LAB 8. POWER SYSTEMS

OBJECTIVES

- Familiarize the students with the use of transformers, motors and generators in power circuits
- Observe the frequency and energy effect in AC sinusoidal waves under human vision conditions.

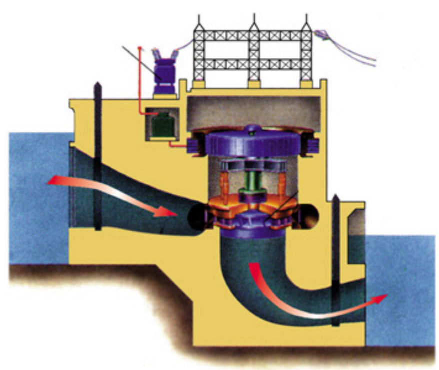
EQUIPMENT AND MATERIALS

- Oscilloscope, Agilent 54622A, 100 MHz
- Signal generator, Agilent 33120A
- 2 Transformers
- Small DC motor
- Motor-Generator system
- Power inverter circuit
- Resistances, lamps, cables and a multimeter

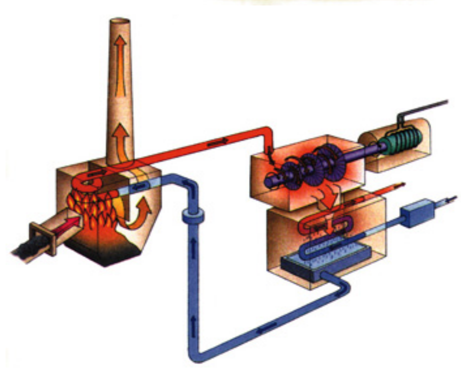
DESCRIPTION

The electricity that we use at our homes is transmitted through a high-voltage power network. It is basically produced by transforming kinetic energy into electric energy. The process requires the use of turbines and generators. The turbines are huge gears which rotate on an axis, driven by an external source. A generator is a machine that transforms kinetic energy, from the movement of the turbines, into electric energy.

Hydroelectric Power Stations (HPS): HPS use the force and velocity of water currents to move the gears of the turbines. There a two types of HPS: uninterrupted flow, which takes advantage of the natural kinetic energy of existing water currents (rivers, oceans, etc.) and interrupted flow, which reserve water with dams, to later release it with larger force (artificial current).



Thermoelectric Power Stations (TPS): TPS use heat to produce electricity. The first stage heats a substance, for example water or a gas, which is subsequently released under pressure to move the turbines and drive the generators. Some substances used to feed a TPS include: carbon, petroleum, natural gas, solar energy, geothermic energy, nuclear energy and biomass.



The electric energy that reaches industries, homes, and businesses are used to power-up assorted equipment and machinery. The energy must be transmitted from the power stations to the location, sometimes for up to several miles. This distribution requires the use of transformers. A transformer has the role of changing the generated electricity's voltage and current to values appropriate for either transmission and distribution or consumption (all three vary significantly).

Transformer

Basically, a transformer consists of two coils, winded around an iron core, which are magnetically coupled. Figure 1, shows the schematic representation of a transformer indicating the basic parts that compose the transformer. The coil that is connected to the generator is called the primary, the number of turns in the coil is N_1, the other coil is connected to the load and is called the secondary with a number of turns equal to N_2. The purpose of the iron core is to provide a mean to concentrate the amount of magnetic flux going through the primary and the secondary.

Transformation Relation: Transformers are used to transform the voltage and currents to lower or higher values, depending on the application. The ratio between the primary and the secondary turns (N_1 and N_2) will determine the voltage and current transformation characteristics. The relationship is expressed as:

$$\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1} = a$$

Where, a is called the transformation ratio, thus, for values with $a > 1$ we have a step-up transformer, since $V_2 > V_1$, while if $a < 1$ we will have a step down transformer since $V_2 < V_1$.

