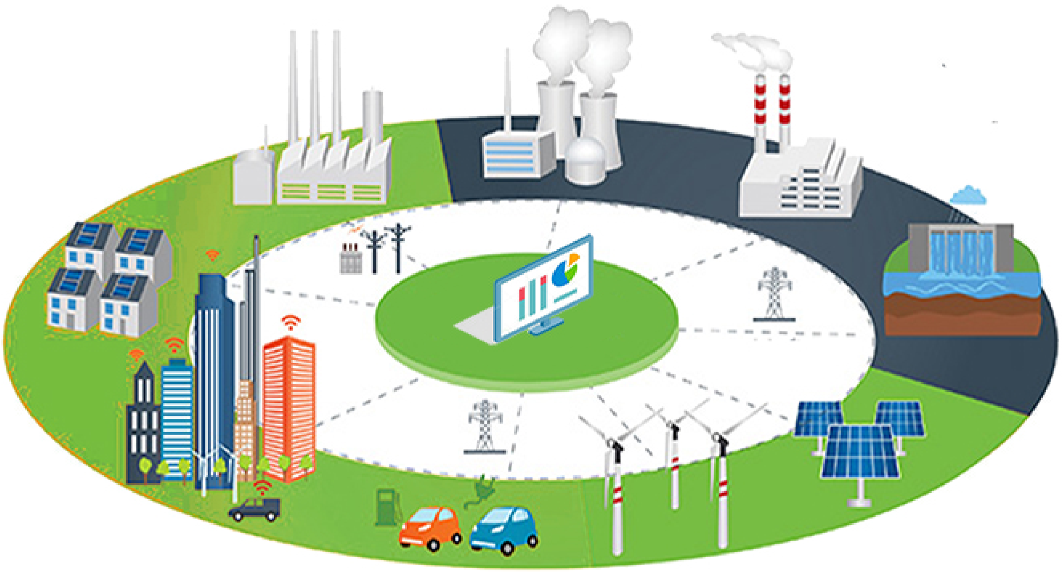
CHRIST
(DEEMED TO BE UNIVERSITY)
BANGALORE · INDIA

BASIC ELECTRICAL ENGINEERING (EE133P/EE233P)



LABORATORY MANUAL

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CHRIST
(DEEMED TO BE UNIVERSITY)
BANGALORE · INDIA

Faculty of Engineering

Department of Electrical and Electronics Engineering

Basic Electrical Engineering Laboratory Manual

(Subject Code: EE133P/233P)

Student Name	
Register Number	
Class/Batch Number	

Vision of CHRIST (Deemed to be University)

Excellence and Service

Mission of CHRIST (Deemed to be University)

CHRIST (Deemed to be University) is a nurturing ground for an individual's holistic development to make effective contribution to the society in a dynamic environment

Department Vision

Facilitating the development of competent professionals in Electrical and Electronics Engineering capable of keeping pace with changing technologies and provide service to the society

Department Mission

M1: Imparting strong fundamental and applied knowledge in Electrical and Electronics Engineering.

M2: Developing professionalism through innovative practices and industry engagement.

M3: Enhancing entrepreneurship skills and emerging technologies in energy sector inline with national and global requirements

M4: Providing sustainable solutions to the challenges faced by rural society.

Program Educational Objectives (PEOs)

PEO1: Graduates will achieve an in depth knowledge which enable them to become leading professionals in the field of electrical engineering.

PEO2: Graduates will acquire skills to develop innovative product and services.

PEO3: Graduates will integrate sustainable technologies to address societal needs through the holistic academic environment.

PEO4: Graduates will acquire communication and managerial skills to adapt to diverse working environments.

Program Specific Outcomes (PSOs)

PSO1: Understand and analyze the generation, transmission, distribution and protection of modern power systems.

PSO2: Design, implement and test power electronics circuits and modern drive systems.

PSO3: Design, develop and analyze control systems in automation using emerging computing frameworks.

PSO4: Design, develop and implement electronics systems for electrical applications through inter disciplinary projects.

Course Objectives

This course is aimed to solve and analyze DC and AC networks. It also covers the fundamental principles of alternator, transformer, motors, renewable energy systems and power converters. It also emphasize the concepts in smart grid and electrical vehicles to cope up with current trends in electrical engineering.

Course Outcomes

CO1: To solve magnetic circuits and DC circuits having independent sources using circuit laws.

CO2: To solve single and three phase AC circuits for steady state operations.

CO3: To illustrate construction features, working principles and power equations of alternator, transformer, DC motors, induction motors and BLDC motors

CO4: To explain working of solar PV and wind power systems in standalone and grid tied configurations with associated power converters

CO5: To outline the concepts of smart grid in view of electrical vehicles and energy storage systems

CO6: To experiment with electric circuits, motors and transformers for their performance study

Experiment List

Evaluation Sheet

No.	Experiment	Date	Marks	Initials
1	Verification of Superposition Theorem			
2	Wiring Practice–Multiple and Two Way Switching			
3	Phase Angle Measurement in R, RL and RLC Circuits			
4	Study of Energy Conservation through Energy Measurement in Single Phase Circuits – with R and RL Loads			
5	Power Factor Improvement			
6	Regulation and Efficiency of Single Phase Transformer			
7	Speed–Torque Characteristics of a DC Shunt Motor			
8	Speed–Torque Characteristics of Single Phase Induction Motor			
9	Characteristics of Solar PV Modules			
10	Electrical Appliances Control using Arduino			
11	Variable DC Voltage using DC-DC Converter (Demonstration)			
12	Power Circuit Control using Relay and Contactor. (Demonstration)			
	Average			

Experiment 1
Verification of Superposition Theorem

Aim: To verify Superposition theorem theoretically and practically in simple DC networks

Experiments:

1. In the given electrical circuit (Figure.1) verify superposition theorem both theoretically and practically.
2. Make a simple electric circuit with the given 5 resistors and the two regulated power supplies to verify superposition theorem for voltage and current in any one branch of the circuit. (Precautions: Do not short circuit the power supply, Do not supply more than the rated values of voltage and current of the elements)

Apparatus/Components/Tools/Software Required:

1. Regulated Power Supply 0-30V, DC -2 Nos.
2. Resistors – 1KΩ, 1.5KΩ - 3 Nos each
3. Multimeter – 1 No
4. Breadboard – 1 No
5. Digital Ammeters – 3 Nos
6. Connecting wires

Theory The superposition theorem for electrical circuits states that voltage or current in any branch of a bilateral linear circuit having more than one independent source equals to the algebraic sum of the responses caused by each independent source acting alone, where all the other independent sources are replaced by their internal impedances. A circuit whose parameters are not changed with respect to Current and Voltage is called Linear Circuit and a circuit whose characteristics are same irrespective of the direction of current through various elements of it, is called bilateral network. The internal resistance of an ideal voltage source is zero and of an ideal current source is infinite. Superposition theorem is useful in solving both DC and AC networks with more than one source. In AC circuits, RMS values of voltage and current are to be measured and the elements should be replaced with impedances.

Circuit diagram

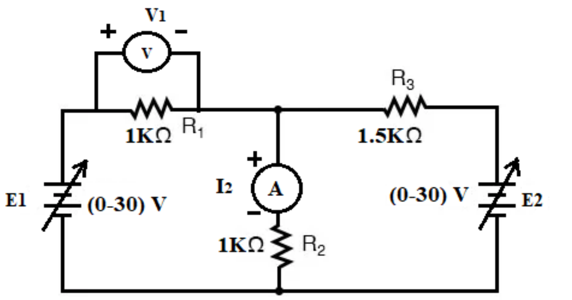


FIGURE 1: Circuit to verify superposition theorem

TABLE 1: When both sources are acting together as in Fig. 1

No.	$E_1(V)$	$E_2(V)$	$V_1(V)$	$I_2(A)$
1	5	20		
2	10	15		
3	15	10		

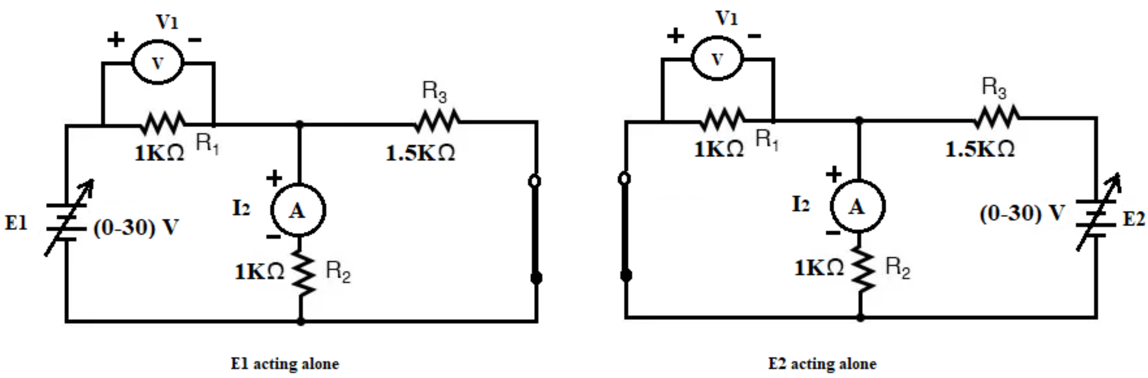


FIGURE 2: Circuits with only one source acting at a time

TABLE 2: When both sources are acting together as in Fig. 1

No.	$E_1(V)$	$E_2(V)$	$V_1(V)$	$I_2(A)$
1	5	0		
2	10	0		
3	15	0		
4	0	20		
5	0	15		
6	0	10		

Procedure for Part 1:

1. Connect the components in a breadboard as shown in fig. 1. Connect voltmeters across the sources to measure the voltage.
2. Switch on the regulated power supplies and apply different combinations of voltage and measure V1 and I2 (Caution: Do not short circuit the power supply directly)
3. Now disconnect the source E2 from circuit and short circuit the circuit as shown in Figure 1. Apply the same voltages in E_1 as applied in step 2. Measure V_1 and I_2.
4. Now disconnect the source E1 from circuit and short circuit the terminals as shown in Figure 2. Apply the same voltages in E_2 as applied in step 2. Measure V_1 and I_2.
5. Verify the measured voltage and current values using superposition theorem.

Procedure for Part 2:

1. Design a DC circuit using 5 resistors and two regulated power supplies and get approval from the faculty.
2. Set up the circuit to measure at least one voltage and one branch current in the circuit.
3. Measure the desired voltage and current using only one source at a time.
4. Verify superposition theorem by the measured values.

Result

.

Calculations

.

Applications

.

Sample Questions

1. What is superposition theorem?
2. Where superposition theorem can be seen in practical system?

Evaluation Table

Parameter	**Score**
Remarks	
Total	
Faculty Initials	

Experiment 2
Wiring Practice–Multiple and Two Way Switching

Aim: Switching operation using independent and two way switches.

Experiments:

1. To make electrical connections for the control of three incandescent lamps (L1, L2 & L3) using one-way switches from one switch-board.

2. To control single filament lamp using two-way switches located in different locations with two-wire control approach and three-wire control approach.

Apparatus/Components/Tools/Software Required:

1. Electric Wiring Practice Kit -1 Nos.
2. Single-way switches - 3 Nos
3. Two-way switches - 2 Nos
4. Incandescent lamps - 3 Nos
5. Electrical Tool Kit
6. Connecting wires

Theory for Experiment 1: Electrical switches are very simple devices that are used to turn things on and off. The most common type of switches is the one that we use to turn our lights on and off. Very little has changed in how switches work since when they were invented. Although there are many types of switches, we are more accustomed to one-way and two-way electrical switches. The main difference between them is the number of contacts that they have. A one-way switch only has two contacts while a two-way switch has three. A one-way switch basically operates as a make or break switch. When it is turned on, the two terminals are connected, and when it is turned off, the contact between the two is broken. In contrast, a two-way switch is basically two, one-way switches combined into one. One of the terminals can be connected to either of the remaining two but not both at the same time. When you want to make a connection with one terminal, the connection with the other is broken. One advantage of two-way switches is allowing the control of a single device like a light from two locations; typically used in long hallways so you do not have to walk all the way to the other end in total darkness. This is achieved by wiring the two terminals of the two switches together so that a path is established when the switches are in the same orientation and none when they are not. When used in this manner there is no defined position for the off or on states.

Circuit diagrams:

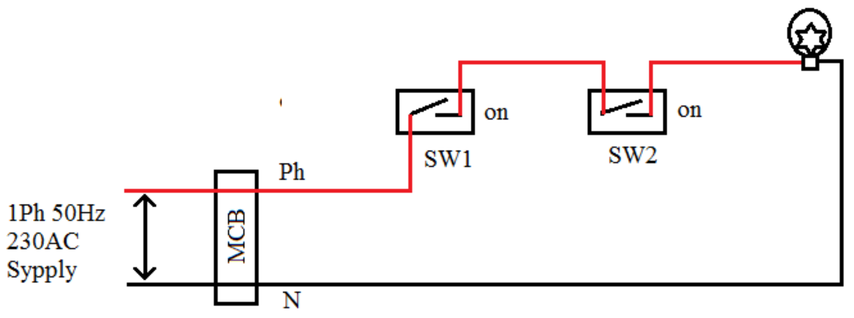


FIGURE 3: Series Connection of Two Switches for One Bulb control

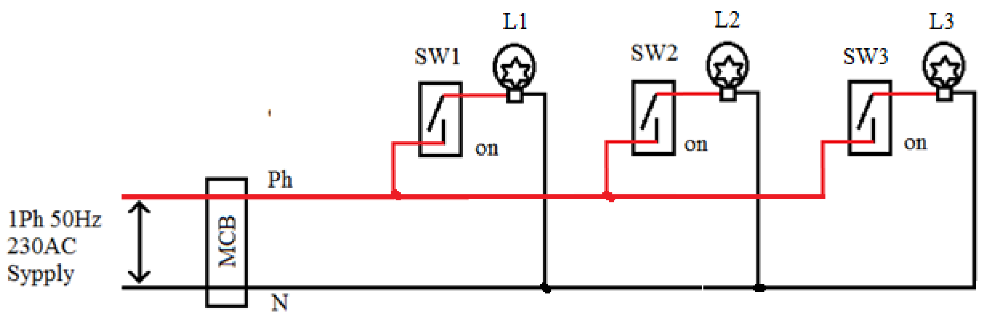


FIGURE 4: Parallel connection of switches for 1 switch :1 bulb control

Basically, just flipping either switch would turn the light on or off. A one-way switch has definite on and off positions and cannot be used to obtain the same effect. Different types of switches can be used to achieve different effects. Still, the one-way switch is the most commonly used switch in homes and in many applications where you want to control the flow of electricity.

