

Basic Measurement and M-G Set

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 and gear 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.

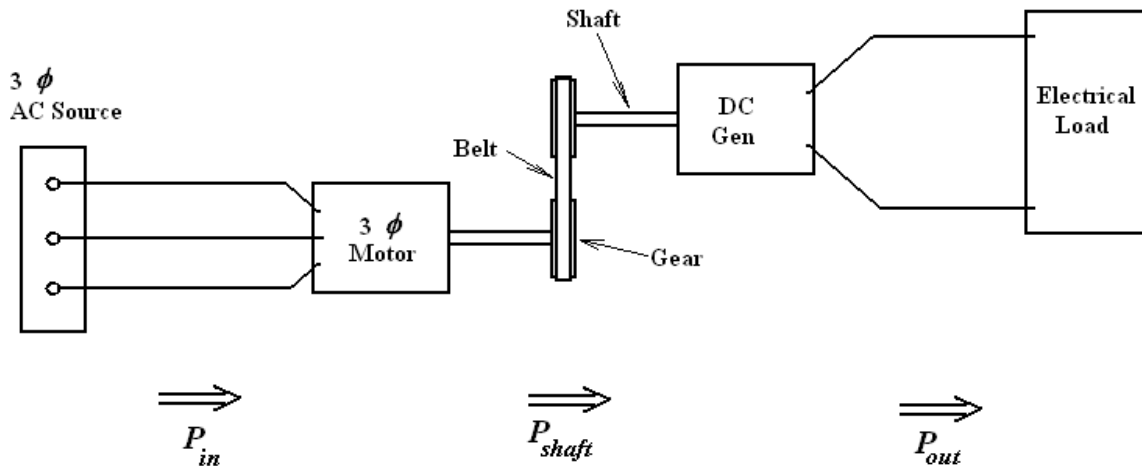


Figure 1

Basic Measurement and M-G Set Lab

The three-phase motor (blue faceplate) in Figure 1 is a 115V (line-line), ¼ 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 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.

$$\begin{aligned} P_{3\phi} &= 3 \cdot P_{I\phi} & S_{I\phi} &= V_{AC} I_{AC} & Q_{I\phi}^2 &= S_{I\phi}^2 - P_{I\phi}^2 \\ \text{pf} &= \frac{P}{S} & \text{pf}_{disp} &= \cos(\theta) & P_{shaft} &= \tau \omega \\ P_{out} &= V_{DC} I_{DC} & P_{loss} &= & \eta &= \frac{P_{out}}{P_{in}} \\ \omega &= N \left(\frac{2\pi}{60} \right) & P_{loss} &= P_{in} - P_{out} & \tau &= P/\omega \end{aligned}$$

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, θ . Furthermore, the oscillatory nature of AC voltages and currents introduces complex terms the calculation and expression of power for AC circuits (as discussed in section 1.8 of the class text). Therefore, the complex power, \vec{S} , can be described by real and imaginary components P and Q , respectively. Expressly,

$$\vec{S} = P + jQ$$

The table below further describes the quantities in this equation.

Symbol	Name	Calculation
\vec{S}	“Complex Power”	$P + jQ$
S or $ \vec{S} $	“Apparent Power”	$\sqrt{P^2 + Q^2}$
P	“Real Power” or “Active Power”	$VI \cos(\theta)$
Q	“Reactive Power”	$VI \sin(\theta)$

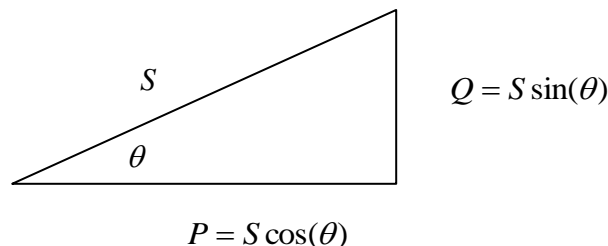
In the above table, θ is the delay between the AC voltage and current waveforms expressed as an angle. Hence, θ can be calculated by the following equation:

$$\theta = \theta_{\text{voltage}} - \theta_{\text{current}}$$

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 AC motor (blue faceplate) and DC generator 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).

