical loads.

The above four options are ordered (arranged) based on the plant operator's preference. That is, the operator prefers to regulate the voltage by adjusting the field currents of generators. If this was not sufficient, he/she would attempt to operate the shunt capacitors, followed by controlling the bus coupler if necessary. The operator would shed loads only if there were no other options left at his/her disposal.

You are required to [**<u>SHOW SUFFICIENT WORK</u>**]:

1- Design a control algorithm that the operator can use to maintain the voltage at the load side at 480V L-L. You need to give a step-by-step description of this algorithm in an "if-then-else" structure.
2- Implement the control algorithm on the system given above. For each hour, clearly identify each generator's real and reactive power outputs, their field currents, internal voltages, and shunt capacitors and bus coupler statuses. Show your results in a tabulated format. If you have developed a computer code (e.g. in Matlab or Excel) to perform your implementation/calculation, you need to submit these codes in soft copies.
3- Calculate the total daily operating cost for the system.
4- Calculate the total daily CO2 emissions for the system.

Date Due: April 27th, 2016