University of Washington
Department of Electrical Engineering
EE 351: Energy Systems

Lab 3: Building Your Own Power Plant

Objectives

- To build a power plant that consists of a prime mover, synchronous generator and three-phase transformer.
- To learn how your power plant is connect to the grid.
- To learn how your power plant regulates the generated real and reactive powers.

Lab Setup

The lab setup is shown in Figure 1. It consists of a prime mover to simulate the action of the power plant's turbine. The prime mover is connected mechanically to a synchronous generator (G) to convert the mechanical energy of the turbine into electrical energy. The terminals of the generator are connected to the terminals of the power grid through the synchronization circuit.

Prime Mover

In the lab, you will be using the prime mover module to simulate the turbine of a power plant. The prime mover is a general purpose motor that can be controlled to provide variable speed or power output at its shaft. The change of power is simulating the governor action of the hydro or thermal power plant.

The prime mover is connected mechanically to the synchronous generator. Therefore, the speed of the generator is the speed of the prime mover, and the mechanical power going into the generator is the mechanical power output from the prime mover (minus frictional losses).

Synchronous Generator

The synchronous generator is an electromechanical conversion device. It converts the mechanical energy at the shaft of the turbine (prime mover) into electrical energy. The magnetic field of the generator is provided by an electrical magnet powered externally. When the rotor spins, the three-phase windings will have induced voltage across them as discussed in Chapter 8 of your textbook. Connect the generator in Y configuration.

Synchronization Circuit

The synchronization circuit consists of three independent light bulbs with a common bypass switch. The generator terminals are connected on one end of the circuit and the grid terminals are connected to the other end. The light intensity, flicker frequency and the synchronous flickers are indications of whether you satisfied the following conditions for grid connection:

1. The phase sequences of the generator and grid are the same.

2. The frequency of the generator voltage is exactly 60Hz
3. The voltage of your generator is the same as the voltage of the grid at the time you close the synchronization switch

If you don't satisfy any of the above three conditions, your power plant will not successfully connect to the grid. Moreover, damaging high current and high torque transients will likely to occur.

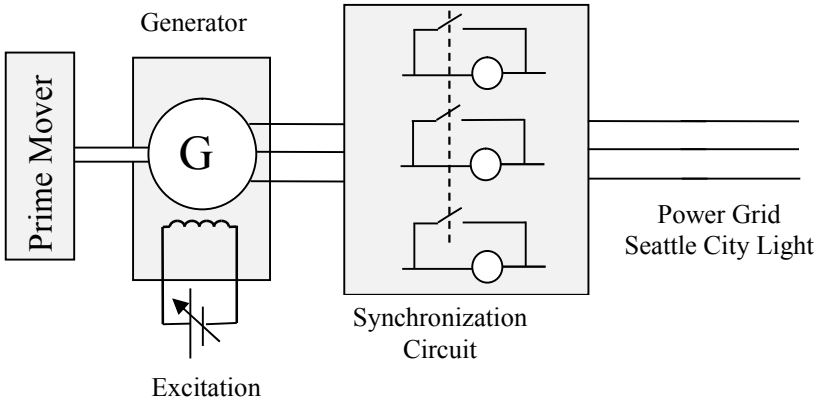

Figure 1: Lab setup

Experiment

Part 1: Connections

1. Draw the wiring diagram that realizes the circuit in Figure 1. You will need to
   - Connect the generator in Y configuration
   - Connect the synchronization circuit.
2. Ask your TA to check your diagram
3. Wire the LabVolt modules according to your wiring diagram
4. Connect the measurements module to display the following:
   - The phase voltage of the generator
   - The phase voltage of the grid
   - The frequency of the generator voltage
   - The phase current of the generator
   - The phase power of the generator (this is found by multiplying the power and current of the *same* phase)
   - Display the waveforms of the phase voltages on the scope

Part 2: Synchronization with the Grid

Without closing the synchronization switch, be sure that

1. The phase sequences of the generator and grid are the same. If not, swap the wires of two phases.
2. The frequency of the generator voltage is exactly 60Hz. If not, adjust the speed of the turbine until 60Hz is achieved.
3. The voltage of your generator is the same as the voltage of the grid at the time you close the synchronization switch. If not, observe the light flickers and close the switch when the flicker is at its dimmest state.

Your Conclusions

- Write the sequence of connecting your power plant to the grid
- Write the sequence of disconnecting your power plant from the grid

Part 3: Effect of turbine speed and excitation voltage on load frequency and voltage

After you have successfully synchronized your power plant, do the following:

- **Slightly and slowly** increase the power output of the turbine and study its impact on real and reactive powers of your power plant. **Do not increase the power of the turbine above the pullout power (the power at which your generator will lose synchronization with the grid).** Make note of the pullout power.
- Change the excitation voltage of the generator and study its effect on the real and reactive powers of your power plant. Find the pullout power again.

Your Conclusions:

- Explain the relationship between the input power of the prime mover and the output real power of your power plant
- Explain the relationship between the input power of the prime mover and the output reactive power of your power plant
- Explain the relationship between the excitation voltage and the output real power of your power plant
- Explain the relationship between the excitation voltage and the output reactive power of your power plant
- Explain how the power plant *as a whole* contributes to the grid power.

Part 4: Effect of Weak Line

Add inductive reactance between the power plant and the grid to simulate a long transmission line. Repeat Parts 2 and 3. In addition, observe the voltage at the power plant. Study the relationship between the generator excitation and the voltage of the generator.

Do not allow the current in any line to exceed 0.6A

Your Conclusions:

- Explain how the line inductance affects the operation of your power plant
- Explain the relationship between the generator excitation and the voltage of the generator.