Procedure for Experiment 1:

1. Check MCB for OFF position at initial stage.
2. Connect the circuit as per given diagram.
3. Verify the connections for error-free and switch on MCB.
4. Check for ON and OFF control of each lamp.
5. If anyone is not working properly, repeat step 1 to 4 to troubleshoot the problem.

Result

.

Circuit diagrams:

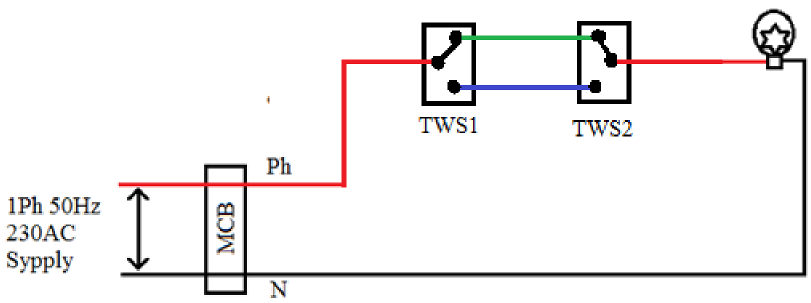


FIGURE 5: Two way light switching schematic using two wire control

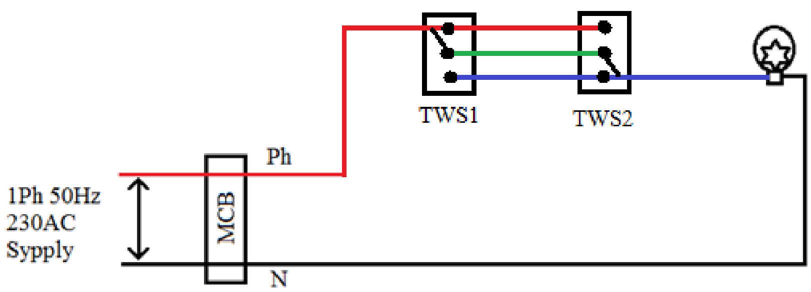


FIGURE 6: Two way light switching schematic using three wire control

TABLE 3: Logic Table: Two wire control

Switch 1	**Switch 2**	**Lamp**
0	0	1
0	1	0
1	0	0
1	1	1

TABLE 4: Logic Table: Three wire control

Switch 1	**Switch 2**	**Lamp**
0	0	1
0	1	0
1	0	0
1	1	1

Theory for Experiment 2: In this experiment, we will show you how to make 2-way switching connection. A 2-way switching connection means you can control an electrical equipment like bulb by two switches placed at different places, generally used in the staircase. Two 2-way switches can be operated from any of the switch independently, means whatever the position of other switch be (ON/OFF), you can control the light with other switch. There are two methods of making 2-way switching connection one is 2-wire control and another is 3-wire control.

1. Connection of 2-way Switch Wiring using Two wire control
   This is the first method to make a 2-way switching connection, this is the old method. If you are going to install a new one then go for three wire control method. As you see in the Schematic Diagram of 2 way switch circuit diagram given in Fig 1, you will find that the phase/live is connected with the common of the first 2-way switch. PIN1 & PIN2 of the first switch is connected with the PIN1 & PIN2 of second switch respectively. One end of the bulb is connected with the common terminal of second switch and other end of the bulb is connected with neutral line of AC power supply.

   Note: In 2-wire control method when switches are in opposite state the light will be in OFF state as shown in Figure 5:

2. Connection of 2-way Switch Wiring using Three wire control
   This is the new method to make a 2-way switching connection as it is slightly different from the two wire control method. This method is commonly used now days as it is efficient than the Two-wire control system. As you can see in the schematic diagram of 2 way switch circuit given in Figure. 6, the common of both the switches are short-circuited. PIN1 of both the switches are connected with the phase or live wire and PIN2 of both the switches are connected with the one end of the lamp. The other end of the lamp is connected with neutral line of AC power supply.

   Note: In 3-wire control method when switches are in same state the light will be in OFF state as shown in Figure 6.

Procedure for Experiment 2:

1. Check MCB for OFF position at initial stage.
2. Connect the circuit as per given diagram. Verify the connections for error-free and switch on MCB.
3. Check for ON and OFF control of each lamp.

Cost Estimation:

.

Applications:

Applications of Two way Switching:

- Mostly in stair case.
- Erroneous tripping of safety/circuit protection equipment.
- A big room having two entry/exit gate.
- To control any AC appliances like fan or light from two places like entry and exit.

.

Result

.

Sample Questions

1. Mention what are the different colors on wires indicates?
2. What is the difference between fuse And circuit breaker?
3. What is a safety switch?

Evaluation Table

Parameter	**Score**
Remarks	
Total	
Faculty Initials	

Circuit diagram

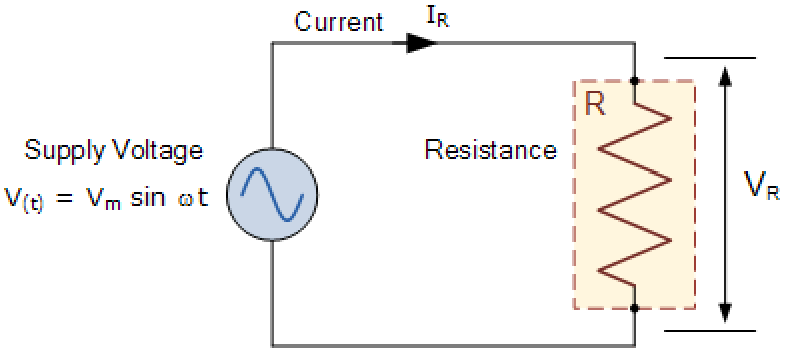


Figure 7: R Circuit

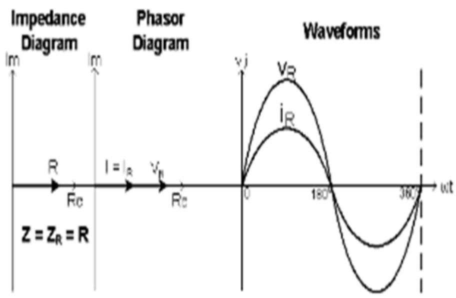


Figure 8: Phasor diagram R Circuit

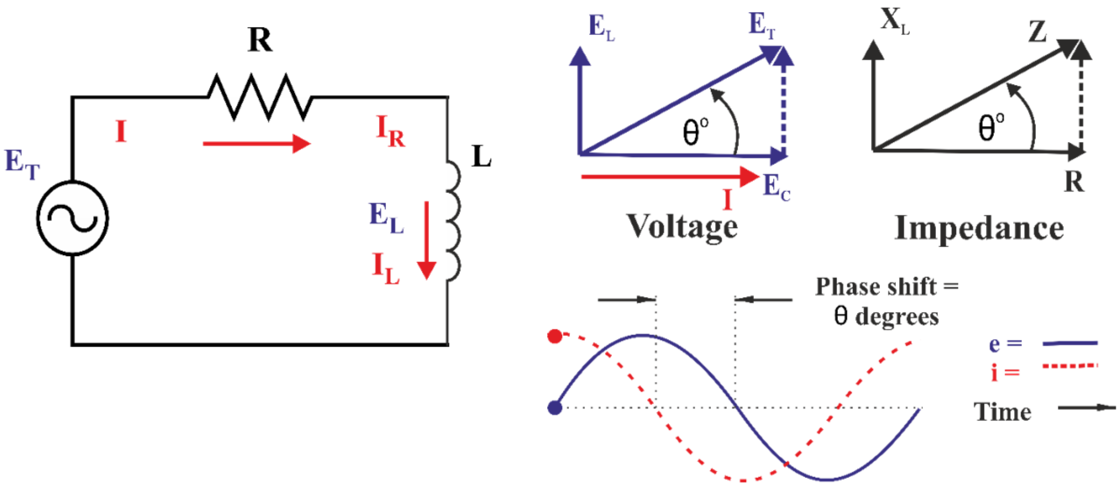


Figure 9: RL Circuit and phasor diagrams

Experiment 3
Phase Angle Measurement in R, RL and RLC Circuits

Aim: To measure the Phase angle of R, RL and RLC Circuit

Apparatus/Components/Tools/Software Required:

1. Functional Generator, Ohmmeter, Ammeter, Voltmeter, Oscilloscope, Breadboard, Connecting Wires,
2. Resistor (1/2 -W): (1) $1k\Omega$, Inductor: (1) $0.68H$ or $0.33H$, Capacitor:(1) 100 μF

Theory on R Circuit A circuit that contains only Resistors is called Resistive Circuit. There is no Phase Shift between the Voltage and the Current in a Resistive Circuit, $\phi = 0^o$ The Current is in-phase with the Voltage.

Theory on RL Circuit A circuit that contains a pure resistance R ohms connected in series with a coil having pure inductance of L (Henry) is known as R L Series Circuit. When an AC supply voltage V is applied the current, I flows in the circuit. IR and IL will be the current flowing in the resistor and inductor respectively, but the amount of current flowing through both the elements will be same as they are connected in series with each other. The circuit diagram of RL Series Circuit is shown in Figure 9.

Equations: RL Circuits

$$\begin{aligned}
&V = \sqrt{V_R^2 + V_L^2} = \sqrt{(IR)^2 + (IX_L)^2} = I\sqrt{R^2 + X_L^2} \\
&I = \tfrac{V}{Z} \\
&Z = \sqrt{R^2 + X_L^2} \\
&\tan\theta = \tfrac{V_L}{V_R} = \tfrac{IX_L}{IR} = \tfrac{X_L}{R} \\
&\Rightarrow \theta = \tan^{-1}\left(\tfrac{X_L}{R}\right)
\end{aligned} \tag{1}$$

Theory on RLC Circuit In the RLC Series Circuit, $X_L = 2\pi f L$ and $X_C = 1/2\pi f C$. When the AC voltage is applied through the RLC Series Circuit the resulting current I flows through the circuit, and thus the voltage across each element will be, $V_R = I_R$ that is the voltage across the resistance R and is in phase with the current I. $V_L = I_X L$ that is the voltage across the inductance L and it leads the current I by an angle of 90 degrees. $V_C = I_X C$ that is the voltage across the capacitor C and it lags the current I by an angle of 90 degrees.

Phasor diagrams

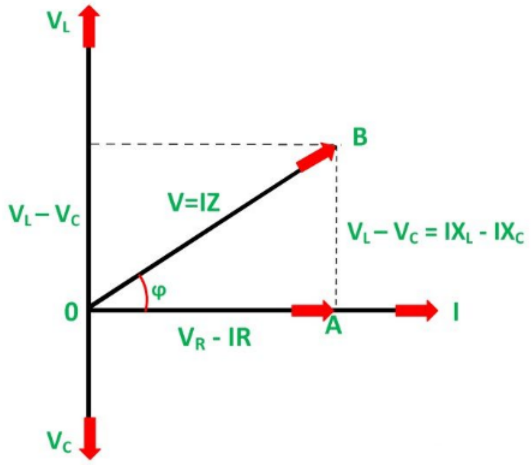


FIGURE 10: RL Circuit

Circuit diagrams

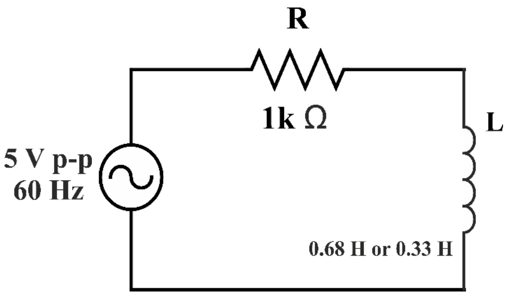


FIGURE 11: RL Circuit

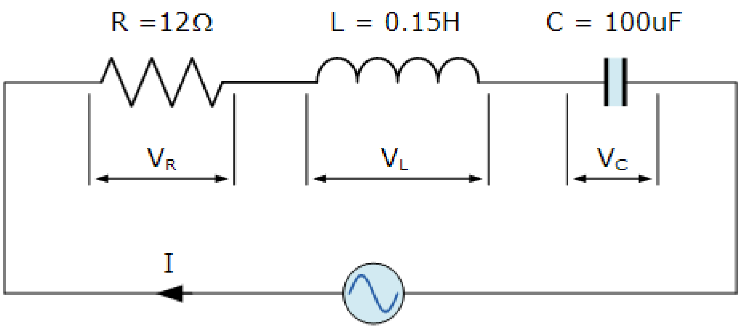


FIGURE 12: RLC Circuit

$$V = \sqrt{(V_R)^2 + (V_L - V_C)^2} = \sqrt{(IR)^2 + (IX_L - IX_C)^2} \quad \text{or}$$

$$V = I\sqrt{R^2 + (X_L - X_C)^2} \quad \text{or}$$

$$I = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{V}{Z}$$

$$\tan\varphi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} \quad \text{or}$$

$$\varphi = \tan^{-1}\frac{X_L - X_C}{R}$$

Equations: RC Circuits Where V is supply voltage, V_R is voltage drop across resistor, V_L is the voltage drop across the inductor and V_C is the voltage drop across the capacitor.

Equations: RLC Circuits

Procedure:

1. Collect all the required components from the lab
2. Connect the circuit in the breadboard as per the Figure 7.
3. Follow the safety precautions
4. Setup the signal generator to 5 volts p-p, at 20 hertz.
5. Using CRO observe the voltages and current waveforms across load.
6. Note down the phase difference between voltage and current waveforms in CRO
7. Remove all the connection.
8. Repeat Step 1 to 7 for the circuit shown in Figure 11 and Figure 12

Calculations

.

Applications

.

Result

.