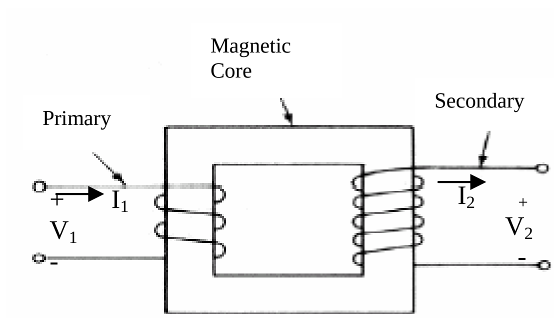
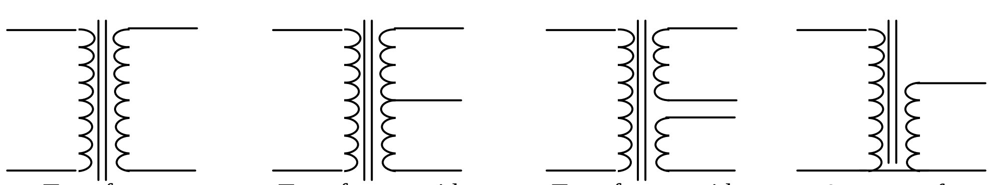


Figure 1 Transformer Schematic

Types of Transformers

There are different types of transformers depending on the specific application or configuration. See figure 2



Transformer with simple secondary (a)

Transformer with central derivation (b)

Transformer with more than one secondary (c)

Auto-transformer (d)

Figure 2

Motors and Generators

Electric motors and generators are a group of machines used to convert mechanical energy into electric energy, or vice-versa, by electromagnetic means. A machine that converts mechanical energy into electric energy is called a generator. If the generator produces alternate current (AC), then it is called an alternator, if it produces direct current (DC) its called a dynamo. A machine that converts electric energy into mechanical energy is called a motor. As is the case with transformers, generators and motors work by means of electromagnetic induction.

Power Inverter

Usually known as an electric power inverter, this circuit is designed to change a DC signal into an AC signal. An example is an inverter which converts the 12 volts DC from an automobile battery, to 120 volts AC used by most household appliances. Inverters are standard circuits studied in the Power Electronics course.

PROCEDURE

Terminal Identification

The transformer given for this practice has the layout shown in Fig. 2c. It consists of a primary coil (terminals 1-4) and two identical secondary coils (terminals 5-6 and 7-8). We could change the layout to a transformer with central derivation (see Fig. 2b) by connecting the two secondary coils in series (linking ends 6 and 7).

- With the Ohmmeter verify all coil connections (1-4, 5-6 and 7-8); you must measure the resistance in the coils.
  $R_{1\text{-}4}$=__________ , $R_{5\text{-}6}$=__________ and $R_{7\text{-}8}$=__________
- Verify there are no other connections in the transformer $R_{1\text{-}5}$=_______, $R_{1\text{-}7}$=_______ and $R_{5\text{-}7}$=_______ .(*Note= No physical connection between ends is called an open circuit. This connection is indicated in the Ohmmeter as* ***0 VL.D***)

Principles of Transformer Operation

Transformers work by means of electromagnetic induction. The induction is possible only if we have a time-varying magnetic field crossing through both coils, primary and secondary. In a transformer, the electric current that runs through the primary coil generates a magnetic field in the iron core, which consequently induces an electric current in the secondary. Induction in a transformer requires the electric current to be AC (either sinusoid, triangular o rectangular).

- Verify that the transformer works with AC signals.
- Configure the generator to generate a sinusoidal signal of 5 V and 5KHz.
- Connect the generator to terminals 1-4 of the transformer and the oscilloscope to terminals 7-8 (or 5-6), as shown in Figure 3.
- Observe if the signal in the output of the transformer preserves the shape, amplitude and frequency of the input. Repeat the same operation for triangular and rectangular signals. Write down the results in Table 1.

Type of signal	Draw the shape of the input	Draw the shape of the output	Amplitude	Frequency
Sinusoidal				
Triangular				
Rectangular				

Table 1

- Indicate which signals preserved their shape: ______________________________
- Indicate which signals did not preserve their shape:_________________________

  explain why____

  ____
- Replace the generator with a DC voltage source, previously set with a 3 VDC output.
- Measure the voltage in the output of the transformer V=_________.

  Explain why the absence of voltage: _____________________________________

  ____
- Disconnect and connect rapidly (switching several times) the wire connected to terminal 1 of the transformer. Observe; is there any change in the oscilloscope?

