Lab 6
Three-Phase Alternator
Due 5/6/2021 at 11:59 PM

Rating information for the alternator is on the last page.

Objectives

- To examine the construction of the three-phase alternator.
- To obtain the short-circuit behavior of the alternator.
- To observe the effect of loading on the output voltage.

Discussion

The terms alternating current generator, synchronous generator, synchronous alternator, and alternator are commonly used interchangeably in engineering literature. Because synchronous generators are so much more commonly used than induction generators, the term alternator, as often used, and as used here, applies only to synchronous generators.

Alternators are, by far, the most important source of electric energy. Alternators generate an AC voltage whose frequency depends entirely upon the speed of rotation. The generated voltage value depends upon the speed, the DC field excitation and the power factor of the load.

As the DC field excitation of an alternator is increased, its speed being held constant, the magnetic flux, and hence, the output voltage, will also increase in direct proportion to the current. However, with progressive increases in DC field current, the flux will eventually reach a high enough value to saturate the iron in the alternator.

The three phases of the alternator are mechanically spaced at equal intervals from each other, and therefore, the respective generated voltages are not in phase, but are displaced from each other by 120 electrical degrees.

The output voltage of an alternator depends essentially upon the total flux in the airgap. At no-load, this flux is established and determined exclusively by the DC field excitation.

Under load, however, the air-gap flux is determined by the ampere-turns of the rotor and the ampere-turns of the stator. The latter may aid or oppose the MMF (magnetomotive force) of the rotor depending upon the power factor of the load. Leading power factors assist the rotor, and lagging power factors oppose it.

Because the stator MMF has such an important effect upon the magnetic flux, the voltage regulation of alternators is quite poor, and the DC field current must continuously be adjusted to keep the voltage constant under variable load conditions.

If one phase of a three-phase alternator is heavily loaded, its voltage will decrease due to the IR and IXL drops in the stator winding. This voltage drop cannot be compensated by modifying the DC field current because the voltages of the other two phases will also be changed.

From "Investigations in Electric Power – Student Manual" by LabVolt

Analysis

The circuit in Fig. 1 shows a Squirrel-Cage Induction Motor connected to the variable 3ϕ output of the in-lab power supply. Assume that this motor is coupled to the Synchronous Machine (which is acting as a generator) through a coupling belt, similar to the coupling that was shown in Lab 4. The synchronous generator has a rheostat (variable resistor) available for control of its input field voltage.

Remember that the PSIM equivalent of the timing belt is the <u>Mechanical Coupling</u> component.

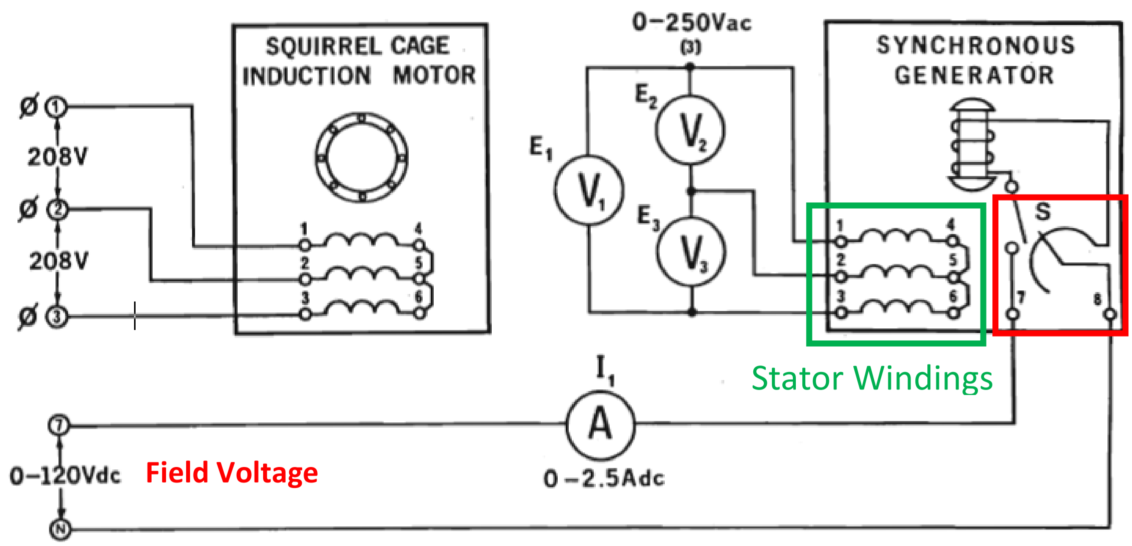


Figure 1: Visualization of the circuit used for Open- and Short-Circut analysis.