Evaluation Table

Parameter	**Score**
Remarks	
Total	
Faculty Initials	

Circuit diagrams

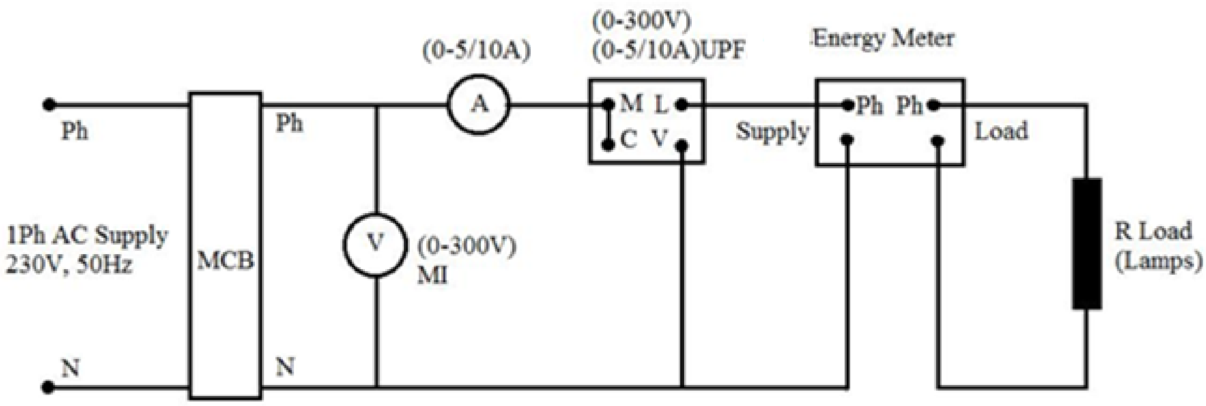


FIGURE 13: R Load Circuit

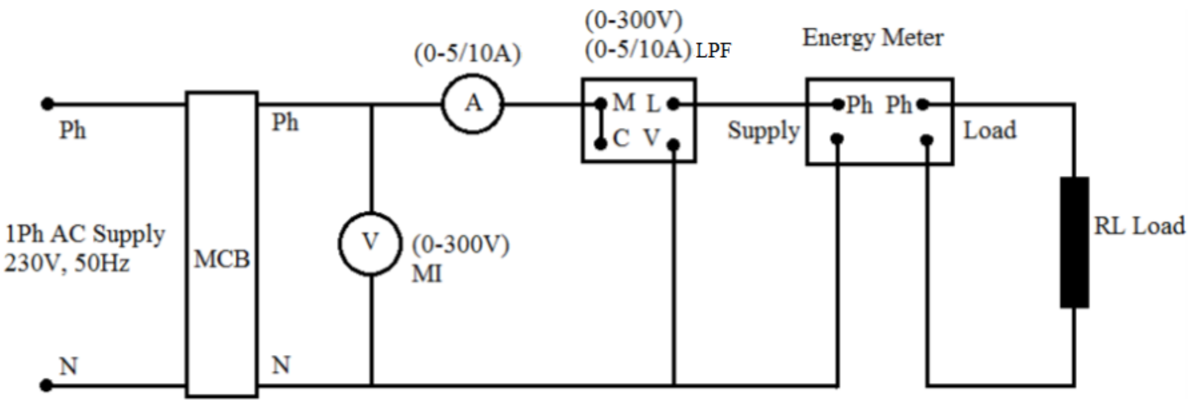


FIGURE 14: R Load Circuit

Experiment 4
Study of Energy Conservation through Energy Measurement in Single Phase Circuits – with R and RL Loads

Aim: To measure the utilized electrical energy in a single phase AC circuit with R and RL load using energy meter.

Apparatus/Components/Tools/Software Required:

Name	**Specifications**	**Quantity**
Wattmeter		
Ammeter		
Voltmeter		
Single Phase Energy Meter		
Stop watch		
Connecting wires		

Theory: Power and energy measurement with R load

Power is rate of spending energy. Watt is the unit for power (joule per second (J/s). The power consumed by the resistive elements in the circuit or the portion of power flow that averaged over a complete cycle of the AC wave form which results in net transfer of energy in one direction is known as real power. It is also called as Active power. It is the power that is actually being consumed by the load. It is given by,

$$P = VI\cos\phi \tag{2}$$

Where, V= voltage in volts, I= current in Amps, ϕ = the phase angle between the voltage and current. Similarly, the electrical energy used by the circuit can be calculated by,

$$E = P \times t \tag{3}$$

Where, E = energy in watt sec, P = power in watts, t = time taken in sec. An Energy meter is used to measure the electrical energy directly and each energy meter has an energy meter constant which says how many revolutions of the disc (or impulses in case of electronic meters) needed to record one kilo-Watt-hour (kWh) of energy. So the energy indicated by each revolution (or impulse) is a constant for a meter.

Table 5: Observations

Load	**V** (V)	**I**(A)	**Power** (W)	$\cos\phi$	**t** (s)	**No. of Rev**	**Measured Energy** (Ws)	**Indicated Energy** (Ws)	**Error**
R load									
R load									
RL load									
RL load									
Desktop/CRO in usage									
Desktop/CRO in standby mode									

When an inductive load is using in a circuit as load, the power factor will be less than one and it will take more current than a resistive load to deliver the same power. The power in the circuit to be measured by using a low power factor wattmeter and the energy meter and calculations remains same as that of the resistive load.

Power and energy measurement with RL load: An inductive load will have some resistance and inductance and which will draw a lagging current from the supply. The power factor of the load depends on the value of resistance and inductance of the load. The phase angle ϕ between the voltage and current can be calculated by the equation $\cos\phi = \frac{P}{V \times I}$ With the presence of the inductance, the circuit will absorb some energy and store it as a magnetic field in one half cycle and it will be flowing back to the source in the next half cycle. This power which is not converted to work in the circuit is known as reactive power. When an inductive load is using in a circuit as load, the power factor will be less than one and it will take more current than a resistive load to deliver the same power. The power in the circuit to be measured by using a low power factor wattmeter and the energy meter and calculations remains same as that of the resistive load.

Procedure: *Energy measurement with R/ R-L load during the regular usage:*

1. Check MCB for OFF position at initial stage.
2. Connect the circuit as per given diagram.
3. Verify the connections and switch on MCB.
4. Connect the load and measure all meter readings.
5. Measure the time taken with a stop watch for five revolutions of disc (or count the time for five impulses) in energy meter.
6. Tabulate the readings.

Procedure: *Energy measurement when the equipment is in standby mode (Power socket is connected with supply in "on" condition):*

1. Check MCB for OFF position at initial stage.
2. Connect the circuit as per given diagram.
3. Verify the connections and switch on MCB.
4. Switch on the load. But do not use the load (switch on the supply to desktop. But keep it in standby mode) and measure all the readings.
5. Measure the time taken with a stop watch for five revolutions of disc (or count the time for five impulses) in energy meter.
6. Tabulate the readings.
7. Repeat the same with the given load at normal working condition and tabulate the readings.

Calculations

For each Load condition,

Power Factor $\cos\phi = P/VI = \ldots\ldots\ldots\ldots\ldots\ldots$

Actual Energy $E_2 = P\times$time for one revolution $=. \ldots\ldots\ldots$ Ws

Indicated Energy = (1/k)*1000*60*60=........ Ws

Where, k= the number of revolution/kWhr (or) the energy meter constant

Percentage Error = (E1-E2)/E1*100 =...............%

.

Applications

.

Inference: The energy lost during the standby mode is .... So, ...
....
is the easy method of energy conservation in domestic applications.

Result

.

Sample Questions

1. What is the purpose of energy meter?
2. What do you mean by the one unit of energy meter?
3. What are the types of energy meter in market?
4. How do you differentiate the energy meter as LPF/UPF?
5. When will you choose LPF meter for energy measurement?
6. When will you choose the UPF for energy measurement?
7. Will the equipment consume zero power during its standby mode?
8. What is the easy method you will implement for reduced energy consumption in your home?
9. What is energy meter constant? How you will identify this value for a given energy meter?
10. How does the energy meter constant use in calculating the energy consumption?

Evaluation Table

Parameter	**Score**
Remarks	
Total	
Faculty Initials	

Circuit diagrams

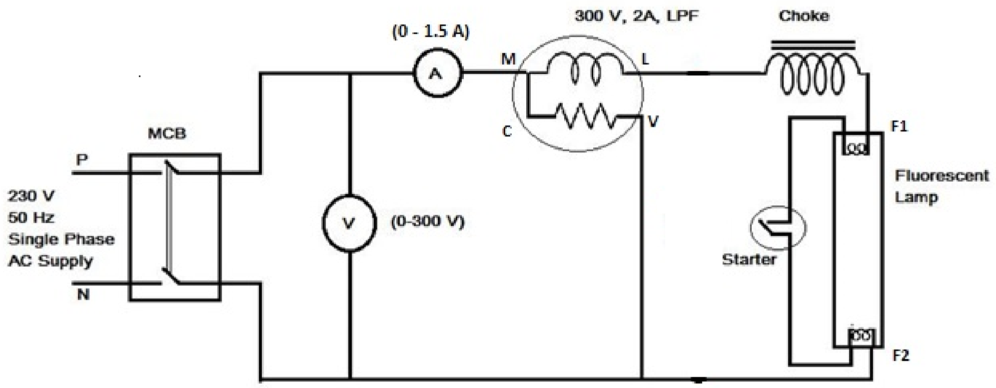


FIGURE 15: Circuit diagram without capacitor

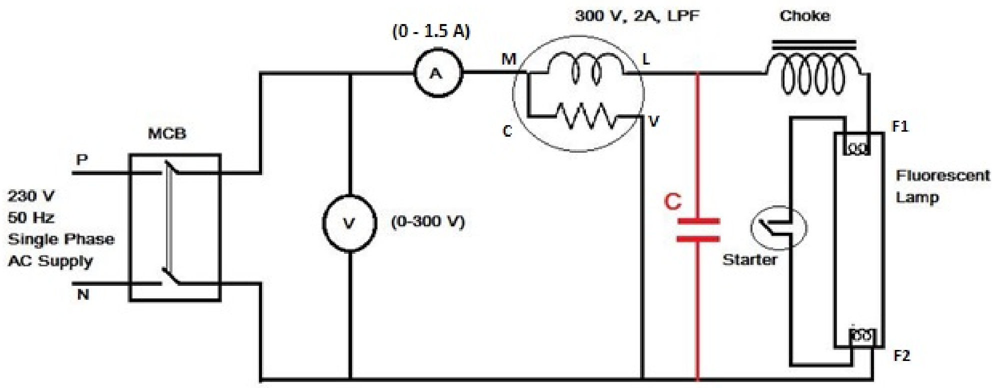


FIGURE 16: Circuit diagram with capacitor

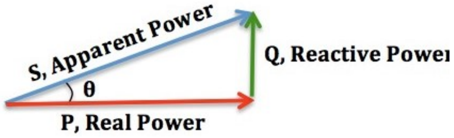
Experiment 5
Power Factor Improvement

Aim: To measure the power factor in a single phase AC circuit and improve the power factor by connecting a capacitor across the load.

Apparatus/Components/Tools/Software Required:

Name	Specifications	Quantity
Wattmeter	300 V, 2 A, LPF	1 No.
Ammeter	(0-2) A, AC	1 No.
Voltmeter	(0-300)V, AC	1 No.
Fluorescent Lamp	40 W, 250 V	1 No.
Choke Coil	250 V	1 No.
Starters		1 No.
Capacitor		1 No.

Theory: The cosine of angle between voltage and current in an A.C circuit is known as power factor. In an A.C circuit, there is generally a phase difference ϕ between voltage and current. The term $\cos\phi$ is called the power factor of the circuit. In any inductive or capacitive circuit, the power taken from the AC source is not completely converted into the useful work, but stored in either magnetic field and electrostatic field in one half cycle of the supply and the same will be flow back to the source in the next half cycle. So the power factor, which defined as the ratio of real power to apparent power will be always less than one. In highly inductive or highly capacitive circuits, the power factor will be low which make the circuit to draw more current from the source to deliver the same power compared to that in a resistive circuit. So low power factor circuit will be less efficient due to higher I^2R losses and will have higher initial cost as it need thick conductors to take current from the source.



The power factor of a low power factor circuit can be improved by compensating the reactive power. In inductive circuits the power factor can be improved by connecting capacitors across the load and hence compensating the reactive component of current.

Table 6: Observation Table

	V(V)	**I**(A)	**Power**(W)	$\cos\phi = \frac{P}{V \times I}$
Without capacitor				
With capacitor				

Consider an inductive load taking a lagging current I at a power factor $\cos\phi_1$. In order to improve the power factor of this circuit, the remedy is to connect such equipment in parallel with the load which takes a leading reactive component and partly cancels the lagging reactive component of the load. Let a capacitor, connected across the load. The capacitor takes a current I_C which leads the supply voltage V by 90 deg. The current I_C partly cancels the lagging reactive component of the load current. The resultant circuit current becomes I' and its angle of lag is ϕ_2. It is clear that ϕ_2 is less than ϕ_1 so that new p.f. $\cos\phi_2$ is more than the previous p.f. cos ϕ_1. One of the parameter in Electric power supply system like, current, voltage etc. A Power factor less than unity in a system results in large KVA rating of equipment, greater conductor size, large copper losses, poor voltage regulation etc.

Procedure:

1. Make sure that the power is switched OFF before starting the connections
2. Connect the circuit without capacitor as per the diagram
3. Switch ON the circuit and take the readings of all the meters
4. Switch OFF the supply
5. Connect the capacitor across the load as per the diagram
6. Switch ON the supply and take the readings of all meters
7. Switch OFF the supply
8. Tabulate the readings and calculate the power factor with and without the capacitor.

Result

.

Calculations

.

Applications

One of the parameter in electric power supply system like, current, voltage etc. A power factor less than unity in a system results in large kVA rating of equipment, greater conductor size, large copper losses, poor voltage regulation etc. .

Sample Questions

1. Why is there phase difference between voltage and current in an a.c. circuit?
2. Explain the concept of power factor.
3. Discuss the disadvantages of a low power factor.
4. Explain the causes of low power factor of the supply system.
5. Discuss the various methods for power factor improvement.
6. Derive an expression for the most economical value of power factor which may be attained by a consumer
7. What is the importance of power factor in the supply system?
8. Why is the power factor not more than unity?
9. What is the effect of low power factor on the generating stations?
10. Why is unity power factor not the most economical p.f.?
11. Why a consumer having low power factor is charged at higher rates?