  ____

  Explain the origin of this effect____

  ____

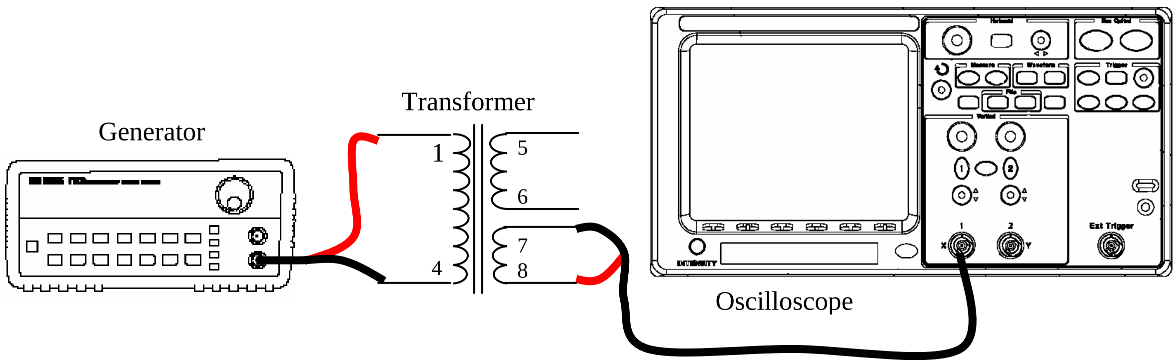


Figure 3

Transformers as a step-up and step-down

We will verify the operation of the transformer as a voltage increaser or reducer.

- Complete the structure of Fig 3. Adjust the generator for a sinusoidal signal of 1 Volt and 60 Hz.
- Measure the voltage in the output terminals of the transformer (terminals 5-6 and 7-8) with the oscilloscope. Write down the results in Table 2.
- Apply other voltage amounts to the transformer input and measure the corresponding amounts in the output as stated in Table 2. Calculate the transformer ratio.

Voltage in the primary	Voltage in the secondary 5-6	Voltage in the secondary 7-8	Transformer ratio
1 V			
2 V			
5 V			
10 V			

Table 2

- Analyze the results; explain if the transformer is a step-up or step-down.

  ____

  ____

  What is the average transformer ratio? Are the secondary coils identical?

  ____

  ____

  ____

- Invert the connections; connect the generator to terminals 5-6 of the transformer and the oscilloscope to terminals 1-4. Adjust the voltage of the generator to 1 V and measure the output voltage with the oscilloscope. Write down the results in Table 3.
- Apply other voltage levels to the input of the transformer as stated in Table 3. Calculate the transformer ratio.

Voltage in the primary 5-6	Voltage in the secondary 1-4	Transformer ratio
500mV		
1 V		
1.5 V		
2V		

Table 3

- Analyze the results; explain if the transformer is a step-up or step-down.

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What is the average transformer ratio?

____

____

DC Motor and Generators.

Verify that the motors and generators are working alternately, i.e., they can convert mechanical energy in electrical or the opposite by electromagnetic means.

- Adjust the voltage of the source to zero VDC.
- Connect the terminals of the miniature DC motor to the voltage source; be aware of the polarities of the motor.
- Slowly increase the source voltage up to a maximum of 3 volts. Notice how the motor's rotation velocity increases with respect to the source voltage and the Gyro.

Explain ____

____

- Again, adjust the voltage of the source to zero VDC and invert the cables in the terminals of the motor.
- Slowly increase the source voltage up to a maximum of 3 volts. Notice how the motor's rotation velocity increases with respect to the source voltage and the Gyro.

Explain ____

____

- Replace the voltage source with the signal generator. Adjust the generator to a sinusoidal signal of de 1 V and 60 Hz. Does the motor work with the following signals? Sinusoidal: _______, Triangular:______, Squared:______

Prove that the motor works as a generator; connect the terminals of the motor to the multimeter.

- Spin continuously the rotor of the motor and observe the voltage readings in the multimeter screen. Voltage without movement:________, Maximum voltage with movement:________

Earlier we saw that the rotation velocity in a motor is proportional to the input voltage. Next we will see how a generated voltage is proportional to the rotational velocity.

- Adjust the voltage source to zero VDC.
- Connect the terminals of one of the motors to the voltage source; be aware of the polarities of the motor (the terminal closest to the red dot is positive). The other motor will be the generator; its terminals must be connected to the multimeter, see Fig. 4.
- Increase the source voltage up to a maximum of 5 volts. Notice how the motor's rotational velocity varies with respect to the velocity of the rotor and the motor's input voltage. Fill out table 4.

- Connect an electric lamp to the output of the generator. Measure again the voltage in the output of the generator using input voltages stated in table 4.