Speed measurements are made with a tachometer. On the bench is a portable digital tachometer. It's the little 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. When the light source is aimed at the coupling, a small amount of light is reflected back each time the tape crosses the beam. The reflected light causes an electrical pulse from the receiver. The blue box times the pulses, converts them to RPM, and displays the speed.

CAUTION – 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. Notice that the line current flow into the motor will be displayed on channel two of the scope. Since the one-ohm resistor must be inserted into a phase in order to measure current, a one-ohm resistor is also inserted into the other two phases in order to keep the circuit balanced. Notice that there is an ammeter and voltmeter connected on both the AC and DC circuits. Also notice that the DWM (digital watt-meter) is configured to display single-phase power, not three-phase power. Set the torque-meter to zero N•m’s before proceeding to the next step.

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, **66.4 volts line-neutral** (115V line-line). The source dial should be roughly on 45% when you reach 66.4 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. Also the torque reading must be a positive value. If it is negative, the direction of the motor must be reversed. Reverse the direction by swapping two of the phases on the motor.

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

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

Data Meters, Scope		Data Scope APP Menu	
V_{IN} (AC)		V_{IN} (ch1)x20	
I_{IN} (AC)		I_{IN} (ch2)x1	
ΔT (delay V to I)		θ	
$P_{IN\ 1\phi}$		$P_{IN\ 1\phi}$	
V_{LOAD} (DC)			
I_{LOAD} (DC)		$Q_{IN\ 1\phi}$	
τ (N-M)		pf	
n (rpm)		f (Hz)	

Table 1

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).

Part II. Rated-Load Test

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

- B. Ramp the AC voltage back up to 66.4 volts. In order to put a load on the system, you must apply DC excitation voltage to the shunt field winding on the generator. This allows the generator to actually produce a voltage at its electrical terminals. Before powering up the DC supply, set the coarse current control dial at about 10 o'clock. Set all other dials on the DC supply at full counter clock-wise. Set all load bank switches in the “up” position.

Slowly increase the voltage on DC Supply 2 until the dynamometer indicates a load of 1.00N-m. Monitor the AC current flowing into the motor it should be about 2.6 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 66.4 volts (this voltage will drop slightly) and reiterate this process until the dynamometer load is 1.00 Nm and motor terminal voltage is 66.4 volts, and the motor current should be about 2.6 amps.

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

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

Data Meters, Scope		Data Scope APP Menu	
$V_{IN} (AC)$		$V_{IN} (ch1)x20$	
$I_{IN} (AC)$		$I_{IN} (ch2)x1$	
ΔT (delay V to I)		θ	
$P_{IN 1\phi}$		$P_{IN 1\phi}$	
$V_{LOAD} (DC)$			
$I_{LOAD} (DC)$		$Q_{IN 1\phi}$	
τ (N-M)		pf	
n (rpm)		f (Hz)	

Table 2

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.