Evaluation Table

Parameter	**Score**
Remarks	
Total	
Faculty Initials	

Circuit diagrams

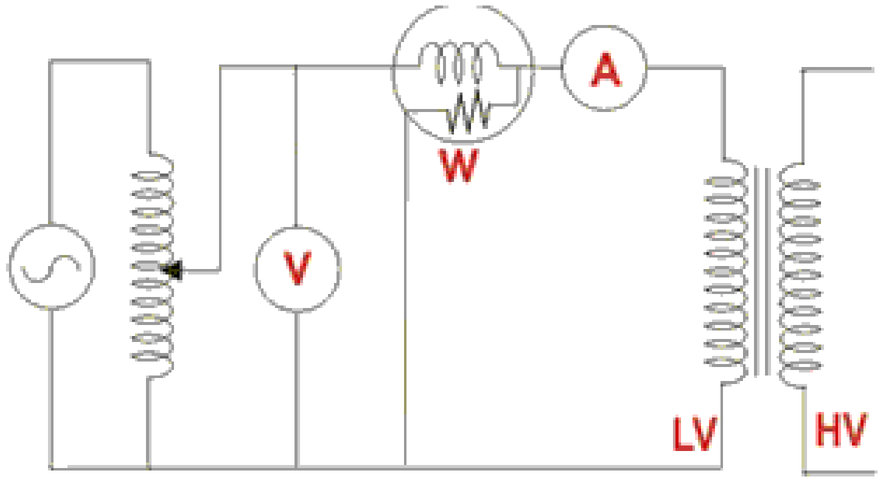


FIGURE 17: Circuit diagram for OC Test

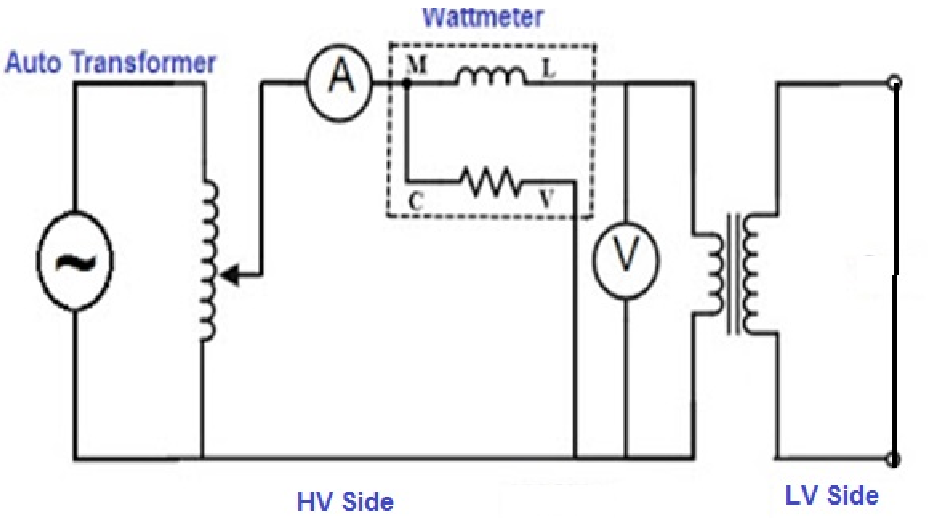


FIGURE 18: Circuit diagram for SC test

Note: Mention the range of all the electrical components in the circuit diagram.

Experiment 6
Regulation and Efficiency of Single Phase Transformer

Aim: To determine Regulation and Efficiency of a single phase transformer by open circuit (O.C.) and short circuit (S.C.) tests

Apparatus/Components/Tools/Software Required:

Name	**Specifications**	**Quantity**
Transformer		
Voltmeter		
Ammeter		
Auto transformer Lamp		

Theory: Transformers are arguably the most universally applied pieces of electrical equipment. As such, they range in size from miniature units weighing ounces to huge units weighing tons. All transformers, however, exhibit the same basic properties. When mutual induction is permitted between two coils or windings, a change in current flowing through one coil induces a voltage upon the other coil. All transformers have a primary winding and one or more secondary windings.

The electromagnetic coupling between the primary and secondary windings allows electrical energy to be transferred from the primary winding to the secondary winding. Electrical current entering the primary winding appears as an electromotive force (emf) at the secondary. Connecting the secondary winding to a load allows the energy to be transferred to the load. Since there is no electrical connection between primary and secondary windings (only a magnetic connection), the source and load can be electrically isolated from each other by means of a transformer. When a transformer is energized and loaded, AC current flowing in its windings creates an alternating magnetic field in its iron core.

A small portion of the current, called the magnetizing current, is dedicated to the magnetic circuit in the creation of the magnetic field. Losses associated with the magnetizing current are reactivepower (VARs). In addition, there are real power losses (Watts) in the transformer, associated with the inherent resistance in the 2 windings (copper losses) and with eddy currents and hysteresis in the core (iron losses). For these reasons, the total power delivered to the primary side of the transformer is always larger than the total power available at the secondary side.

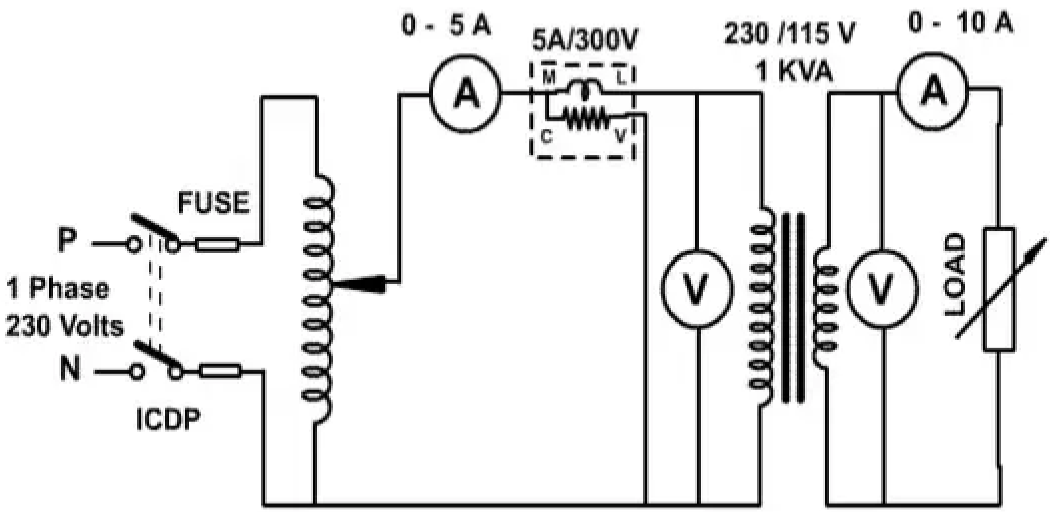


FIGURE 19: Circuit diagram for load test

Tabular Column

Short Circuit Test Readings		
V_{oc} (Volt)	I_{sc} (Amp)	W_{sc} (Watt)

FIGURE 20: Open circuit readings

Open Circuit Test Readings					
V_{oc} (Volt)	I_{oc} (Amp)	W_{oc} (Watt)	I_C	I_M	$\cos\theta$

FIGURE 21: Short circuit readings

Even so, it is still reasonable to say that energy is conserved in the transformer and that the real, reactive and apparent power applied to the primary of almost any transformer equals the real, reactive and apparent power available at the secondary. When the voltage applied to the primary winding is raised above rated value, the iron core begins to saturate, which leads to a rapid increase in the magnitude of the magnetizing current. Saturation of the core also distorts the sinusoidal voltage and current waveforms. The resulting harmonics can lead to mechanical resonances which, in large transformers, can be damaging. Transformers are also very susceptible to damage from short circuit currents.

Open Circuit Test:

The main aim of this test is to determine the Iron losses & No-load current of the T/F which are helpful in finding R_o & X_o. In this test generally supply will be given to primary and secondary kept open. Since secondary is opened a small current (magnetizing current will flow and it will be 5 to 10% of full load current. The wattmeter connected in primary will give directly the Iron losses (core losses).

Short Circuit Test:

The main aim of this test is to determine the full load copper losses which is helpful in finding the magnitude of the total effective winding resistance, leakage reactance, efficiency and regulation of the Transformer. Generally low voltage side will be short circuited and supply will be given to high voltage side & it will be of 5-10% of the rated voltage. The wattmeter connected in primary will give directly the full load copper losses of the Transformer

Load Test:

The load on a large power transformer in a sub-station will vary from a very small value in the early hours of the morning to a very high value during the heavy peaks of maximum industrial and commercial activity. The transformer secondary voltage will vary somewhat with the load, and because motors, incandescent lamps, and heating devices are all quite sensitive to voltage changes, transformer regulation is of considerable importance. The secondary voltage also depends upon whether the power factor of the load is leading, lagging, or unity. Therefore, it should be known how the transformer will behave (its voltage regulation) when connected to a capacitive, an inductive, or a resistive.

Loading Factor %	**W_{prim} (Watts)**	**V_{prim} (volts)**	**I_{prim} (Amp)**	**I_{sec} (Amp)**	Output Power	Efficiency	Regulation

FIGURE 22: Load test readings

Calculations

.

Procedure: Turn Ratio

1. Examine the construction of the Transformer Module,its terminals and Input/output voltages.
2. List the rated voltage between each of the identified connection terminals, and list the rated current for connections.
3. Find the turn ratio between the windings.

Open Circuit Test

1. Connect the circuit diagram as shown in the Figure.
2. Gradually increase the voltage using the auto-transformer till the voltmeter reads 220V.
3. Record the voltmeter, ammeter and wattmeter readings. The ammeter indicates the no-load current and wattmeter indicates the iron losses.
4. Switch off the supply and set the auto-transformer at zero position.
5. Find the values of the equivalent core loss resistance R_c and magnetizing reactance X_m.
6. Calculate $\cos\theta$, the angle θ, I_c and I_m, from the test results recorded. Then construct the phasor diagram.
7. Plot the no-load current I_{oc}, magnetizing current IM and core loss W_0 and no-load power factor $\cos\theta$, against the applied voltage V_{oc} on the same graph paper.

Short Circuit Test

1. Connect the circuit diagram as shown in the Circuit
2. Gradually increase the voltage using the auto-transformer till the ammeter reads the rated current of the transformer on HV side.
3. Record the voltmeter, ammeter and wattmeter readings.The ammeter indicates I_{sc}, voltmeter indicates V_{sc} and wattmeter indicates W_{sc} copper losses of the transformerat full load condition.
4. Switch off the supply and set the auto-transformer at zero position. Compute the equivalent circuit parameter R_s and X_s at the rated high voltage winding current.
5. Draw the equivalent circuit of the transformer in the form having all impedances on the primary side of the ideal transformer.
6. Mark in the values calculated in this practical and include all the calculated parameters.

Applications

.

Result

.

Evaluation Table

Parameter	**Score**
Remarks	
Total	
Faculty Initials	

Circuit diagrams

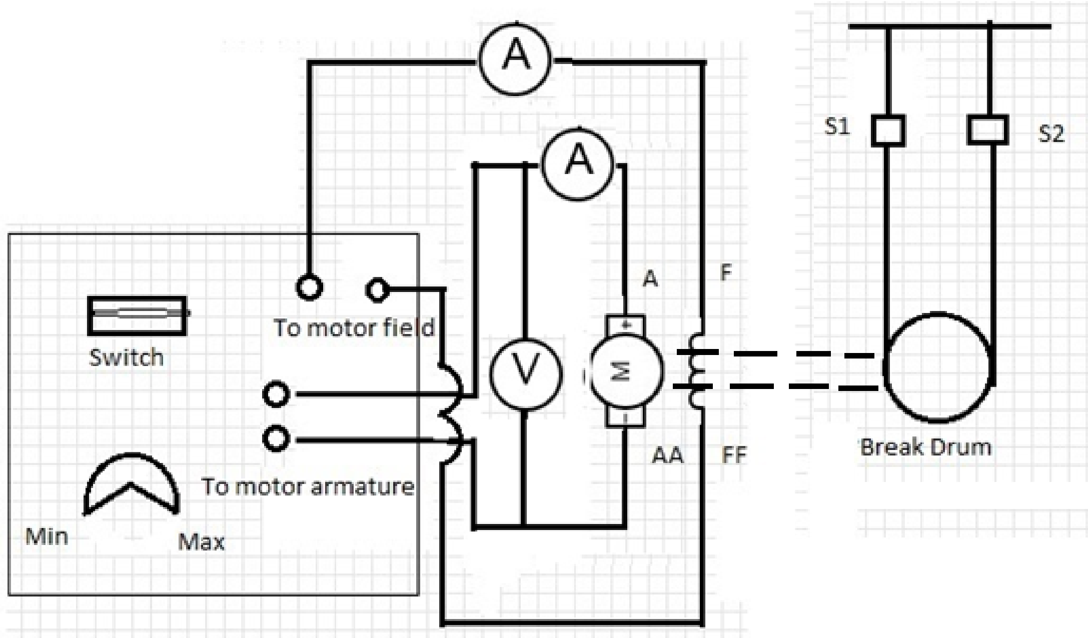


FIGURE 23: Connection diagram

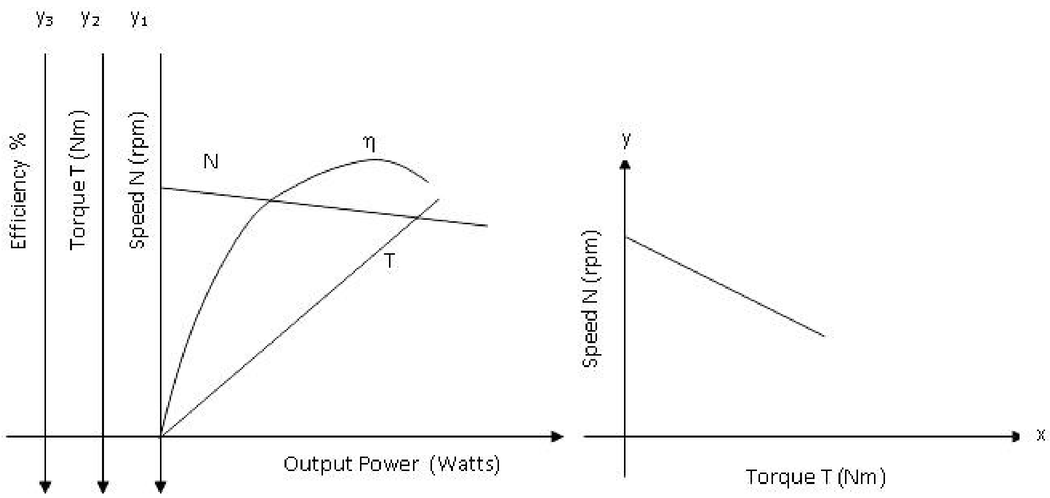


FIGURE 24: Typical Speed – Torque Characteristics

Note: Mention the range of all the electrical components in the circuit diagram.

Experiment 7
Speed–Torque Characteristics of a DC Shunt Motor

Aim: To determine the Speed – Torque characteristics of a DC Shunt Motor

Apparatus/Components/Tools/Software Required:

Name	Specifications	Quantity
Ammeter	(0 – 300 V) DC	1 No.
Ammeter	(0 – 2 A) DC	1 No.
Connecting wires	(0 – 20A) DC	1 No.
Auto transformer Lamp	-	10 No.

Name plate details: Students to note down the same

Theory: In a Dc shunt motor flux ϕ is almost a constant. Therefore Speed of a Shunt DC motor can be easily controlled. Despite the load changes, Shunt DC motor can maintain constant speed. When the load increases the armature tends to slow down. This results in less back EMF. This results in a slight decrease in speed. But at the same time the armature reaction increases reducing the flux. This compensates for the reduction in speed. Thus, even when the load increases, the net effect of load on speed in a Shunt DC motor is almost nil.

$$N = \frac{V - I_a R_a}{\phi} \tag{4}$$

Precautions

1. DC shunt motor should be started and stopped under no load conditions
2. Brake drum should be cooled with water when it is under load

Tabular Column

No	**Voltage**	**Current**	**Spring Balance**			**Speed**	**Torque**
			S1	S2	S1-S2		$T = (S1 - S2)rg$
	V	A	Kg	Kg	Kg	RPM	Nm

Calculations

Radius r of Brake drum = ... m

$T = (S1 - S2) \times r \times g$ in Nm .