Voltage in l motor	Vout of the generator	Vout of the generator with the load
1 V		
3 V		
5 V		
7 V		

Table 4

- Explain the behavior of the output voltage with respect to the input voltage. ____

- What is the effect of the load on the generated voltage? ____

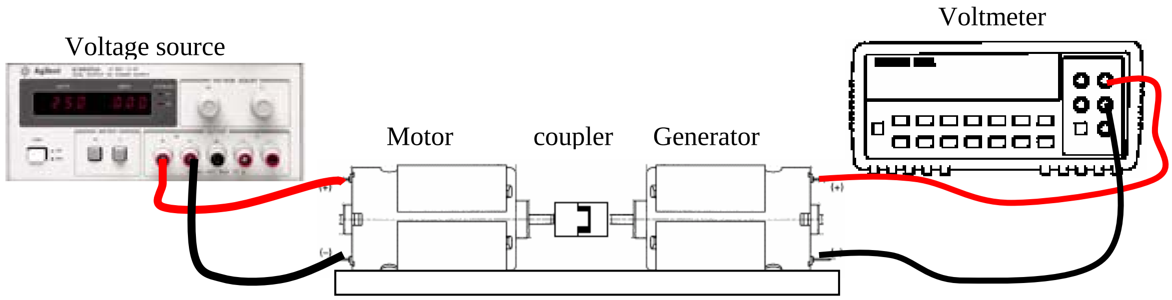

Figure 4

Power Inverter

Verify the performance of a power inverter circuit from the conversion of a DC signal to an AC signal. Figure 5.a shows the basic inverter circuit used in the laboratory. The oscillations are generated from a multi-vibrator of two transistors.

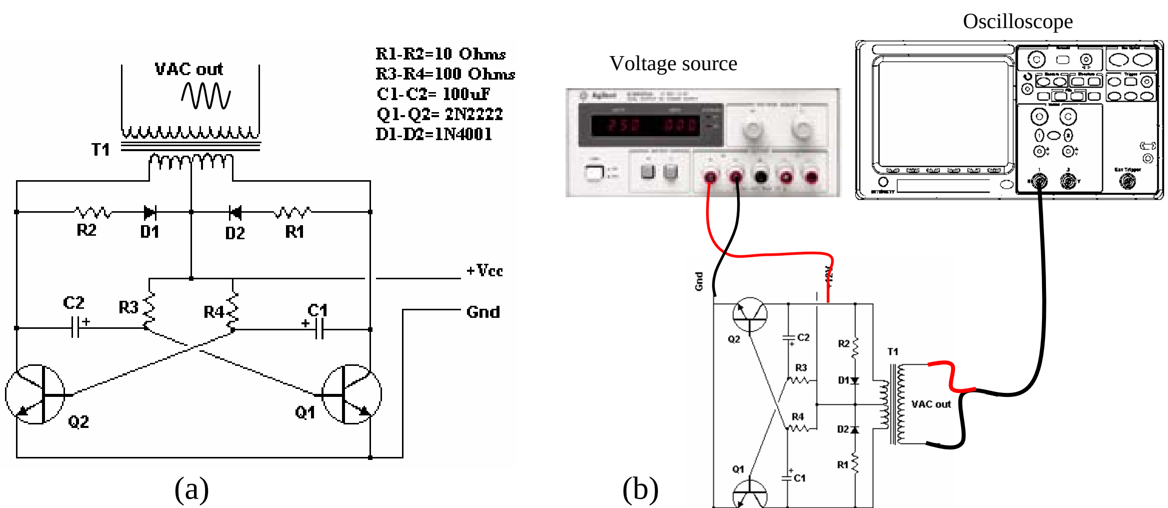

Figure 5

- Adjust the voltage source to Vcc=3 Volts.
- Connect the power inverter to the voltage source and the oscilloscope as shown in Figure 5.b.
- Measure with the oscilloscope the amplitude and frequency of the signal obtained through the terminals of the transistor. Write down the results in Table 5. Repeat the same operation for each input voltage stated in table 5.

Voltage Vcc	Output Voltage	frequency
2 V		
3 V		
4 V		
5 V		

Table 5

- Explain the behavior of the output voltage and frequency with respect to (as a function of) the input voltage.

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Motor-Generator system and power inverter

We will integrate the motor-generator system with the power inverter. This configuration will let us understand the electric energy generation and distribution process.

- Complete the structure of Fig 6. Adjust the voltage source to 0 V.
- Measure the output voltage in transformers T1 and T2 (labeled *a* and *b* in Fig 6). Write down the results in Table 6. Repeat the same operation for each input voltage stated in table 5.
- From the circuit configuration and the obtained results, explain how the motor/generator/inverter system works.