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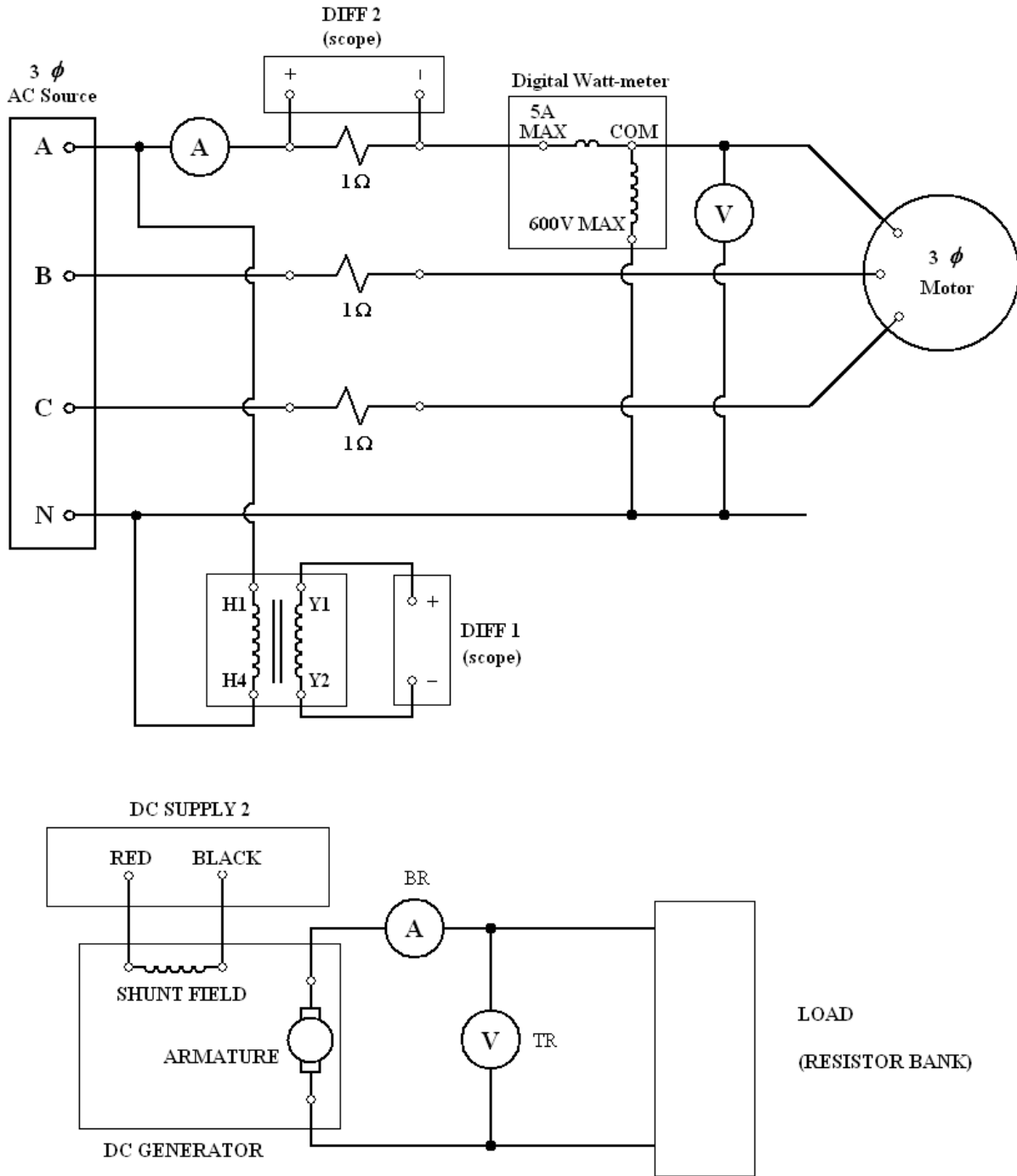


Figure 2

REPORT

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).

No load Calculations (Part 1 data)

$S_{IN\ 1\Phi}$		$S_{IN\ 3\Phi}$		$P_{LOSS\ MOT}$	
$P_{IN\ 1\Phi}$		$P_{IN\ 3\Phi}$		$P_{LOSS\ DYNO}$	
$Q_{IN\ 1\Phi}$		$Q_{IN\ 3\Phi}$		$P_{LOSS\ SYS}$	
ω		P_{SHAFT}		η_{MOT}	
θ		$P_{OUT\ (DC)}$		η_{DYNO}	
$pf=P/S$		$pf= \cos\theta$		η_{SYS}	

Table 3

Rated Load Calculations (Part 2 data)

$S_{IN\ 1\Phi}$		$S_{IN\ 3\Phi}$		$P_{LOSS\ MOT}$	
$P_{IN\ 1\Phi}$		$P_{IN\ 3\Phi}$		$P_{LOSS\ DYNO}$	
$Q_{IN\ 1\Phi}$		$Q_{IN\ 3\Phi}$		$P_{LOSS\ SYS}$	
ω		P_{SHAFT}		η_{MOT}	
θ		$P_{OUT\ (DC)}$		η_{DYNO}	
$pf=P/S$		$pf= \cos\theta$		η_{SYS}	
$\tau(\text{meter})$		$\tau= P_{OUT}/\omega$			

Table 4

Basic Measurement and M-G Set Lab

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.

Quiz will be closed book and closed notes.