Procedure:

1. Connections are made as per the circuit diagram
2. The motor is brought to the rated speed by adjusting the speed control knob on the drive
3. The motor is gradually loaded using the brake drum and spring balance arrangement and the readings of current and speed are noted down at various loads till the rated current of the motor is reached
4. The load is decreased gradually
5. Motor is switched off after reducing the speed
6. The radius of the brake drum is measured.

Result

.

Sample Questions

1. What is principle of working of DC Shunt Motor?
2. What will happen if the d.c. machine is operated below rated speed?
3. What will happen if the d.c. shunt motor opened accidentally running on no-load has its shunt field winding?
4. A d.c. shunt motor is found suitable to drive fans because they require?
5. Why a dc shunt motor is called a constant speed motor?
6. How fan will work with a DC motor?
7. In the event of starting, the starting rheostat is kept at maximum and field rheostat at minimum. Give reasons.
8. Can the starting rheostat be used for speed control also.

Applications

DC shunt motors are commonly used in constant speed is essential.

Eg., Centrifugal Pumps, Blowers, Lathe, Fans, Conveyors, Lifts, Spinning Machines, Weaving Machines etc., .

Evaluation Table

Parameter	**Score**
Remarks	
Total	
Faculty Initials	

Circuit diagrams

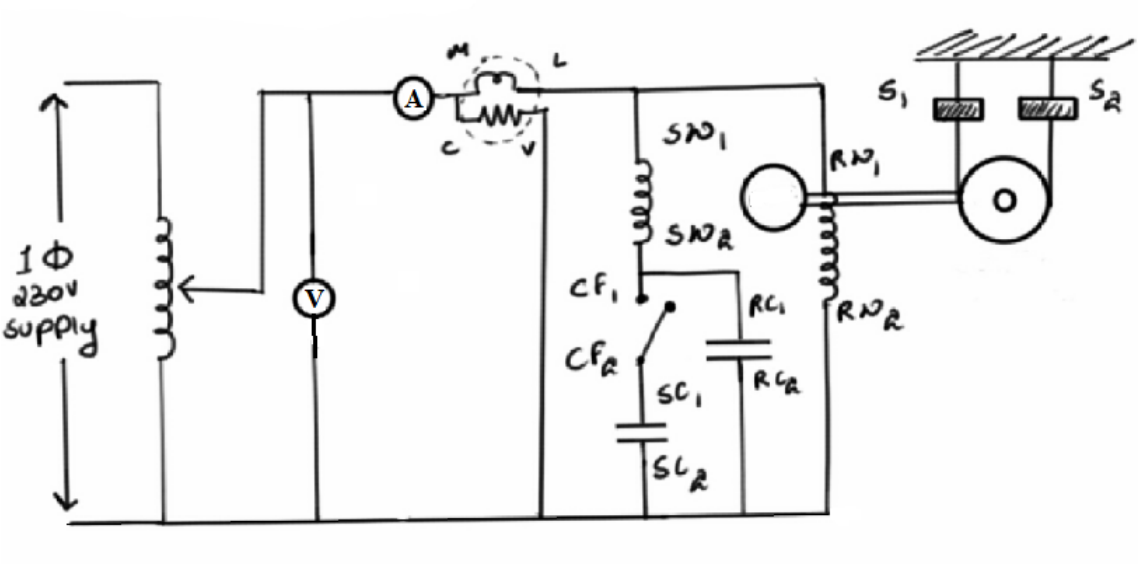


FIGURE 25: Connection diagram

Name Plate Details

.

Experiment 8
Speed–Torque Characteristics of Single Phase Induction Motor

Aim: To conduct load test on a given 1-ϕ induction motor and

1. Plot the torque vs speed/slip characteristics.
2. calculate efficiency at different loads.

Apparatus/Components/Tools/Software Required:

Name	**Specifications**	**Quantity**
Voltmeter		
Ammeter		
Wattmeter		

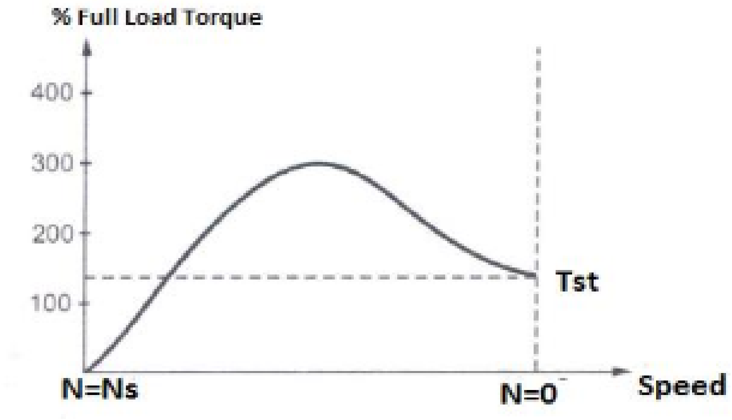
Procedure

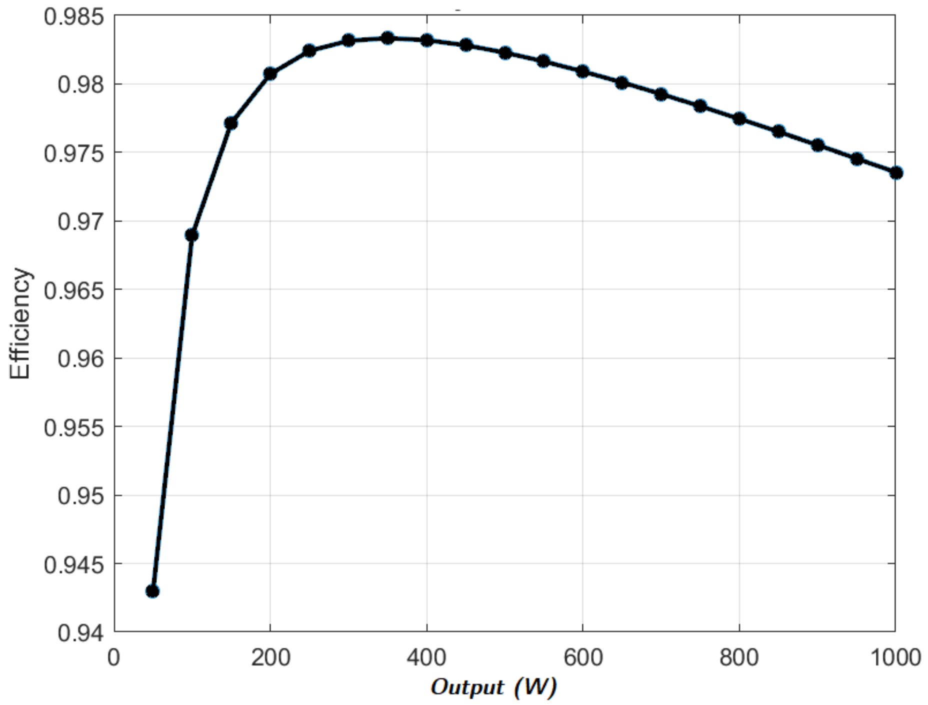
1. Connections are made as shown in the circuit diagram.
2. Measure and note down the circumference of brake drum by using cotton thread.
3. Note down No load speed (Ns rpm)
4. Spring balances S1 and S2 are kept in zero position by operating the adjustment wheels.
5. By keeping the auto-transformer voltage in zero position, the supply switch is closed.
6. Vary the auto-transformer voltage gradually , apply the rated voltage of induction motor. [say 230V]
7. The no-load readings of all the meters and speed are noted down.
8. The Induction motor is loaded gradually by tightening the belt till the rated current. At each load all the meters and speed readings are noted down.
9. To stop the motor, the load is removed (belt is loosened), the auto-transformer voltage is reduced to its initial zero position and then the supply switch is opened.

TABLE 7: Observations

No	**Voltage**	**Current**	**Power**	**Spring Balance**			**Speed**	**Torque**	**Output**	**%**
	V	*A*	*W*	S1 *Kg*	S2 *Kg*	S1-S2 *Kg*	*RPM*	*Nm*	*W*	**Efficiency**

Expected graphs





Calculations

Circumference of the brake drum = ... cm = ...m

Radius of the brake drum (r) = circumference of the brake drum = ...meters

No load speed = N_s rpm

Torque $T = (S1 \sim S2) * r =$ .... Kg-m

Output power(watts) = $\frac{2\pi NT}{60}$

I/P power(watts) = $W1$

Efficiency(%) = $\frac{Output\ power}{Input\ power}$.

Applications

.

Result

.

Evaluation Table

Parameter	Score
Remarks	
Total	
Faculty Initials	

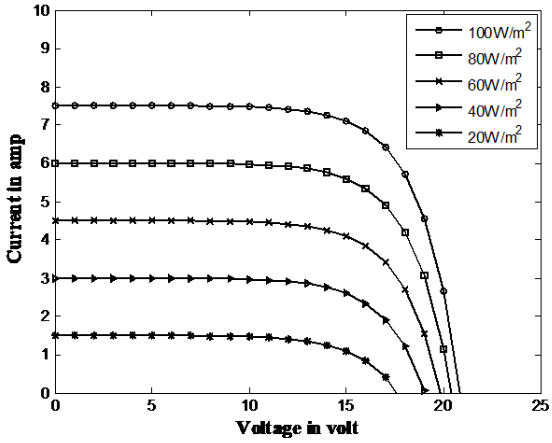


Figure 26: VI Characteristics

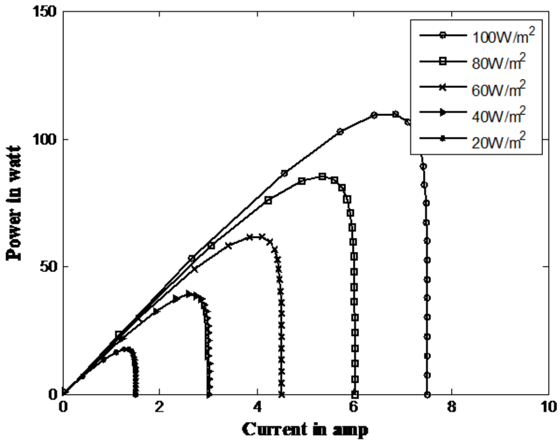


Figure 27: PI Characteristics

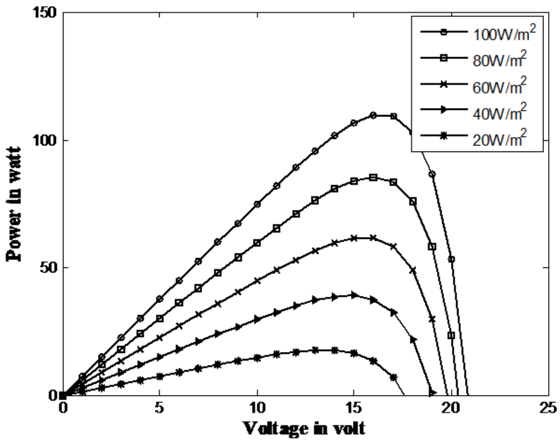


Figure 28: PV Characteristics

Experiment 9
Characteristics of Solar PV Modules

Aim: To determine VI and PI characteristics of solar panels connected in series or parallel or individual.

Apparatus/Components/Tools/Software Required:

Name	Specifications, Type & Range	Quantity
Solar Kit		
Voltmeter		
Ammeter Resistive Load Connecting wires		

Theory: Photovoltaic power systems are generally classified according to their functional and operational requirements, their component configurations, and how the equipment is connected to other power sources and electrical loads. The two principal classifications are grid-connected or utility-interactive systems and stand-alone systems. Photovoltaic systems can be designed to provide DC and/or AC power service, can operate interconnected with or independent of the utility grid, and can be connected with other energy sources and energy storage systems.

Grid-connected or utility-interactive PV systems are designed to operate in parallel with and interconnected with the electric utility grid. The primary component in grid-connected PV systems is the inverter, or power conditioning unit (PCU). The PCU converts the DC power produced by the PV array into AC power consistent with the voltage and power quality requirements of the utility grid, and automatically stops supplying power to the grid when the utility grid is not energized. A bi-directional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance. This allows the AC power produced by the PV system to either supply on-site electrical loads, or to back-feed the grid when the PV system output is greater than the on-site load demand. At night and during other periods when the electrical loads are greater than the PV system output, the balance of power required by the loads is received from the electric utility. This safety feature is required in all grid-connected PV systems, and ensures that the PV system will not continue to operate and feed back into the utility grid when the grid is down for service or repair.

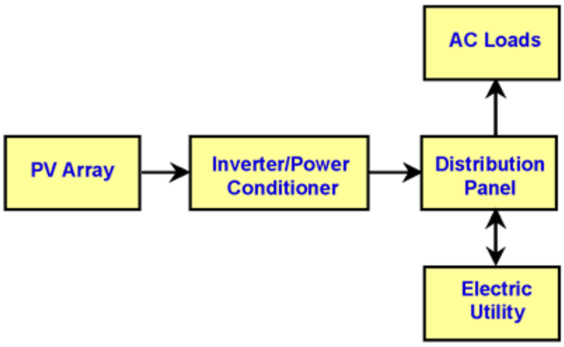


FIGURE 29: Diagram of grid-connected photovoltaic system

FIGURE 30: Direct-coupled PV system

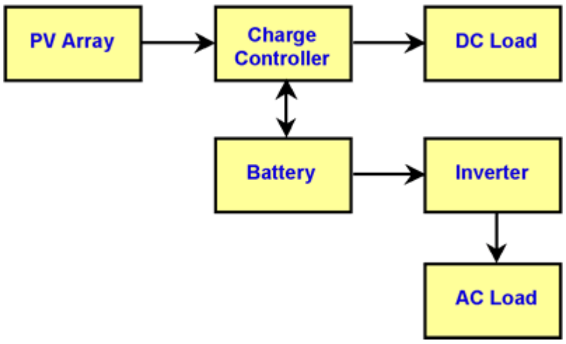


FIGURE 31: Diagram of stand-alone PV system with battery storage powering DC and AC loads

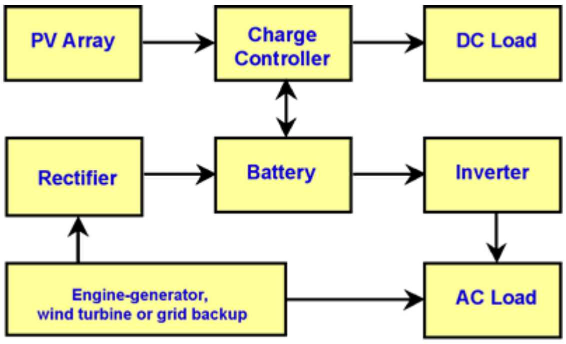


FIGURE 32: Diagram of photovoltaic hybrid system

Stand-Alone Photovoltaic Systems: Stand-alone PV systems are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain DC and/or AC electrical loads. These types of systems may be powered by a PV array only, or may use wind, an engine-generator or utility power as an auxiliary power source in what is called a PV-hybrid system. The simplest type of stand-alone PV system is a direct-coupled system, where the DC output of a PV module or array is directly connected to a DC load (Figure 31). Since there is no electrical energy storage (batteries) in direct-coupled systems, the load only operates during sunlight hours, making these designs suitable for common applications such as ventilation fans, water pumps, and small circulation pumps for solar thermal water heating systems. Matching the impedance of the electrical load to the maximum power output of the PV array is a critical part of designing well-performing direct-coupled system. For certain loads such as positive-displacement water pumps, a type of electronic DC-DC converter, called a maximum power point tracker (MPPT), is used between the array and load to help better utilize the available array maximum power output.

