Basic Measurement and M-G Set with the 208V_{L-L} Motor

OBJECTIVE

This goal is to 1) get acquainted with measurement equipment and 2) experiment with the relationships between real power, apparent power, reactive power, power factor and system losses. The system that we'll use to do this investigation is the so-called M-G set, or motor – generator set.

BACKGROUND INFORMATION

Motor – Generator sets have many practical applications. Our main interest with the present lab is to gain an understanding of basic power relationships in a simple electromechanical system in lieu of exploring practical applications. In understanding M-G set operation it is critical understand the "power flow path." This path is defined as follows: power flows from the electrical source in the console into the motor. The motor converts this electrical power into mechanical power. This mechanical power is transferred to the generator via a belt or coupling assembly and the generator converts this mechanical power into electrical power. Finally this electrical power is absorbed by the electrical load at the "end" of the system. Figure 1 shows the corresponding electromechanical diagram with energy flow direction.



Figure 1

The three-phase motor in Figure 1 is a 208V (line-line), 1/3 horsepower motor. The generator is a 125 Volt, 1/3 horsepower DC machine that is an integral part of the dynamometer setup. The electrical load is a resistor bank with a total of five toggle switches which must be in the "**up**" position (maximum load) while running the experiment. Measurement equipment is not shown in figure one. In order to connect the measurement equipment needed to conduct the experiment you must make connections according to Figure 2

As you conduct this experiment you should assume that all of the power that flows into the system also flows out of the system – either in the form of losses or in the form of electrical and mechanical energy, depending on which component in the system is being observed. You must assume that none of the power that flows into the system will be stored in the system – all of it flows out! Following is an equation set that you may use to calculate various power quantities from the measured data.

$$P_{3\phi} = 3 \cdot P_{I\phi} \qquad S_{I\phi} = V_{AC} I_{AC} \qquad Q_{I\phi}^2 = S_{I\phi}^2 - P_{I\phi}^2$$

$$pf = \frac{P}{S} \qquad pf_{disp} = \cos(\theta) \qquad P_{shafi} = \tau \omega$$

$$P_{out} = V_{DC} I_{DC} \qquad P_{loss} = \qquad \eta = \frac{P_{out}}{P_{in}}$$

 $\omega = N(2\pi/60)$ Ploss = Pin – Pout T = P / ω

An Explanation of Complex Power

In DC circuits, we are familiar with computing the power sourced to any arbitrary device under test (DUT) as:

P = VI

In AC circuits however, the voltage and current waveforms are sinusoidal and can be misaligned. In essence, these waveforms have a phase shift, \Box . Furthermore, the oscillatory nature of AC voltages and currents introduces complex terms the calculation and expression of power for AC circuits. Therefore, the complex power, *S*, can be described by real and imaginary components *P* and $^{\circ}$, respectively. Expressly,

$$S = P + jQ$$

The table below further describes the quantities in this equation

Symbol	Name	Calculation
S	Complex power	P + jQ
S or S	Apparent power	$\sqrt{(P^2 + Q^2)}$
Р	Real or Active Power	VIcos(Θ)
Q	Reactive power	VIsin(Θ)

In the above table, Θ is the delay between the AC voltage and current waveforms expressed as an angle. Hence, Θ can be calculated by the following equation:

$$\Theta = \Theta_{Voltage} - \Theta_{current}$$

The cosine of this angle Θ , is also important and defines what is called the power factor or PF.

$$PF = cos(\Theta)$$

The power factor is a fraction that expresses the amount of apparent power that is actually tangible to the load as real power. The "power triangle" shown below expresses the content of this section visually.



TEST SETUP

The 208V AC induction motor and DC generator (dynamometer) have already been placed on the bench and mechanically coupled. On the right-hand end of the dynamometer is a clamp which locks the generator's rotor and stator. You must remove this lock before conducting the experiment and replace it after you are finished with the entire experiment.

Force required to counteract the shaft torque is measured by the strain gauge that connects the overhanging arm to the DC generator stator. The strain gauge is connected through a cable (follow it) to a gray box on top of the bench. This box contains the display that shows the actual torque on the generator's shaft. The display indicates torque in Newton-meters. Be sure to set the torque meter to zero before starting each step in the experiment. In other words, each time that you start up the M-G set. The M-G set must be at rest when resetting the torque meter.

The generator is loaded by the resistor bank shown in Figure 2. All switches should be in the "off" position (center position) for no-load tests. To load the generator, move all 5 switches to the "up" position (50Ω load).

Measure the speed with a tachometer. On each bench, there is a portable digital tachometer. The blue box that has RPM on the front. Attached to the box is a grey-colored cable with an optical head at the remote end. This head contains a light source and an optical receiver. On the side of coupling on the end of generator's shaft where the lock is you'll find a piece of reflective tape. Aim the light source at the coupling, a small amount of light reflected back each time the tape crosses the beam. The reflected light causes an electrical pulse from the receiver. The tachometer times the pulses, converts them to RPM, and displays the speed.

<u>CAUTION</u> – Do not look into the light source. It is very intense and will hurt your Eyes!!!! Set Channel 1: probe to 20x Voltage. Set Channel 2: probe 1A/V Current

SUGGESTED PROCEDURE

Part I. No-Load Test

A. Connect the system shown in Figure 2. The transformer is used as 20:1 step down transformer on channel 1 set to x20 voltage probe. Notice that the line current flow into the motor will be displayed on channel 2 set to 1V/1A current probe of the scope. We insert the one-ohm resistor shunt (red box) into phase A in order to measure line current. Insert one-ohm resistor shunts into the other two phases in order to keep the circuit balanced. Notice that there is a Fluke ammeter and voltmeter connected on both the AC and DC circuits. Notice that the DACI will to display single-phase power, not three-phase power.