1) In reviewing the Synchronous Machine's info on the [LabVolt website](), the following is stated:

   "The machine rotor is equipped with a squirrel-cage damper."

   Explain what the synchronous machine uses the squirrel-cage for, and what the damper is. (Refer to Section 6.3 of your textbook for the operational properties of synchronous machines).

2) Using the values given in the figure (ignore the meter ratings) along with the PSIM defaults for the **IM** and **Synchronous Machine**, recreate the above circuit. For the synchronous generator, add a resistor to the field winding (we'll adjust it later). Pay special attention to the AC and DC voltages needed and the positive terminal (dot) on each device. Given the lab uses the standard AC outlet, make sure to use the correct AC frequency.

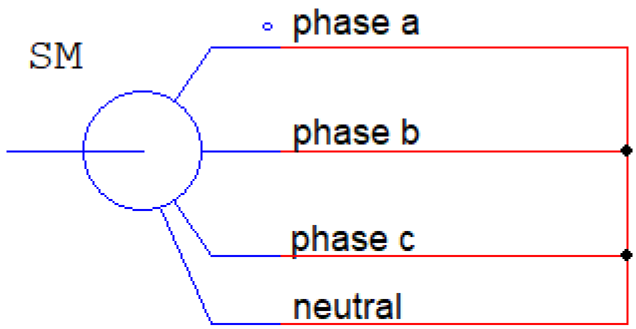
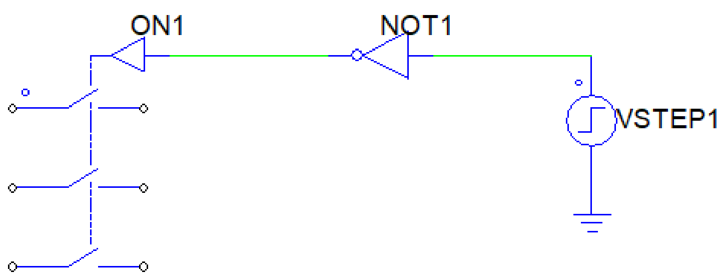


Figure 2: Synchronous Machine stator connections.

3) **Open-Circuit Voltage:** Along each phase (not the neutral), place a push button set to the OFF state (PSIM doesn't like floating nodes) and adjust the field resistor until the SM's phase ("phase-to-neutral") voltage reads 120 V. Provide plots of the field current and the phase voltage with the case running for 4 seconds. What is the line current? What is the steady-state mechanical speed (and does this value make sense)?

4) **Short-Circuit Current:** Insert the following setup (which includes a **3-ph Bidirectional Switch**, **NOT Gate**, **Step Voltage** and **On-Off controller**) in place of the push buttons to simulate a three-phase short-circuit on the generator at time t = 2.5s. All values can be kept at their defaults besides the Time step. Make sure to short phase a, b, c, and the neutral on the right-hand side of the switch. Provide plots of the synchronous generator line current and phase voltage.



For the next parts, you are welcome to use the R3, L3, and C3 components.

5) **Resistive Load:** Connect a three-phase resistive load of 30 Ω and record the phase voltage. What is the voltage regulation (VR) for this particular load (NL = full load = open-circuit, FL = full-load)? What is the power factor (make sure to indicate leading or lagging)?

$$VR = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

6) **Inductive Load:** Repeat Part 5 for an inductive load with reactance X_L = 30 Ω.
7) **Capacitive Load:** Repeat Part 5 for a capacitive load with reactance X_c = 30 Ω.
8) **Changing Field:** Increase and reduce the field resistance by 25%. Is there any change in the generator's power factor?

Report format is the same as previous assignments, just make sure to address 1-8 as required.