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Voltage Vcc	Output Voltage T1	Output Voltage T2
2 V		
3 V		
4 V		
5 V		

Table 6

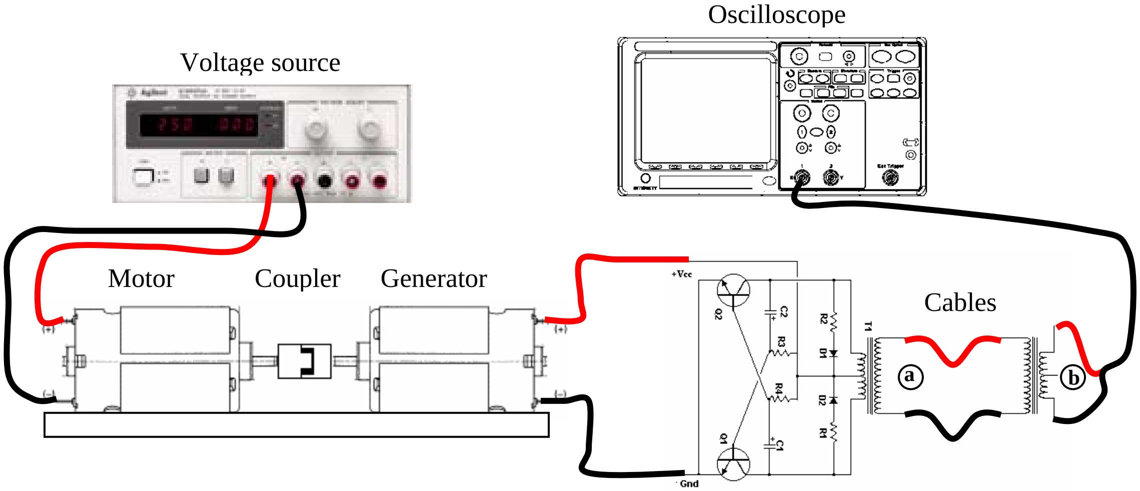

Figure 6

Can you see with your naked eye an AC signal?

Now we will see if your eyes are fast enough to notice the effect of an AC signal using an incandescent bulb.

- Modify the generator to output a sinusoidal signal of 10 Vpp and 4 Hz.
- Connect the generator directly to the luminous lamp as shown in Fig 7.a. Verify that the lamp flicks or switches between on and off. Explain this performance. Why does the lamp act this way?

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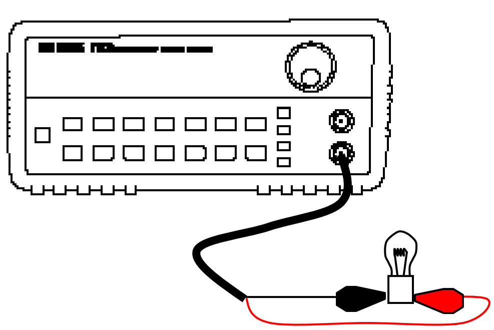
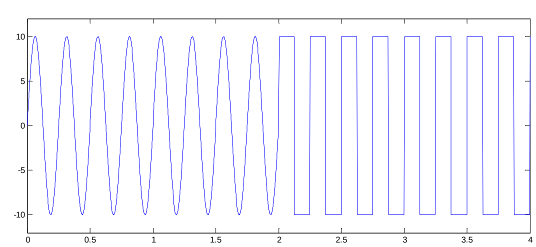
- Increase the signal's frequency until the lamp emits a continuous beam (the bulb should shine steadily). Register the frequency value where the light stops flickering fc=______Hz



(a)



(b)

Figure 7

- ¿Explain why your eyes can not see the effect of the alternate current when the generator frequency is above fc.

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Using the signal generator we will create an alternate signal formed of two shapes of equal amplitude and frequency. Part of the signal will be sinusoidal while the other part will be rectangular as shown in Fig 7. The purpose is to observe if this two-shape signal of equal amplitude and frequency can produce the same flashing effect on the lamp. What is your prediction?

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- Modify the generator to output a sinusoidal signal of 10 Vpp and 4 Hz.
- Connect the generator directly to the luminous lamp as shown in Fig 7a. Use the oscilloscope to visualize the signal which feeds the lamp.
- To obtain the signal shown in Fig 7b. you must alternate every two seconds the shape of the signal generated. This is done by first choosing a squared signal, then every two seconds press the shape button to change it to a sinusoidal signal. Continue the same pattern for various seconds.

- How does the light of the lamp act with each signal?______________________

  ____

  ____

  ____

  Explain this phenomenon ______________________________

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  ____

  ¿If we change the frequency can we make both signals produce the same effect in the lamp?______________________________________

  ____

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