In many stand-alone PV systems, batteries are used for energy storage. Figure 31 shows a diagram of a typical stand-alone PV system powering DC and AC loads. Figure 32 shows how a typical PV hybrid system might be configured.

The procedure to determine I-V characteristics of PV system i.e., system can be either single module or many modules in series/parallel is same. The apparatus connections in experiment for single module, two modules in series and parallel are given in Fig. 33, Fig. 34 and Fig. 35 respectively.

The panels if they are connected in series, voltage will become double to single panel voltage and current remains same.

Similarly, when panes are connected in parallel, voltage will remains same across the two panels, but net current will be doubled.

The model graphs are given in Figure 26, 27, and 28.

Procedure

1. Connect the circuit as shown in figure.
2. Increase the load across panel(s) in steps.
3. For each step, measure all meter readings.
4. Plot the graphs as illustrated in model graphs.
5. Repeat the steps 1 – 4 for panels in series and parallel combinations separately.

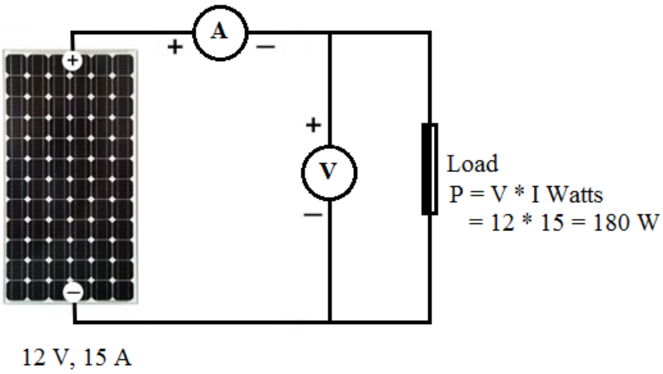


FIGURE 33: Single module set-up

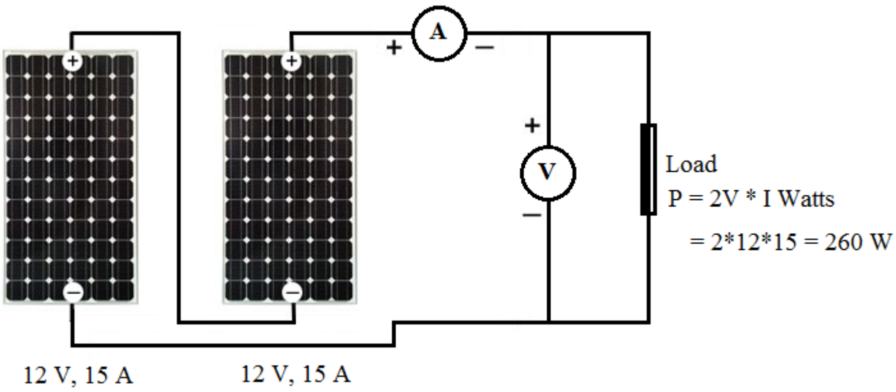


FIGURE 34: Two modules are in series set-up

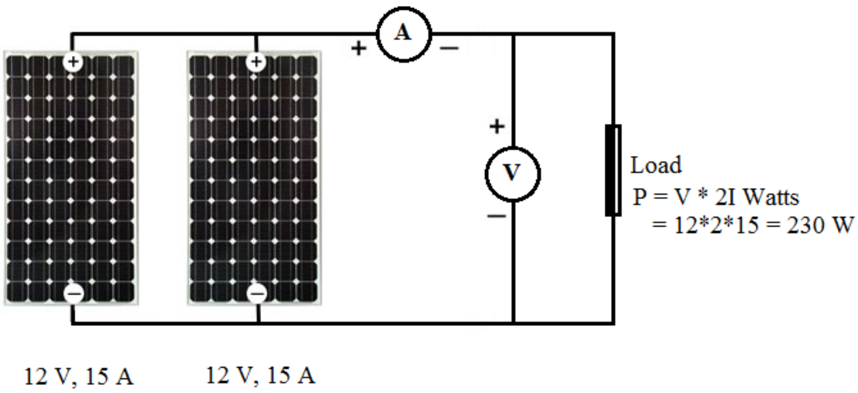


FIGURE 35: Two modules are in parallel set-up

Sample Questions

1. What is a residential solar electric system?

   Answer: We offer comprehensive, code-compliant systems that allow you to generate your own electricity at home. Designed to interconnect with your existing utility service, they feature solar modules, plug-and-play wiring, power electronics and our patented mounting kits. Our installer network provides system installation and service.
2. Will solar PV system work at night?

   Answer: No. Sunlight must be present for your solar modules to produce power. At night, you draw power from your utility.
3. Will solar PV system work on cloudy days?

   Answer: Yes, though they produce less electricity. Under a light overcast sky, panels might produce about half as much as under full sun.
4. What do the terms on-grid, grid-connected, grid-tied and off-grid mean?

   Answer: On-grid, grid-connected or grid-tied means connected to the utility electrical grid. Off-grid refers to systems that are not connected to the utility electrical grid. An off-grid system must be custom designed by a solar power expert.
5. Why is shade a problem?

   Answer: Because of the wiring design of a solar module, all of the individual solar cells on a module must receive full sunlight for the module to work properly. If any portion of the module is shaded, the entire module power output-even those sections still exposed to sunlight-is lowered.
6. Can I add reflectors or mirrors around the solar panels to increase the power they generate?

   Answer: No. ANY solar panel designed for use in direct sunlight only.
7. What is net metering?

   Answer: Net metering measures the difference between the electricity you buy from your utility and the electricity you produce with your solar energy system. Under net metering, any excess electricity produced by your solar energy system is delivered back into the utility grid, effectively spinning your meter backwards. Your meter spins forward when your solar energy system is not producing all of the electricity you are currently using. Your electric meter keeps track of this net difference as you generate electricity and take electricity from the utility grid.
8. How much power will a residential system produce?

   Answer: The amount of power produced by a system varies depending on the size of the system, your geographic location and climate and whether the system has a battery backup.

Table 8: Observation Table: For single panel

No.	**V**(V)	**I**(A)	**Power**(W)

Table 9: Observation Table: For panels in series

No.	**V**(V)	**I**(A)	**Power**(W)

Table 10: Observation Table: Panels in parallel

No.	**V**(V)	**I**(A)	**Power**(W)

Applications

.

Result

.

Evaluation Table

Parameter	Score
Remarks	
Total	
Faculty Initials	

Circuit diagrams

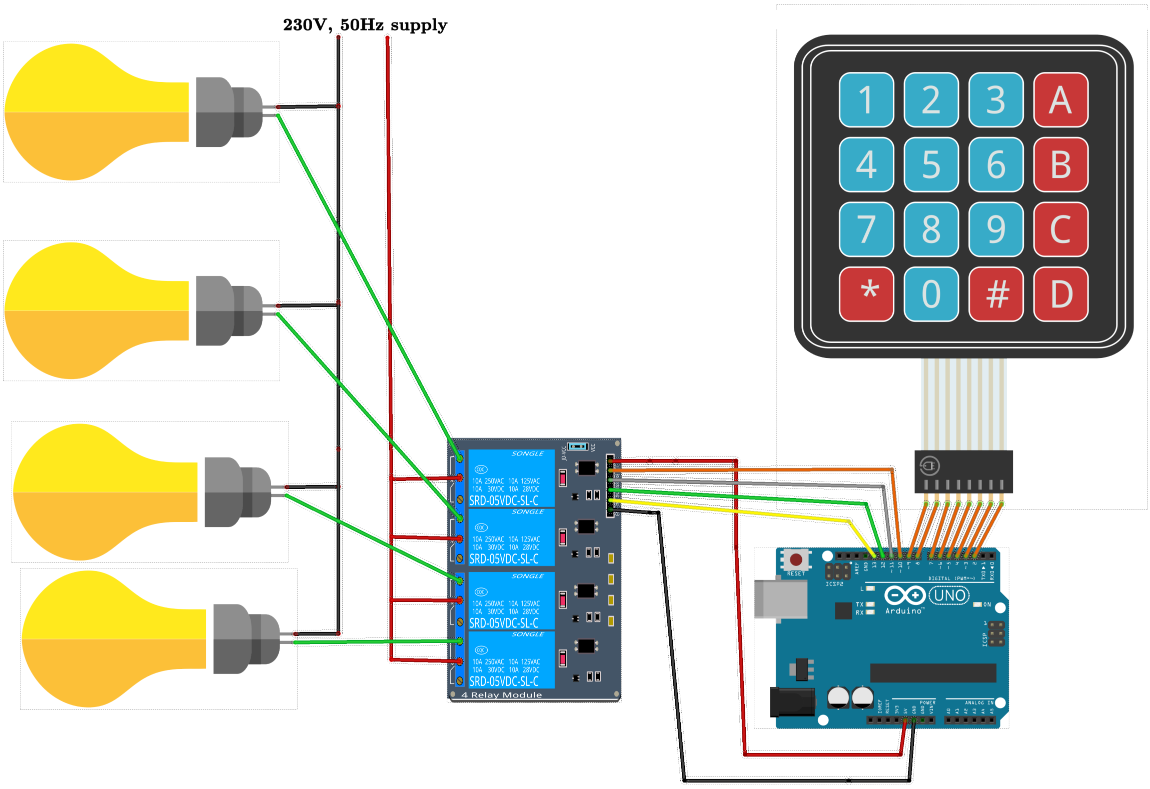


FIGURE 36: Connection diagram

```
// Basic Electrical Laboratory Exp-10
// Manual electrical load control
// Automatic scheduling

// Program Parameter
#include <Keypad.h>

const byte ROWS = 4; // Four rows
const byte COLS = 4; // Four columns

char keys[ROWS][COLS] = { // Define the Keymap
  {'1','2','3','A'},
  {'4','5','6','B'},
  {'7','8','9','C'},
  {'*','0','#','D'}
};

byte rowPins[ROWS] = { 2, 3, 4, 5 };
byte colPins[COLS] = { 6, 7, 8 ,9};

Keypad kpd = Keypad( makeKeymap(keys), rowPins, colPins, ROWS, COLS );// Create the Keypad
```

Experiment 10
Electrical Appliances Control using Arduino

Aim: Multiple lamps switching operation single board computer

Apparatus/Components/Tools/Software Required: Arduino Uno with USB cable, Matrix Keyboard, Jumper wires, Three lamps, Four channel Relay board, Arduino IDE, Keypad library.

Theory: Smart city, Smart grid, Industry 4.0, Home automation, E-mobility and Societal projects are the key future establishments that would perhaps changes every entities. It changes the life style of people. It drives the industry to work on these accomplishments. It merely possible because of the introduction of information and communication technologies in various domains. Many technologies such as Internet of things, AI techniques and data sciences are the back bone of every system in future. Understanding of some primitive component such as microcontroller, communication devices and programming is essential to build interdisciplinary system. In this direction, it is required to know how electronics components drive electrical system. In this experiments, a program written inside the SBC will control high power devices. The knowledge thus obtained can be extended to execute various cutting edge problems and projects.

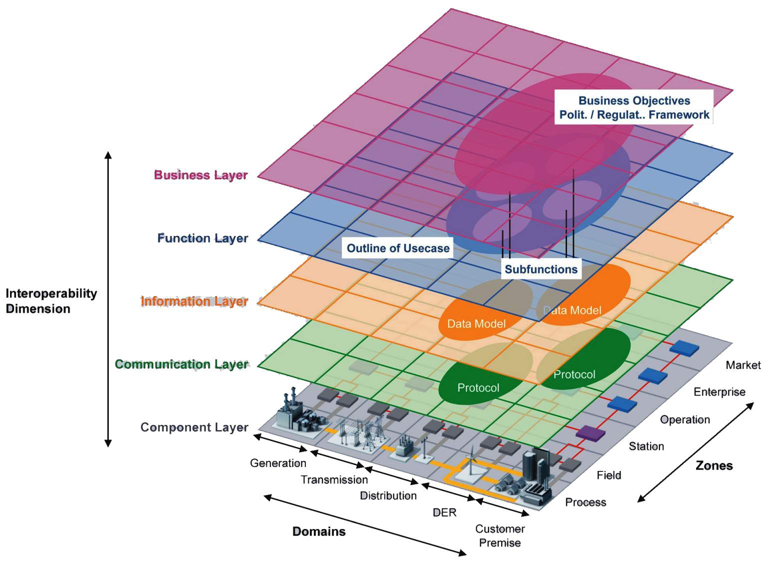


FIGURE 37: Future of Electrical System

```
#define relaypin1 13
#define relaypin2 12
#define relaypin3 11
#define relaypin4 10

// System Parameter

const int LoadSchedulingDuration=10;  // seconds
const int NoofDurations=6;
const int NoofLoad=4;
const int LoadSchedulingPattern[NoofDurations][NoofLoad]={
  {1,0,0,1},
  {1,1,0,1},
  {1,0,0,0},
  {1,0,1,1},
  {0,0,0,1},
  {1,0,0,0}
};

void setup()
{
   pinMode(relaypin1,OUTPUT);
   pinMode(relaypin2,OUTPUT);
   pinMode(relaypin3,OUTPUT);
   pinMode(relaypin4,OUTPUT);

  Serial.begin(9600);
}

void loop()
{
  char key = kpd.getKey();
  if(key)  // Check for a valid key.
  {
    switch (key)
    {
      case '1':
        digitalWrite(relaypin1, HIGH);
        break;
      case '2':
        digitalWrite(relaypin2, HIGH);
        break;
      case '3':
        digitalWrite(relaypin3, HIGH);
        break;
      case 'A':
        digitalWrite(relaypin4, HIGH);
        break;
      case '4':
        digitalWrite(relaypin1, LOW);
        break;
      case '5':
        digitalWrite(relaypin2, LOW);
        break;
```

Procedure

1. Connect the Arduino board, keypad and relay board as shown in circuit diagram.
2. Connect the power circuit as shown in the figure.
3. Interface Arduino and PC via USB cable.
4. Open Arduino IDE. Check COM port is associated to Arduino Uno.
5. Import 4x4 Keypad from the library
6. Write the program given below.
7. Compile and upload the program to Arduino board.
8. Press 1, 2, 3 or 4 to turn on. Press 5, 6, 7 or 8 to turn off. Press * to turn on all. Press 0 to turn off all lamps.

```
      case '6':
        digitalWrite(relaypin3, LOW);
        break;
      case 'B':
        digitalWrite(relaypin4, LOW);
        break;
      case '*':
        digitalWrite(relaypin1, HIGH);
        digitalWrite(relaypin2, HIGH);
        digitalWrite(relaypin3, HIGH);
        digitalWrite(relaypin4, HIGH);
        break;
      case '0':
        digitalWrite(relaypin1, LOW);
        digitalWrite(relaypin2, LOW);
        digitalWrite(relaypin3, LOW);
        digitalWrite(relaypin4, LOW);
        break;
      case '8':
        for(int i=0; i<NoofDurations; i++){
          digitalWrite(relaypin1, LoadSchedulingPattern[i][0]);
          digitalWrite(relaypin2, LoadSchedulingPattern[i][1]);
          digitalWrite(relaypin3, LoadSchedulingPattern[i][2]);
          digitalWrite(relaypin4, LoadSchedulingPattern[i][3]);
          delay(LoadSchedulingDuration*1000);
        };
        digitalWrite(relaypin1, LOW);
        digitalWrite(relaypin2, LOW);
        digitalWrite(relaypin3, LOW);
        digitalWrite(relaypin4, LOW);
        break;
      default:
        Serial.println(key);
    }

  }
}
```

Applications

Write any ten interdisciplinary projects. .

