EXPERIMENT NO. 19

STARTING AND SYNCHRONIZING SYNCHRONOUS MACHINES

PURPOSE:

To discover the method of starting synchronous motors.

BRIEFING:

When three-phase is applied to the stator of a three-phase motor, a revolving stator magnetic field is created. This field revolves at synchronous speed, which is a speed determined by the number of poles per phase of the motor and the frequency of the incoming power.

The rotor of a synchronous motor becomes "locked in" on the revolving stator field. It then rotates at synchronous speed. To accomplish this, the rotor contains a DC field winding.

The problem is in starting. If you have DC applied to the field coil, while the rotor is standing still, the revolving field passes the stationary field much too fast to be locked onto.

First the DC field coils on the rotor must be made to rotate almost as fast as the revolving stator field. Then, when you apply DC to it, the rotor is pulled into synchronism. That means that the rotor turns at synchronous speed.

To get the rotor turning in the first place, a squirrel-cage winding is used. The bars are inbedded in the rotor core. When power is applied to the stator, the revolving field induces voltage into these windings. In other words, a synchronous motor starts as an induction motor. When the rotor reaches 95% of synchronous speed, DC is switched into the rotor field winding.

Now, during the start process, there will also be voltage induced into the DC field winding as the rotor turns. Rather than have a charged-up field coil, its terminals are shorted through a resistor while the squirrel-cage winding is getting the rotor started.

Because synchronous motors must achieve 95% synchronous speed before being synchronized, they are rarely started under load. Load is applied after it is running as a synchronous motor. The rotor, however, continues to turn at synchronous speed.
It is possible to load a synchronous motor beyond its ability to stay in synchronism. The counter-torque of a load overcomes the torque (pull) on the rotor from the revolving stator field. When that happens, the motor pulls out of step with the stator field.

It will not simply fall back to running smoothly as an induction motor, however. Induced currents, added to the excitation current in the DC field winding, make the rotor pulsate. Therefore, field excitation should be removed as soon as possible after the rotor pulls out of synchronism. Then, if you want to re-synchronize the motor, you must first remove the overload.

**PERFORMANCE OBJECTIVES:**

Upon successful completion of this experiment, the student will be able to:

1. Explain the principle of synchronous motors.
2. Start and synchronize a synchronous motor.

**MACHINES REQUIRED:**

SM-100-3A Synchronous Machine  
DYN-100A-DM Dynamometer

**POWER REQUIRED:**

208 volts Fixed AC  
0 - 150 volt Variable DC, 1 amp  
0 - 125 volt Variable DC, 5 amps

**METERS REQUIRED:**

(2) 0 - 150 volt DC Voltmeters  
0 - 1 amp DC Ammeter  
0 - 2.5 amp DC Ammeter  
0 - 300 volt AC Voltmeter  
0 - 2 amp AC Ammeter

**ADDITIONAL MATERIAL REQUIRED:**

MGB-100-DG Bedplate  
RL-100A Resistance Load  
SLA-100D Strobe-Tachometer
PROGRAM PLAN:

Step 1. Place the two machines on the bedplate. Motor on the left, dynamometer on the right. Couple and clamp the machines securely.

Step 2. Connect the synchronous motor as shown in Figure 19-1. Note that the stator is wye-connected.

Step 3. Connect the dynamometer as shown in Figure 19-1. Note that this is a separately-excited shunt generator connection. Be sure that all of the load switches on the RL-100A are in the downward (OFF) position.

Step 4. Have someone check your connections to be sure they are correct. Adjust the field rheostat on the dynamometer to its maximum resistance position, fully clockwise.

Figure 19-1
Step 5. With the motor circuit breaker OFF, turn ON the main AC and the 0 - 125 VDC excitation supply.

Step 6. Put the motor switch in the SYNC RUN position and adjust the excitation supply until 0.6 amps flows in the field coil. Then return the switch to the IND START position.

Step 7. Turn ON the motor circuit breaker.

Step 8. The synchronous motor is now running as an induction motor. Measure the speed, and stator current. Record these values in TABLE 19-1.

<table>
<thead>
<tr>
<th>SPEED</th>
<th>STATOR CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE SYNCHRONIZING</td>
<td></td>
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<tr>
<td>AFTER SYNCHRONIZING</td>
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TABLE 19-1

Step 9. Switch the toggle on the motor to SYNC RUN.

Step 10. Turn ON the 0 - 150 volt DC supply and adjust its output to 115 volts. Adjust the dynamometer's field rheostat until the terminal voltage is 120 volts.

Step 11. Adjust the 0 - 125 VDC excitation current until the stator current is at its lowest point.

Step 12. Measure speed and stator current. Record these values in TABLE 19-1.

Step 13. Zero the dynamometer scale by positioning the weight at the rear.

Step 14. Turn ON the resistance load switches one at a time. As each one is turned ON, measure speed, stator current and torque. Record these values in TABLE 19-2.

Step 15. As you turn ON the ninth or tenth load switch, the motor will pull out of synchronism. Immediately switch back to IND START and start removing load steps one at a time. After each, attempt to re-synchronize. Make a note of the number of switches that were still on when you were able to re-synchronize.

Step 16. Turn OFF all circuit breaker switches. Disconnect all leads.
TEST RESULTS:

<table>
<thead>
<tr>
<th>LOAD STEPS</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>5</th>
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<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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<tbody>
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<td>SPEED</td>
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</table>

**TABLE 19-2**

DE-BRIEFING:

1. The damper winding (squirrel-cage) starts the rotor and gets it up to 95% synchronous speed. After DC is applied to the rotor field coil and the rotor pulls up to synchronous speed, what is the job of the damper winding?

   Explain.

2. Why isn't DC applied to the rotor field coil right away instead of waiting until the rotor is up to speed?

3. What happened to rotor speed as you synchronized the rotor?

   What happened to stator current?
Explain why rotor speed changed the way it did.

4. What was the "pull-out torque" for this motor? (Pull-out torque is the maximum torque the motor will produce before dropping out of synchronism).

5. As you attempted to re-synchronize, how many switches were ON when your attempt was successful?

QUICK QUIZ:

1. When a synchronous motor is loaded, its speed:
   a) Increases.
   b) Decreases.
   c) Remains the same.

2. Normally, the stator current of a synchronous motor is:
   a) Higher than that of an induction motor.
   b) Lower than that of an induction motor.
   c) The same as that of an induction motor.

3. A synchronous motor will not "synchronize" if:
   a) The stator has a revolving field.
   b) The load on the rotor is too great.
   c) DC is applied to the field coil on the rotor.
4. As the motor was loaded, stator current:
   a) Increased.
   b) Decreased.
   c) Remains the same.

5. You can easily tell when a synchronous motor drops out of synchronism, because the rotor begins to:
   a) Speed up.
   b) Pulsate.
   c) Reverse direction.
1.) List the major parts of a synchronous machine and explain their functions.

2.) Explain why synchronous machines must be started unloaded. Also explain the correct procedure to follow when starting a synchronous motor.

3.) Explain the function of the damper windings during synchronous motor start-up and as load is applied.

4.) Explain how the torque angle of a synchronous machine changes as mechanical load is added. Is there a torque limit? If one exists, at what angle does it occur?

5.) Explain what happens to a synchronous motor both electrically and mechanically when the torque limit is exceeded.