Set the torque-meter to zero N•m's before proceeding to the next step.

Add DACI (Data Acquisition Control Interface) to the circuit of Figure 2 the DACI Current connections with I1 (40A) after the 1Ω shunt and before the digital wattmeter current input. Add E1 Voltage connection from the DACI across the phase A of the motor connection and neutral. Add I4 (40A) in series with the **lload** ammeter connection to the dynamometer load bank. Add E4 in parallel with **Vload** voltmeter connection to the dynamometer load bank. Remember to change current scales on the right hand menu to 40A.

B. Energize the system with no-load on the DC generator as follows: Remove the lock on the dynamometer. Slowly increase the voltage on the three-phase AC source until rated voltage is applied to the motor, **120 volts line-neutral** (208V line-line). The source dial should be roughly on 100% when you reach 120 volts. The motor should begin to spin before you reach 10 or 15% on the dial. If it does not, stop and trouble shoot your setup. The torque reading must be a positive value. If it is negative, reverse motor direction. Reverse the direction by swapping two of the phases on the motor.

Fill in the following chart with two sets the raw data. The first set is from the DACI meters and scope for delay time between V and I. The second set from scope power applications menu (Power Analysis, and Waveform Analysis).

You must convert the delay into an angle before proceeding to the calculations (which you will do after you have completed the entire experiment). You must also convert the measured speed "n" (in revolutions per minute) into angular speed " ω " (in radians per second).

DACI Meters, Scope	Scope APP Menu	
V _{IN} (AC)	V _{IN} (ch1)x20 Voltage	
I _{IN} (AC)	I _{IN} (ch2)x1 Current	
∆T (delay V to I)	θ	
P _{IN} 1Φ	P _{IN} 1Φ	
V _{LOAD} (DC)	S _{IN} 1Φ	
I _{LOAD} (DC)	Q _{IN} 1Φ	
т (N-М)	pf	
n (rpm)	f (Hz)	

No-Load Test Raw Data (Note: Remember Units)

Table 1

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Part II. Rated-Load Test

A. Decrease the AC source voltage to zero. Reset the torque meter to zero.

B. Adjust the AC voltage back up to 120 volts. In order to put a load on the system, you must apply DC excitation voltage to the shunt field winding on the dynamometer. This allows the dynamometer produce a voltage at armature terminals. Before powering up the DC supply, set the coarse current control dial at about 11 o'clock. Set all other dials on the DC supply at full counter clockwise. Set all load bank switches in the "up" position maximum load.

Slowly increase the voltage on DC Supply 3 until the dynamometer indicates a load of about 1.00N-m. Set the AC line current flowing into the motor to about 1.2 amps (voltmeter on the DC supply will need to be set at roughly 70V). To increase this DC voltage, use the coarse voltage dial. Maintain the AC voltage at $120V_{L-N}$ (this voltage will drop slightly) and reiterate this process until the dynamometer load is 1.00 Nm and motor terminal voltage is $120V_{L-N}$, and the motor current should be about 1.2 amps.

Once you reach the above operating conditions. Fill in the following chart with two sets the raw data. First set is from the DACI meters and scope delay time between V and I. The second set from scope power applications menu (Power Analysis, and Waveform Analysis).

After you are finished collecting data. Remove DC voltage from the generator's shunt field winding, remove AC voltage from the motor, and replace the dynamometer's lock.

DACI Meters, Scope	Scope APP Menu	
V _{IN} (AC)	V _{IN} (ch1)x20 Voltage	
I _{IN} (AC)	l _{ıℕ} (ch2)x1 Current	
${\scriptstyle \Delta}$ T (delay V to I)	θ	
Ρ _{ιΝ} 1Φ	Ρ _{IN} 1Φ	
V _{LOAD} (DC)	S _{IN} 1Φ	
I _{LOAD} (DC)	Q _{IN} 1Φ	
т (N-М)	pf	
<i>n</i> (rpm)	f (Hz)	

Rate Load (1.00 Nm) Test Raw Data (Note: Remember Units)

Table 2



Figure 2

<u>REPORT to prepare for quiz</u> The Quiz will be online with scholar.

1. Use the raw data from Part's I and II to calculate the power quantities shown in tables 3 and

4. The quantity η in both tables is total system efficiency – and efficiency of an individual system component (i.e. motor or generator).

S _{IN} 1Φ	S _{IN} 3Φ	P _{LOSS} MOT
Ρ _{ΙΝ} 1Φ	P _{IN} 3Φ	PLOSS DYNO
Q _{IN} 1Φ	Q _{IN} 3Φ	PLOSS SYS
ω	P _{SHAFT}	η ΜΟΤ
θ	P _{OUT} (DC)	η DYNO
pf=P/S	pf= Cosθ	η SYS

No load Calculations (Part 1 data)

Table 3

Rated Load Calculations (Part 2 data)

S _{IN} 1Φ	S _{IN} 3Φ	P _{LOSS} MOT	
P _{IN} 1Φ	Ρ _{IN} 3Φ	P _{LOSS} DYNO	
Q _{IN} 1Φ	Q _{IN} 3Φ	P _{LOSS} SYS	
ω	P _{SHAFT}	η ΜΟΤ	
θ	Р _{оυт} (DC)	η DYNO	
pf=P/S	pf= Cosθ	η SYS	
т(meter)	τ= Ρ ουτ/ω		

Table 4

Have instructor sign off the calculations before you leave the lab.

Use these calculations to study for the quiz. Know the equations for the quiz.