Sample Questions

1. What is embedded system?
2. What is microcontroller?
3. How relay works?
4. What are the various peripherals hosted in Arduino Uno Board?
5. How matrix keypad works?
6. What is smartgrid?
7. What is smart city?
8. How can we make our campus smart?

Result

.

Evaluation Table

Parameter	**Score**
Remarks	
Total	
Faculty Initials	

Circuit diagrams

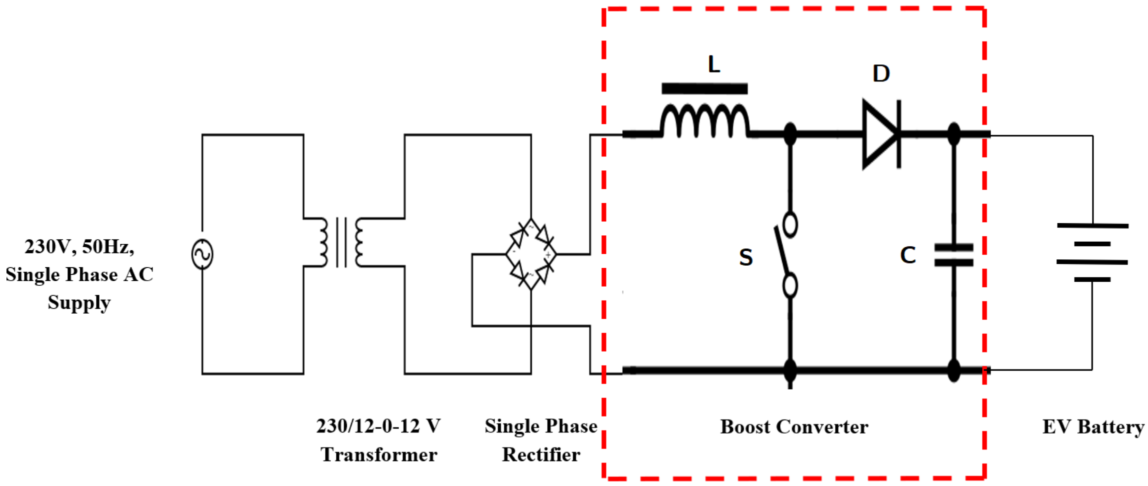


FIGURE 38: DC-DC converter for charging 48V electric vehicle battery from grid

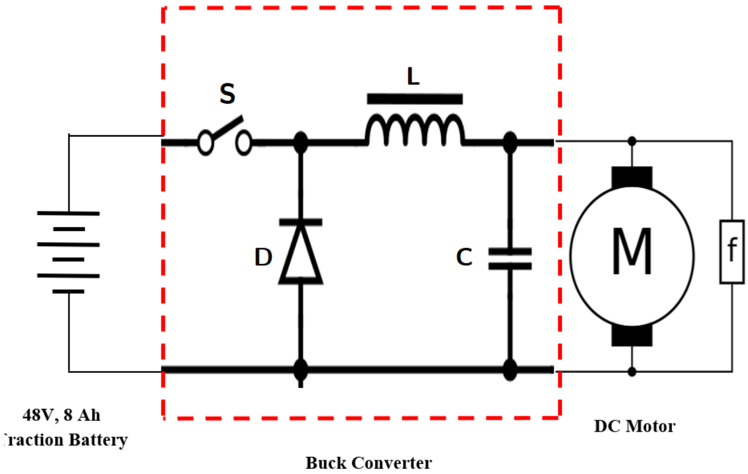


FIGURE 39: DC-DC converter for operating a 24V traction motor using a 48 V battery source

Experiment 11
Variable DC Voltage using DC-DC Converter (Demonstration)

Aim: To realize DC- DC converters for automotive applications and

1. To develop a charging circuit for 48V electric vehicle battery charging from grid.
2. To develop a DC-DC converter for operating a 24V traction motor using a 48 V battery source.

Apparatus/Components/Tools/Software Required: Transformer (230V/12-0-12, 5A), 1N4001 Diode based rectifier circuit, Buck converter, Boost converter, 48V, 8Ah Li ion battery pack, 24 V Dc motor, Multi meter, DSO, Connecting wires.

Theory:

To develop a DC-DC Converter for charging 48V Electric Vehicle battery from grid: The charging of a typical electric vehicle battery from grid requires the conversion of AC grid voltage at 230 V, 50 Hz to 24 V Dc voltage and then stepping up that DC voltage to 48V terminal voltage. The two power electronic circuits are required to implement the same which are, a rectifier to convert AC to DC and a boost converter to convert DC voltage to variable DC voltage. The EV battery pack considered is a Li ion battery pack of rating 48V,8 Ah. The charging of the battery pack has to be regulated using a charge controlling circuit as over charging would make the Li ion cells highly unstable which could lead to explosion. Battery management systems are provided to perform the necessary protection and regulation of the battery pack. The grid voltage is stepped down using a 230V/12-0-12 V step down transformer. The transformer steps down the ac voltage to 24V end tap voltage.The rectifier circuit is made up of four 1N4001 diodes. The rectifier converts the Ac to Dc supply which would be given to the boost converter. The boost converter is used to obtain the stepping up of the voltage from 24 V to 48 V Dc. The stepped up voltage would be used to charge the 48V Li ion Battery pack. The boost converter operates in two modes which are Mode-I and Mode –II. During Mode-I an inductor is charged by the regulation of the switch. During Mode-II the inductor is made to discharge. This charging discharging of the inductor controlled by a switch enables to regulate the dc voltage. The design of the Boost converter is based on the following equation:

Output voltage,

$$V_O = \frac{V_d}{1 - D} \tag{5}$$

Result

.

Applications

.

Duty Ratio,

$$D = \frac{T_{on}}{T} \tag{6}$$

where V_O is output Dc voltage, V_d is the input Dc voltage, D is the duty ratio, T_{on} is the on time, T is the total time.

Procedure:

1. Connections are made as shown in circuit diagram.
2. The battery terminal voltage is measured.
3. The boost converter output voltage is measured.
4. The boost converter is adjusted such that the output voltage is 0.5V more than the battery terminal voltage.
5. The SPST switch is turned on and the ammeter current is noted.
6. If the ammeter current is above 0.8C the boost converter voltage is adjusted to bring the charging current below 0.8C.
7. The waveforms are noted for inductor voltage, V_L, capacitor voltage , V_C, output voltage, V_0.

To develop a DC-DC Converter for operating a 24V traction motor using a 48 V battery source: The traction motors usually used in EV are BLDC motor and three phase induction motor. The BLDC motor is easy to operate but is very costly and therefore Three phase Induction motors are more preferred due to flexibility of operation. The setup uses a DC motor as a traction motor rated at 24 V and would be operated using a 48V, 8Ah Li ion battery pack. However to match the required terminal voltage of the motor a buck converter has to be used. The buck converter is a DC-DC converter used to step down the voltage. A buck converter has two modes of operation which are Mode-I and Mode-II. The regulation of the voltage is performed based on the switching regulation. The charging/discharging of the inductor is regulated by the switching.

Procedure:

1. Connections are made as shown in circuit diagram.
2. The battery terminal voltage is measured.
3. The buck converter output voltage is measured.
4. Two lead acid batteries are used to set the 24V field supply to be given Dc motor.
5. The buck converter is adjusted to regulate the speed of the Dc motor.
6. The duty cycle is measured using the DSO for various samples.
7. The output voltage of the buck converter and the speed of the motor is also noted.

Circuit diagrams

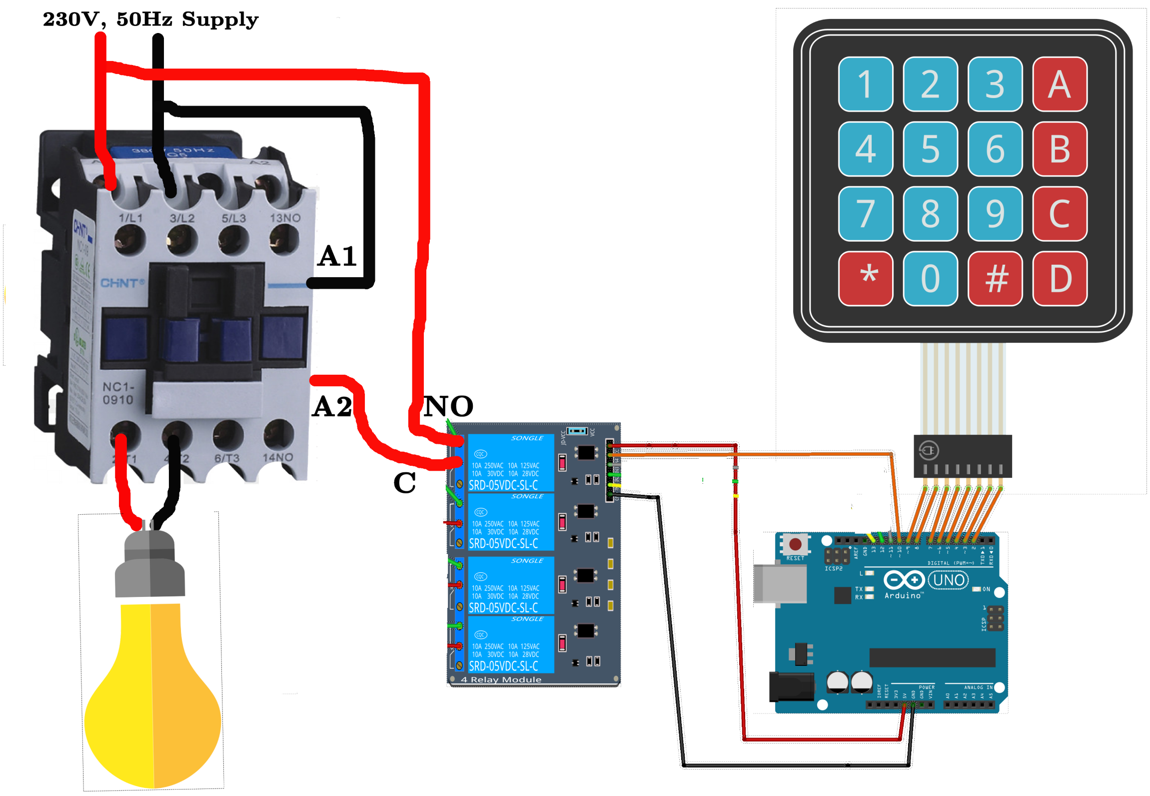


FIGURE 40: Connection diagram

```
// Basic Electrical Laboratory Exp-12
// Manual electrical load control of high current applications
// Current range: 32A, 50A

// Program Parameter
#include <Keypad.h>

const byte ROWS = 4; // Four rows
const byte COLS = 4; // Four columns

char keys[ROWS][COLS] = { // Define the Keymap
  {'1','2','3','A'},
  {'4','5','6','B'},
  {'7','8','9','C'},
  {'*','0','#','D'}
};

byte rowPins[ROWS] = { 2, 3, 4, 5 };
byte colPins[COLS] = { 6, 7, 8 ,9};

Keypad kpd = Keypad( makeKeymap(keys), rowPins, colPins, ROWS, COLS );// Create the Keypad
```

Experiment 12
Power Circuit Control using Relay and Contactor. (Demonstration)

Aim: Emulation of load scheduling connected to high tension supply using controlled switch.

Apparatus/Components/Tools/Software Required: Arduino Uno with USB cable, Matrix Keyboard, Jumper wires, One lamps, Four channel Relay board, Arduino IDE, Keypad library, Contactor.

Theory: There are many practical applications which draws more current for its operations. Increase in current value increases the overall size of the system. In our day-to-day life also we use relatively high current devices such as geyser, water pump, heater etc. The control of industrial equipment merely the current control. The fast charging station is also a high current application wherein smooth and discrete control is essential. The contactor is controlled switch for power circuit. In this experiment, its operation and application in various domain is demonstrated. The motto of this experiment is switching from prototype to product development.

FIGURE 41: Motor Controller and Starter

```
#define relaypin 10
// System Parameter
const int LoadSchedulingDuration=10;  // seconds
const int NoofDurations=6;
const int LoadSchedulingPattern[NoofDurations]={1, 0, 1, 0, 1, 1};

void setup()
{
   pinMode(relaypin,OUTPUT);
   Serial.begin(9600);
}
void loop()
{
  char key = kpd.getKey();
  if(key)  // Check for a valid key.
  {
    switch (key)
    {
      case '1':
        digitalWrite(relaypin, HIGH);
        break;
      case '0':
        digitalWrite(relaypin, LOW);
        break;
      case '*':
        for(int i=0; i<NoofDurations; i++){
          digitalWrite(relaypin, LoadSchedulingPattern[i]);
          delay(LoadSchedulingDuration*1000);
        };
        digitalWrite(relaypin, LOW);
        break;
      default:
        Serial.println(key);
    }

  }
}
```

Applications

Write any four high current control applications. .

Procedure

1. Connect the Arduino board, keypad and relay board as shown in circuit diagram.
2. Connect the power circuit as shown in the figure.
3. Interface Arduino and PC via USB cable.
4. Open Arduino IDE. Check COM port is associated to Arduino Uno.
5. Import 4x4 Keypad from the library
6. Write the program given below.
7. Compile and upload the program to Arduino board.
8. Press 1, 2, 3 or 4 to turn on. Press 5, 6, 7 or 8 to turn off. Press * to turn on all. Press 0 to turn off all lamps.

Sample Questions

1. What is embedded system?
2. What is microcontroller?
3. How relay works?
4. What are the various peripherals hosted in Arduino Uno Board?
5. How matrix keypad works?
6. What is smartgrid?
7. What is smart city?
8. How can we make our campus smart?

Result

.

Appendix A
Study of Basic Electrical Components & Devices

Fuse: A fuse is an electrical safety device that operates to provide overcurrent protection of an electrical circuit. Its essential component is a metal wire or strip that melts when too much current flows through it, thereby interrupting the current.

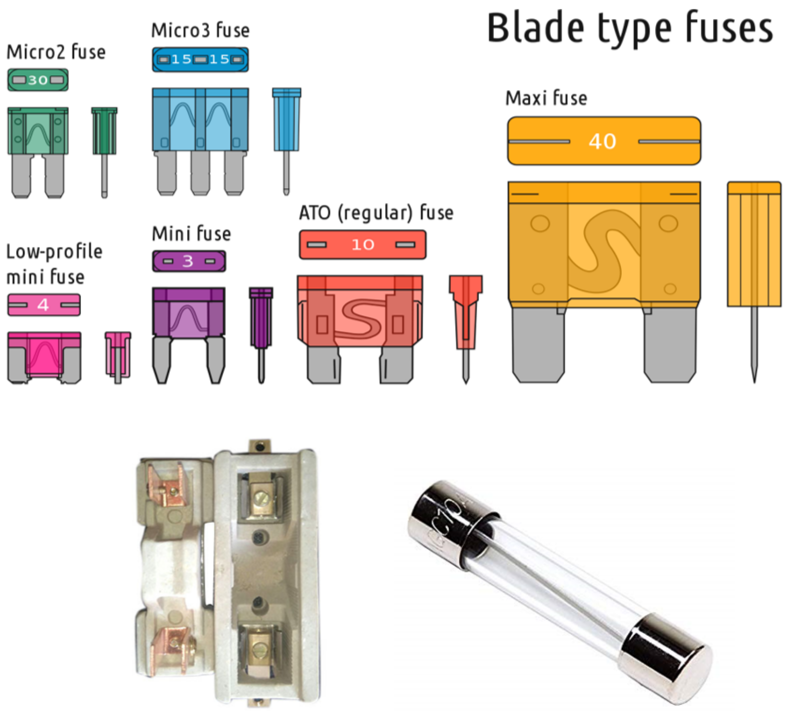


FIGURE 42: Different Types of Fuses

MCB: A miniature circuit breaker (MCB) automatically switches off electrical circuit during an abnormal condition of the network means in overload condition as well as faulty condition. If the circuit is overloaded for a long time, the bi-metallic strip becomes overheated and deformed. This deformation of Bi-metallic strip causes, displacement of latch point. The moving contact of the MCB is arranged by means of spring pressure, with this latch point, that a little displacement of latch causes, release of spring and makes the moving contact to move for opening the MCB. The current coil or trip coil is placed so that during short circuit fault the magneto-motive force (mmf) of the coil causes its plunger to hit the same latch point and make the latch to be displaced. Again, when operating lever of the miniature circuit breaker is operated by hand, that means when MCB goes off position manually, the same latch point is displaced as a result moving contact separated from fixed contact in the same manner.

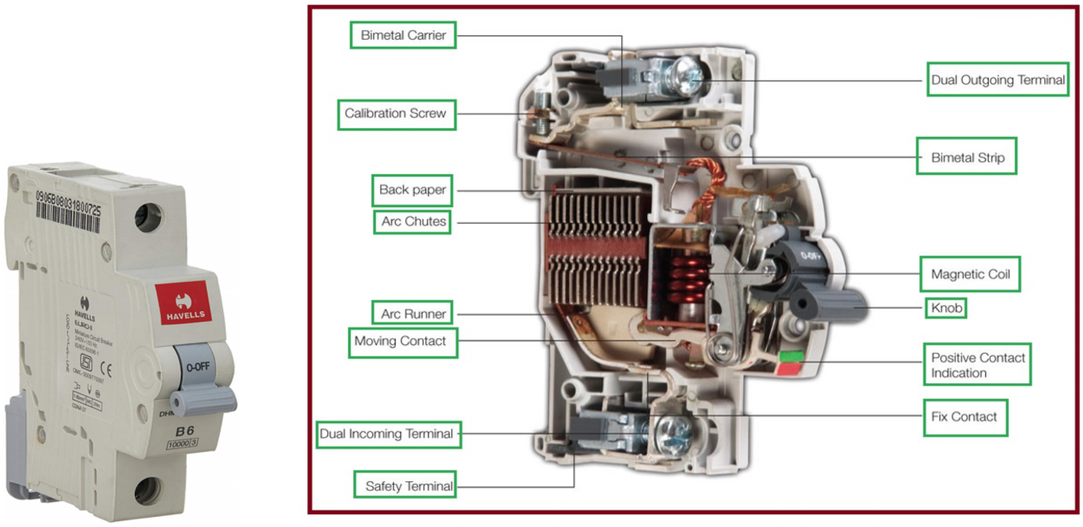


FIGURE 43: View and Construction of an MCB

Resistors: Resistors are passive elements that oppose/restrict the flow of current. A voltage is developed across its terminal, proportional to the current through the resistor. The resistors are of two types which are Variable resistors and fixed resistors.

Symbol : 

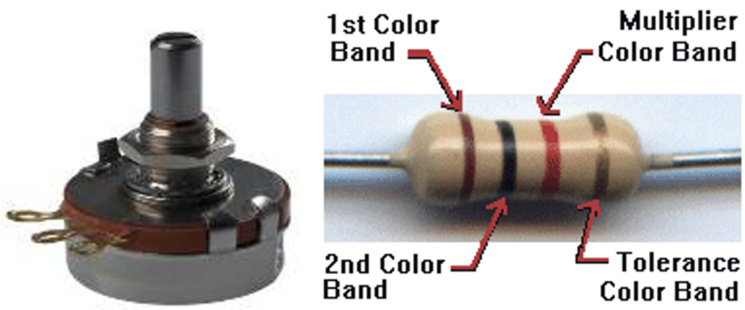


FIGURE 44: Types of Resistors

Capacitors: Capacitors are charge storage devices. They behave like a tiny rechargeable battery which can store energy and release it later. These are made of two parallel conductors separated by a dielectric. Capacitors are used for filtering, tuning, separating signals , etc. The ability of a capacitor to store charge is called "Capacitance".

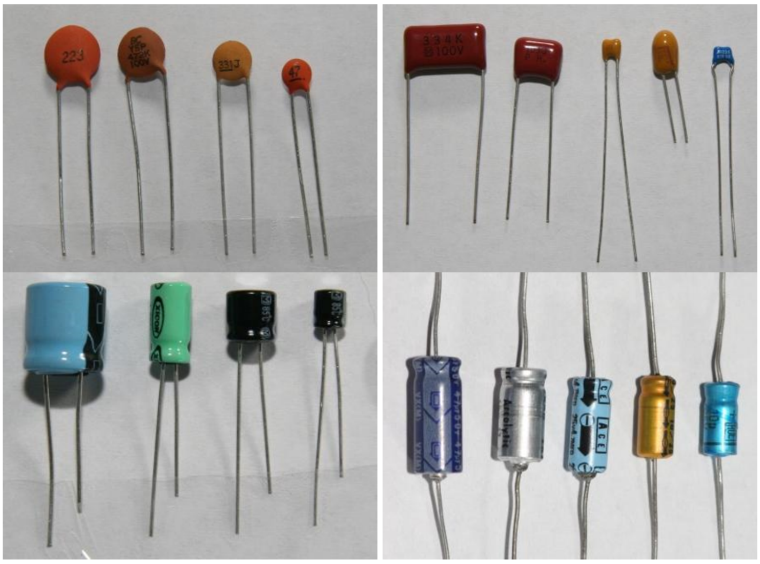


FIGURE 45: Types of Capacitors

Relays: A Relay consists of a coil, yoke, armature, spring and a set of contacts. When current flows through the coil, it produces a magnetic field. The coil is wrapped around a yoke, commonly an iron core, that provides low resistance to magnetic flux. When enough current is flowing through the coil and a strong enough field is produced, it attracts the armature toward itself, moving it into a position where it connects the contacts. Most of the time it will make an audible clicking sound. The coil is not actually connected to the armature, so the switching signal (current through the coil) is independent of the signal moving between the contacts via the armature.

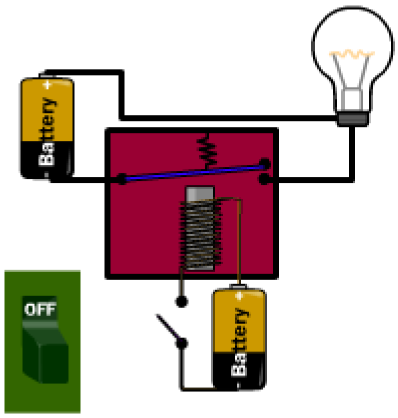


FIGURE 46: Relay

Synchronous Machines: A synchronous electric motor is an AC motor in which, at steady state,[1] the rotation of the shaft is synchronized with the frequency of the supply current; the rotation period is exactly equal to an integral number of AC cycles. Synchronous motors contain multiphase AC electromagnets on the stator of the motor that create a magnetic field which rotates in time with the oscillations of the line current. The rotor with permanent magnets or electromagnets turns in step with the stator field at the same rate and as a result, provides the second synchronized rotating magnet field of any AC motor.

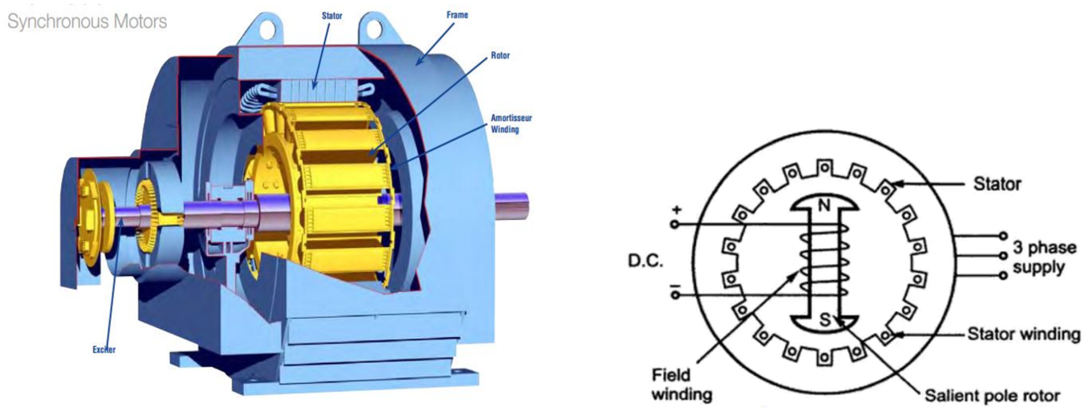


Figure 47: Synchronous motor

Induction Machines: An induction motor or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor can therefore be made without electrical connections to the rotor. An induction motor's rotor can be either wound type or squirrel-cage type. Three-phase squirrel-cage induction motors are widely used as industrial drives because they are self-starting, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives(VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and variable-frequency drive (VFD) applications.

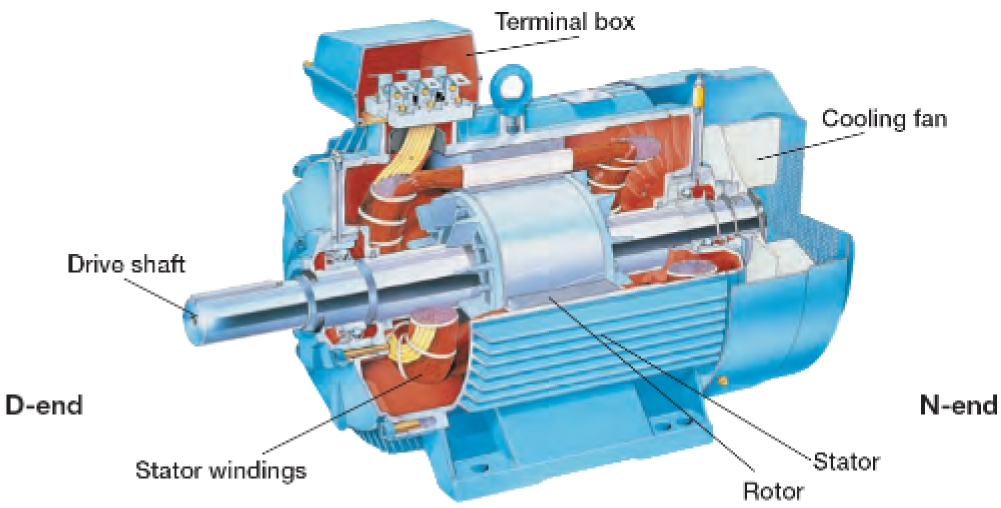


FIGURE 48: Asynchronous/Induction motor

Brushed DC Machines: A brushless DC motor (BLDC motor) is an electronically commuted DC motor which does not have brushes. The controller provides pulses of current to the motor windings which control the speed and torque of the synchronous motor. These types of motors are highly efficient in producing a large amount of torque over a vast speed range. In brushless motors, permanent magnets rotate around a fixed armature and overcome the problem of connecting current to the armature. Commutation with electronics has a large scope of capabilities and flexibility. They are known for smooth operation and holding torque when stationary.

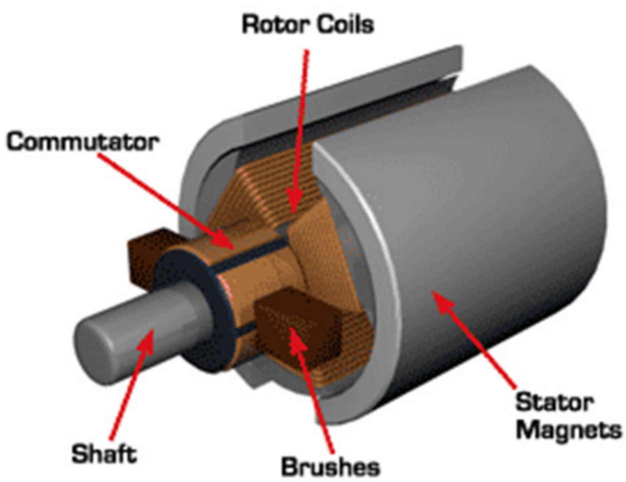


FIGURE 49: Brushed DC Motor

CHRIST
(DEEMED TO BE UNIVERSITY)
BANGALORE · INDIA

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING