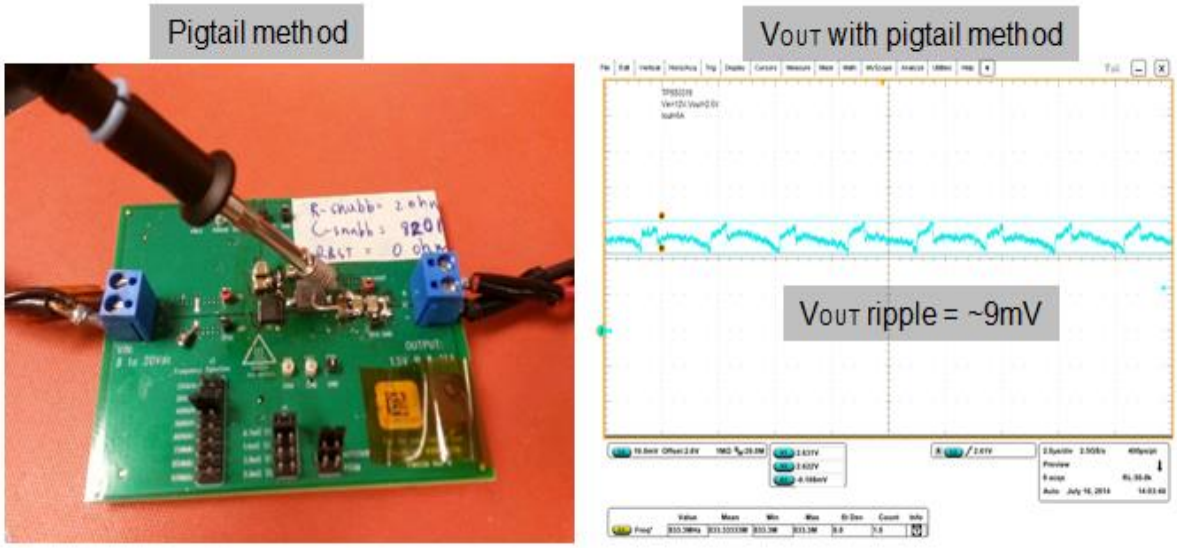
Industrial Electrical/Electronic Control Technology

Level Iv

Based on October 2023, Curriculum Version 1



Module Title: Problems In Single/Three Phase Electro Power Control Circuits

Module Code: EIS IEC4 M10 1023

Nominal duration: 125 Hours

Prepared by: Ministry of Labor and Skill

October, 2023

Addis Ababa, Ethiopia

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Acknowledgment

Ministry of Labor and Skills wish to extend thanks and appreciation to the many representatives of TVET instructors and respective industry experts who donated their time and expertise to the development of this Teaching, Training and Learning Materials (TTLM).

Acronym

AC: ..... Alternating Current

DC: ..... Direct Current

RMS: ..... Root Mean Square

VFD: ..... Variable Frequency Drive

PLC: ..... Programmable Logic Controller

MCC: ..... Motor Control Center

VSD: ..... Variable Speed Drive

PWM:..... Pulse Width Modulation

SCR:..... Silicon Controlled Rectifier

TRIAC: ..... Triode for Alternating Current

IGBT: ..... Insulated Gate Bipolar Transistor

MOSFET ..... Metal-Oxide-Semiconductor Field-Effect Transistor

PID: ..... Proportional-Integral-Derivative

SCAD: ..... Supervisory Control and Data Acquisition

HMI: ..... Human-Machine Interface

Introduction to the Module

In Industrial Electrical/Electronic Control Technology field, problem solving in single/three phase electrical power control circuit is very important for the overall problem solving. It helps to know basic power control circuit concepts, single/three phase rectifier and converter and identifying and solving a problem and documentation.

This module is designed to meet the industry requirement under the Automotive Electrical and Electronics occupational standard, particularly for the unit of competency: problem solving in single/three phase electrical power control circuit**.**

Module covers the units:

- problem in single/three phase electronic power control circuits
- Solve problems in single/three phase electronic power control circuits

Learning Objective of the Module

- Notify WHS/OHS requirement and procedure
- Identify hazard and risk assessment
- Identify problems in single/three phase electronic power control circuit
- Identify equipment and testing device
- Understand problem solution controlling
- Know and understand single/three phase electro control circuit testing
- Apply documentation

Module Instruction

For effective use these modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the “LAP test” giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

Unit One:single/three phase electro power control circuits problem

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- WHS/OHS requirements and procedures
- Hazard Identification and Risk Assessment
- Single /three electronic power control circuits
- problems in single /three electro power control circuits
- work plan
- equipment and testing devices

This unit will also assist you to attain the learning outcomes stated in the cover page.

Specifically, upon completion of this learning guide, you will be able to:

- Knowledge of WHS/OHS requirements and procedures
- Ability to identify hazards and assess risks in the workplace
- Understanding of the principles and operation of single/three electro power control circuits
- Ability to troubleshoot and repair problems in single/three electro power control circuits
- Ability to develop and implement a work plan for troubleshooting and repairing single/three electro power control circuits
- Knowledge of the equipment and testing devices required to troubleshoot and repair single/three electro power control

1.1 WHS/OHS requirements and procedures

workplace health and safety (WHS) or occupational health and safety (OHS) requirements and procedures are essential to ensure the safety and well-being of workers. Here are some considerations for WHS/OHS requirements and procedures for power electronic control maintenance:

1. **Risk Assessment:**

Conduct a thorough risk assessment of the maintenance tasks associated with power electronic control systems. Identify potential hazards, such as electrical shock, fire, or chemical exposure, and assess the severity and likelihood of these risks.

Identify potential hazards: Conduct a thorough examination of the work environment and the tasks involved in power electronic control maintenance. Identify potential hazards such as electrical hazards, fire risks, chemical exposure, ergonomic issues, and any other risks specific to the equipment or work area.

- **Assess the severity and likelihood of risks:** Evaluate the potential consequences and likelihood of each identified hazard. This assessment helps prioritize risks and determine the appropriate control measures.
- **Involve relevant stakeholders:** Include maintenance workers, supervisors, safety professionals, and any other relevant personnel in the risk assessment process. Their expertise and input can provide valuable insights into potential hazards and risk control measures.
- **Implement control measures:** Based on the risk assessment findings, implement appropriate control measures to mitigate or eliminate identified hazards. This may involve engineering controls (e.g., guarding, insulation), administrative controls (e.g., procedures, training), or personal protective equipment (PPE).
- **Review and reassess**: Regularly review and reassess the risks associated with power electronic control maintenance. Changes in equipment, work processes, or the work environment may introduce new hazards or alter existing risks. Stay proactive in identifying and addressing these changes to maintain a safe working environment.
- **Document the risk assessment**: Keep a record of the risk assessment process, including the identified hazards, risk levels, and implemented control measures. This documentation helps ensure consistency, track compliance, and serve as a reference for future risk assessments or audits.

2. **Personal Protective Equipment (PPE):**

Identify the appropriate PPE required for power electronic control maintenance tasks. This may include insulated gloves, safety glasses, arc flash protective clothing, and ear protection. Ensure that workers are trained in the proper use and maintenance of PPE.

List of electrician PPE

Before the implementation of preventive measures, the employer must identify the risks due to electric current for each electrician. The implementation of the **compulsory wearing** of personal protective equipment makes it possible to reduce incidents due to direct contact upstream or downstream of the circuit breakers.

There are several types of **PPE for electricians**. Equipment they should wear includes hard hats, safety shoes, **protective of hands**, workwear and many more.

Electrician's clothing and standards

Prevention against contact voltage

Electrical professionals put on work clothes to reduce the risk of injury. These workers must wear a jacket, work pants, overalls and coveralls. These work clothes correspond to the **EN 340 standard**. They are made of flame-retardant cotton.

Awareness and training of electricians is the responsibility of the employer. He must inform these workers of the risks due to currents. Likewise, wearing **PPE** helps prevent electrostatic discharge.

Gloves against bare live parts

The electrician gloves are **essential PPE**. This equipment must follow **safety standards**. The part of the body most exposed to currents are the hands. Gloves must have a high insulating capacity. Electricians wear these hand guards to protect themselves from various accidents. They therefore use insulating gloves and gloves against mechanical risks.

Personal protective equipment for electricians: face and eyes

Electricians are exposed to electrostatic discharge, as well as electric arcs during a short circuit.

When the eyes and faces of electricians are exposed to an electric arc, wearing a UV protective face shield is required for eye protection. These Electricians PPE are useful during lockout procedures when the worker carries out the installation or maintenance operations. They are also ideal for installing grounding devices. In addition, this type of PPE protects against the electric arc of the short circuit.

Isolating helmets to reduce electrical risk

Electrical professionals use **insulated helmets** to protect themselves from head shocks and falling objects. These preventive measures are certified to comply with **NF EN 50365 standards**.

Worker hard hats help prevent head impacts, especially inside buildings and electrical contacts. This type of PPE has a limited service life of 3 to 5 years. Apart from shocks to the head, the helmet also protects electrical professionals against electric arcs in the event of a short circuit.

Respiratory protection for electrical safety

Disposable masks are used to protect the respiratory tract. The objective is to avoid any inhalation of dust. In the field of electricity, the risks of toxicity of certain solvents are often overlooked.

Insulated safety shoes

The safety shoes are made without conductive material to avoid electrostatic discharges. Wearing **ESD-standard safety shoes** avoids the accumulation of loads. In a dry environment, safety sneakers remain the most suitable.

Fall protection

Electricians sometimes work at heights. Other kits are needed such as a lanyard and a safety harness.

Electrician PPE kits

In order to work in complete safety, employees have kits according to their levels of authorization

3. **Electrical Safety:**

Follow established electrical safety procedures, such as de-energizing and locking out the power supply before performing maintenance work. Use appropriate voltage testing equipment to verify that the system is de-energized.

4. **Fire Safety:**

Have fire extinguishers readily available in the maintenance area and ensure workers are trained in their proper use. Implement fire prevention measures, such as regular equipment inspections and maintenance, and proper storage and handling of flammable materials.

5. **Emergency Procedures:**

Develop and communicate emergency procedures, including evacuation plans and reporting mechanisms for incidents or injuries. Ensure workers are familiar with these procedures and conduct regular drills to reinforce safety protocols.

6. **Documentation and Reporting**:

Maintain records of maintenance activities, including safety inspections, incident reports, and training records. Encourage workers to report any safety concerns or near-miss incidents to promote continuous improvement in safety practices.

7. **Maintenance Procedures:**

Develop and document clear maintenance procedures specific to power electronic control systems. Include step-by-step instructions for tasks such as inspection, testing, troubleshooting, and repair. Emphasize safe work practices and highlight potential risks and precautions.

8. **Lockout/Tagout (LOTO):**

Implement LOTO procedures to control hazardous energy sources during maintenance. Clearly define the lockout/tagout steps for isolating and de-energizing power electronic control systems to prevent accidental startup or release of stored energy.

9. **Hazardous Substances:**

Identify any hazardous substances that may be encountered during power electronic control maintenance, such as cooling fluids or chemicals. Provide appropriate handling procedures, including storage, use, and disposal guidelines, and ensure workers are aware of potential health risks and safety measures.

10. **Emergency Response**:

Establish emergency response procedures for power electronic control maintenance activities. Train workers on how to respond to electrical accidents, fires, chemical spills, or other potential emergencies. Maintain readily accessible emergency contact information.

1.2 Hazard Identification and Risk Assessment

Introduction to Electrical Hazards

Electrical hazards refer to the potential dangers and risks that are associated with electrical systems. These hazards can cause dangers such as burns, electrocution, arc flash, electric shock, and other serious injuries. In extreme cases, they can even lead to fires or explosions, posing a threat to life, property, and the overall safety of a place and its occupants.

Important to Know About electrical Hazards

Working around electricity can be very safe on the job site when workers properly identify and control hazards. But, inadequate training, lack of experience, and failure to recognize potential hazards could result in electric shock or death.

The construction industry is most in danger from electrical hazards, accounting for 52% of all electrical fatalities in the US workplace. Most of these incidents and fatalities were caused by direct worker contact with overhead power lines and contact with machines, tools, and hand-carried metallic objects. So how do we protect ourselves against these dangers?

One of the best ways to protect yourself against these dangers is through awareness. Knowing the potential risks associated with electricity allows you to take precautions to prevent electrical accidents and fatalities. Having this knowledge can also help you spot the signs of electrical hazards immediately for prompt action, thereby contributing to the overall safety of the workplace.

Causes of Electrical Hazards

Electrical hazards, while dangerous, can be prevented when you're aware of the factors that contribute to them. Here's a list of the most common causes of electrical hazards to watch out for:

- **Insufficient insulation** – Over time, electrical insulation can deteriorate due to wear and tear, rodents, or exposure to moisture. This degradation can lead to exposed wires and increase the risk of electric shock or short circuits.
- **Circuit breaker failure** – If the circuit breaker fails to trip during an overload, it loses its protective functioning, further increasing the risk of electrical hazards.
- **Damaged electrical appliances** – Loose connections, frayed wires, or cracked insulation can result in electrical malfunctions.
- **Improper use of extension cords** – Practices like daisy chaining and overloading can cause overheating and ignite electrical fires.
- **Inadequate maintenance** – Failing to regularly inspect electrical systems, ignoring warning signs, or bypassing safety procedures can trigger severe electrical hazards over time.

Electrical Hazards Examples

Electrocution is one of the most common hazards across construction sites according to OSHA. Identifying electrical hazards can help raise awareness of the risks, their severity, and how they can harm workers.

In this section, learn about common electrical hazards in the workplace and electrical safety tips to prevent them:

- Overhead power lines
- Damaged tools and equipment
- Inadequate wiring and overloaded circuits
- Exposed electrical parts
- Improper grounding
- Damaged insulation
- Wet conditions

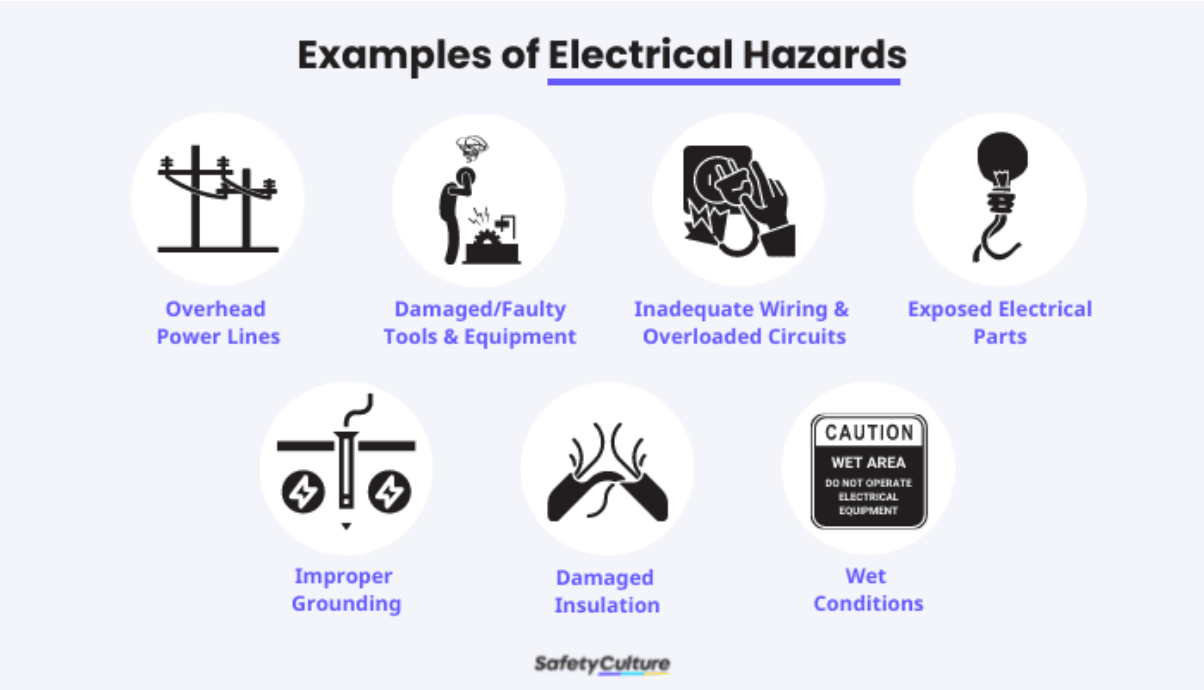


Fig. Examples of Electrical Hazards

1. **Overhead Power Lines**

Overhead powered and energized electrical lines have high voltages which can cause major burns and electrocution to workers. Remember to maintain a minimum distance of 10 feet from overhead power lines and nearby equipment. Conduct site surveys to ensure that nothing is stored under overhead power lines.

In addition, safety barriers and signs must be installed to warn nearby non-electrical workers of the hazards present in the area.

2. **Damaged Tools and Equipment**

Exposure to damaged electrical tools and equipment can be very dangerous. Do not fix anything unless you are qualified to do so. Thoroughly check for cracks, cuts, or abrasions on cables, wires, and cords. In case of any defects, have them repaired or replaced.

Aside from this, Lock Out Tag Out (LOTO) procedures should be performed at all times before commencing electrical maintenance and repairs. LOTO procedures are there to protect all workers on a worksite.

3. **Inadequate Wiring and Overloaded Circuits**

Using wires of inappropriate size for the current can cause overheating and electrical fires to occur. To prevent this, use the correct wire suitable for the operation and the electrical load to work on. Use the correct extension cord designed for heavy-duty use.

Make sure to not overload an outlet and use proper circuit breakers. Perform regular fire risk assessments to identify areas at risk of bad wiring and circuits.

4. **Exposed Electrical Parts**

Examples of exposed electrical parts include temporary lighting, open power distribution units, and detached insulation parts on electrical cords. These hazards can cause potential shocks and burns. Secure these items with proper guarding mechanisms and always check for any exposed parts to be repaired immediately.

5. **Improper Grounding**

The most common OSHA electrical violation is the improper grounding of equipment. Proper grounding can eliminate unwanted voltage and reduce the risk of electrocution. Never remove the metallic ground pin as it is responsible for returning unwanted voltage to the ground.

6. **Damaged Insulation**

Defective or inadequate insulation is a hazard. Be aware of damaged insulation and report it immediately. Turn off all power sources before replacing damaged insulation and never attempt to cover them with electrical tape.

7. **Wet Conditions**

Never operate electrical equipment in wet locations. Water greatly increases the risk of electrocution especially if the equipment has damaged insulation. Have a qualified electrician inspect electrical equipment that has gotten wet before energizing it.

8. **Preventing Hazards Through Electrical Inspections**

Electrical inspections are an essential preventive measure to avoid electrical hazards in the workplace. This procedure helps detect and address potential hazards, reducing the risk of electrical injuries and contributing to a safer working environment. Failure to conduct these inspections regularly can also lead to accidents caused by electric shock or even death.

So how do these inspections aid in preventing electrical hazards? Here's a quick overview to help you get started:

- **Assessing the condition of electrical equipment** – During an electrical inspection, a property's electrical equipment undergoes quality and safety checks to ensure that they are in working condition before being operated.
- **Detecting electrical hazards** – Regular electrical inspections allow electricians to identify faulty wiring, damaged cords, or malfunctioning equipment and carry out the necessary repairs or replacements.

- **Ensuring compliance with safety codes** – These inspections are conducted by electrical servicing companies to make sure that a property follows electrical safety laws and regulations.
- **Evaluating electrical safety procedures** – Electrical inspections provide an overall assessment of the worksite, training provided, and equipment used. These results allow you to identify and bridge any gaps in safety procedures.
- **Recommending corrective actions** – After completing the inspection, inspectors provide recommendations on areas for improvement based on the identified risks and non-compliances. These can range from repairs and replacements to upgrades and safety training.

2.1. Hazards Associated With Electricity

Electricity is widely recognized as a serious workplace hazard, exposing employees to electric shock, burns, fires, and explosions. It is well known that the human body will conduct electricity. If direct body contact is made with an electrically energized part while a similar contact is made simultaneously with another conductive surface that is maintained at a different electrical potential, a current will flow, entering the body at one contact point, traversing the body, and then exiting at the other contact point, usually the ground. Each year many employees suffer pain, injuries, and death from such electric shocks. Current through the body, even at levels as low as 3 milliamperes, can also cause injuries of an indirect or secondary injuries in which involuntary muscular reaction from the electric shock can cause bruises, bone fractures and even death resulting from collisions or falls.

Table 1Current and their causes electric Shock

mA	**Affect on Person**
0.5 – 3	**Tingling sensations**
3 – 10	**Muscle contractions and pain**
10 – 40	**“Let-go” threshold**
30 – 75	**Respiratory paralysis**
100 – 200	**Ventricular fibrillation**
200 – 500	**Heart clamps tight**
1500 +	**Tissue and Organs start to burn**

Burns suffered in electrical accidents can be very serious. These burns may be of three basic types: electrical burns, arc burns, and thermal contact burns. Electrical burns are
the result of the electric current flowing inthe tissues, and may be either skin deep or may

affect deeper layers (such as muscles and bones) or both. Tissue damage is caused by the heat generated from the current flow; if the energy delivered by the electric shock is high, the body cannot dissipate the heat, and the tissue is burned. thermal contact burns are those normally experienced from the skin contacting hot surfaces of overheated electric conductors, conduits, or other energized equipment. In some circumstances, all three types of burns may be produced simultaneously.

If the current involved is great enough, electric arcs can start a fire. Fires can also be created by overheating equipment or by conductors carrying too much current. Extremely high energy arcs can damage equipment, causing fragmented metal to fly in all directions. In atmospheres that contain explosive gases or vapors or combustible dusts, even low-energy arcs can cause violent explosions.

2.2 Nature of Electrical Accidents

Electrical accidents, when initially studied, often appear to be caused by circumstances that are varied and peculiar to the particular incidents involved. However, further consideration usually reveals the underlying cause to be a combination of three possible factors: work involving unsafe equipment and installations; workplaces made unsafe by the environment; and unsafe work practice. The first two factors are sometimes considered together and simply referred to as unsafe conditions. Thus, electrical accidents can be generally considered as being caused by unsafe conditions, unsafe work performance or, in what is usually the case, combinations of the two. It should also be noted that inadequate maintenance can cause equipment or installations that were originally considered safe to deteriorate, resulting in an unsafe condition.

1.3 Single /three electronic power control circuits

Introduction to power electronics:

Power Electronics is a field which combines Power (electric power), Electronics and Control systems. Power engineering deals with the static and rotating power equipment for the generation, transmission and distribution of electric power. Electronics deals with the study of solid state semiconductor power devices and circuits for Power conversion to meet the desired control objectives (to control the output voltage and output power). Power electronics may be defined as the subject of applications of solid-state power semiconductor devices (Thyristors) for the control and conversion of electric power. Power electronics deals with the study and design of Thyristor’s power controllers for variety of application like Heat control, Light/Illumination control, Motor control - AC/DC motor drives used in industries, High

voltage power supplies, Vehicle propulsion systems, High voltage direct current (HVDC) transmission.

Power Electronics refers to the process of controlling the flow of current and voltage and converting it to a form that is suitable for user loads. The most desirable power electronic system is one whose efficiency and reliability is 100%.

Take a look at the following block diagram. It shows the components of a Power Electronic system and how they are interlinked.

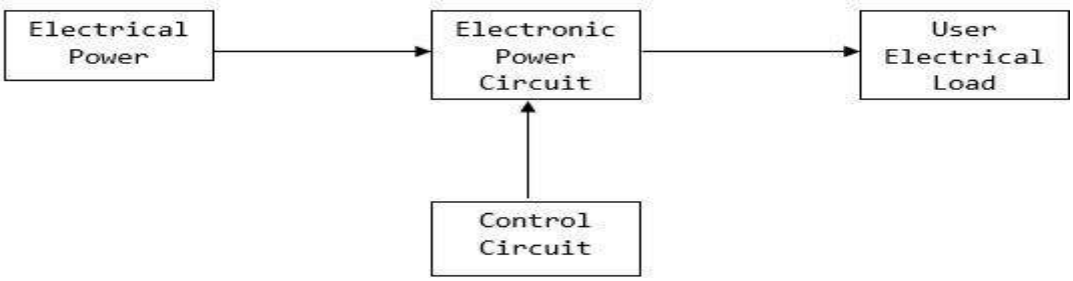


Figure. Block diagram of DC power supply

A power electronic system converts electrical energy from one form to another and ensures the following is achieved −

Maximum efficiency	Minimum cost
Maximum reliability	Least weight
Maximum availability	Small size

Applications of Power Electronics are classified into two types Static Applications and Drive

Static Applications

This utilizes moving and/or rotating mechanical parts such as welding, heating, cooling, and electro- plating and DC

powerDC Power Supply



Figure. Block diagram of DC power supply

Drive applications have rotating parts such as motors. Examples include compressors, pumps, conveyer belts and air conditioning systems.

Air Conditioning System

Power electronics is extensively used in air conditioners to control elements such as compressors. A schematic diagram that shows how power electronics is used in air conditioners is shown below.

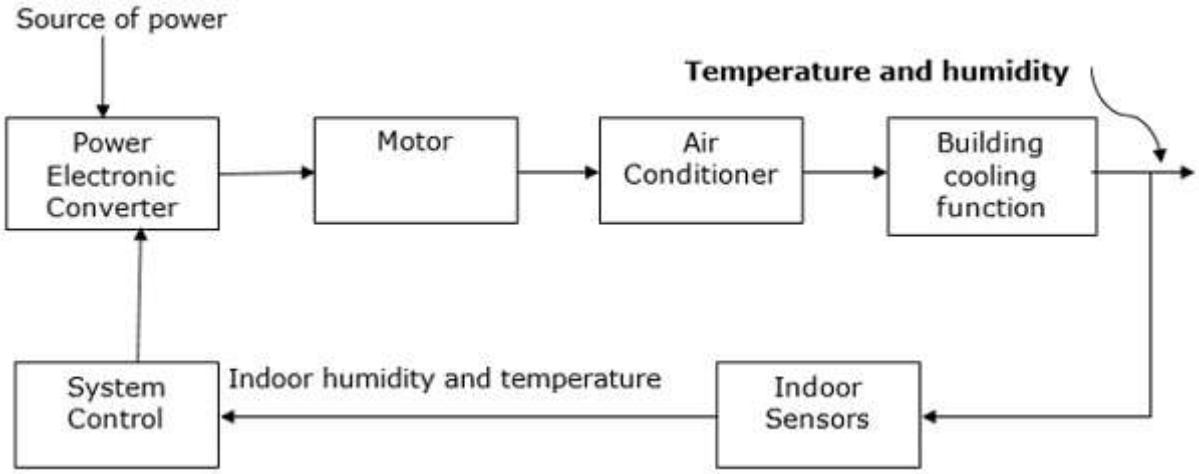


Figure: 1.3. Block diagram of Air Conditioning System

Power electronic applications

Commercial applications Heating Systems Ventilating, Air Conditioners, Central Refrigeration, Lighting, Computers and Office equipment, Uninterruptible Power Supplies (UPS), Elevators, and Emergency Lamps

Domestic applications Cooking Equipment's, Lighting, Heating, Air Conditioners, Refrigerators & Freezers, Personal Computers, Entertainment Equipment's, UPS

Industrial applications Pumps, compressors, blowers and fans Machine tools, arc furnaces, induction furnaces, lighting control circuits, industrial lasers, induction heating, welding equipment

Aerospace applications Space shuttle power supply systems, satellite power systems, aircraft power systems.

Telecommunications Battery chargers, power supplies (DC and UPS), mobile cell phone battery chargers

Transportation Traction control of electric vehicles, battery chargers for electric vehicles, electric locomotives, street cars, trolley buses, automobile electronics including engine controls

Utility systems High voltage DC transmission (HVDC), static VAR compensation (SVC), Alternative energy sources (wind, photovoltaic), fuel cells, energy storage systems, induced draft fans and boiler feed water pumps

Types of power electronic converters

1. Rectifiers (AC to DC converters): These converters convert constant ac voltage to variable dc output voltage.
2. Choppers (DC to DC converters): Dc chopper converts fixed dc voltage to a controllable dc output voltage.
3. Inverters (DC to AC converters): An inverter converts fixed dc voltage to a variable ac output voltage.
4. AC voltage controllers: These converters converts fixed ac voltage to a variable ac output voltage at same frequency.
5. Cycloconverters: These circuits convert input power at one frequency to output power at a different frequency through one stage conversion.

Power semiconductor devices

- Power Diodes.
- Power transistors (BJT's).
- Power MOSFETS.
- IGBT's.
- Thyristors

Thyristors are a family of p-n-p-n structured power semiconductor switching devices

Power diodes

Power diodes are made of silicon p-n junction with two terminals, anode and cathode. P-N junction is formed by alloying, diffusion and epitaxial growth. Modern techniques in diffusion and epitaxial processes permit desired device characteristics. The diodes have the following advantages High mechanical and thermal reliability High peak inverse voltage Low reverse current Low forward voltage drop High efficiency Compactness.

Power transistors

Power transistors are devices that have controlled turn-on and turn-off characteristics. These devices are used a switching device and are operated in the saturation region resulting in low on-state voltage drop. They are turned on when a current signal is given to base or control terminal. The transistor remains on so long as the control signal is present. The switching speed of modern transistors is much higher than that of thyristors and is used extensively in dc-dc and dc-ac converters. However, theirvoltage and current ratings are lower than those of thyristors and are therefore used in low to medium power applications. Power transistors are

classified as follows o Bipolar junction transistors (BJTs) o Metal-oxide semiconductor filed-effect transistors (MOSFETs) o Static Induction transistors (SITs) o Insulated-gate bipolar transistors (IGBTs)

Advantages of BJT'S

- BJT's have high switching frequencies since their turn-on and turn-off time are low.
- The turn-on losses of a BJT are small.
- BJT has controlled turn-on and turn-off characteristics since base drive control is possible.
- BJT does not require commutation circuits

Demerits of BJT

- Drive circuit of BJT is complex.
- It has the problem of charge storage which sets a limit on switching frequencies.
- It cannot be used in parallel operation due to problems of negative temperature coefficient.

Thyristors – Silicon Controlled Rectifiers (SCR's)

A silicon controlled rectifier or semiconductor-controlled rectifier is a four-layer solidstate current- controlling device. The name "silicon controlled rectifier" is General Electric's trade name for a type of thyristor.

SCRs are mainly used in electronic devices that require control of high voltage and power. This makes them applicable in medium and high AC power operations such as motor control function.

An SCR conducts when a gate pulse is applied to it, just like a diode. It has four layers of semiconductors that form two structures namely; NPNP or PNPN. In addition, it has three junctions labeled as J1, J2 and J3 and three terminals(anode, cathode and a gate). An SCR is diagrammatically represented as shown below.

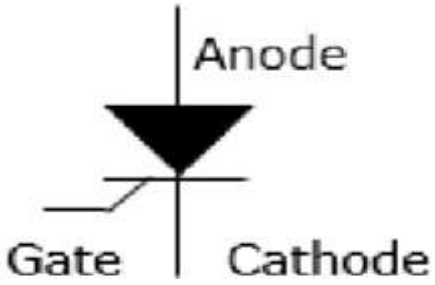


Figure: Symbol of thyristor

The anode connects to the P-type, cathode to the N-type and the gate to the P-type as shown below.

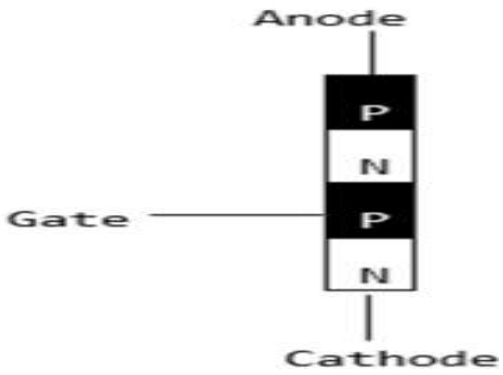


Figure. Structure of thyristor

In an SCR, the intrinsic semiconductor is silicon to which the required dopants are infused. However, doping a PNPN junction is dependent on the SCR application.

Modes of Operation in SCR

OFF state (forward blocking mode) − Here the anode is assigned a positive voltage, the gate is assigned a zero voltage (disconnected) and the cathode is assigned a negative voltage. As a result, Junctions J1 and J3 are in forward bias while J2 is in reverse bias. J2 reaches its breakdown avalanche value and starts to conduct. Below this value, the resistance of J1 is significantly high and is thus said to be in the off state.

ON state (conducting mode) − An SCR is brought to this state either by increasing the potential difference between the anode and cathode above the avalanche voltage or by applying a positive signal at the gate. Immediately the SCR starts to conduct, gate voltage is no longer needed to maintain the ON state and is, therefore, switched off by −

- Decreasing the current flow through it to the lowest value called holding current
- Using a transistor placed across the junction.

Reverse blocking − This compensates the drop in forward voltage. This is due to the fact that a low doped region in P1 is needed. It is important to note that the voltage ratings of forward and reverse blocking are equal.

Characteristics of Thyristor

A thyristor is a four layer 3 junction p-n-p-n semiconductor device consisting of at least three p-n junctions, functioning as an electrical switch for high power operations. It has three basic terminals, namely the anode, cathode and the gate mounted on the semiconductor layers of

the device. The symbolic diagram and the basic circuit diagram for determining the Page **21** of **83**characteristics of thyristor is shown in the figure below,

V-I Characteristics of a Thyristor

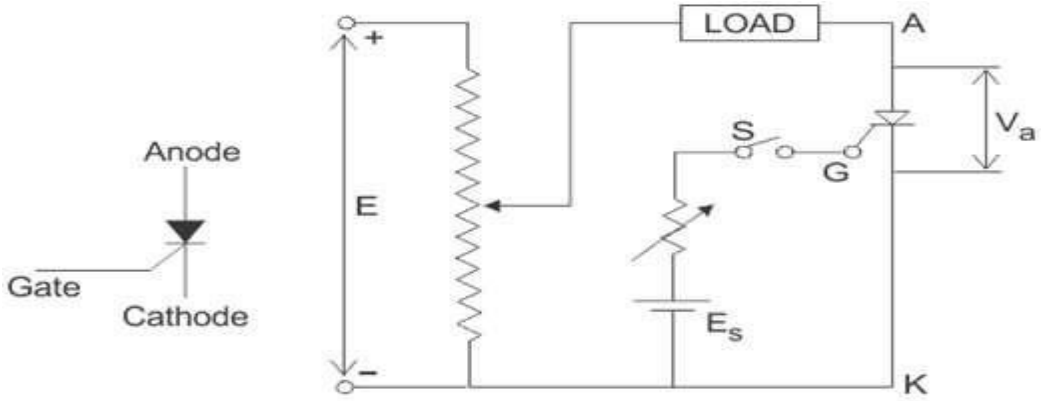


Figure. Circuit diagram for characteristics of SCR

From the circuit diagram above we can see the anode and cathode are connected to the supply voltage through the load. Another secondary supply E_s is applied between the gate and the cathode terminal which supplies for the positive gate current when the switch S is closed. On giving the supply we get the required V-I characteristics of a thyristor show in the figure below for anode to cathode voltage $V_a$and anode current I_a as we can see from the circuit diagram. A detailed study of the characteristics reveal that the thyristor has three basic modes of operation, namely the reverse blocking mode, forward blocking (off-state) mode and forward conduction (on-state) mode. Which are discussed in great details below, to understand the overall characteristics of a thyristor.

Single phase half wave rectifier converts AC voltage to DC voltage. It requires only one diode for rectification.

The rectifier is the device that converts alternating current(AC) into direct current(DC). The alternating current periodically reverses its direction whereas the direct current does not periodically change its direction.

What is Half-Wave Rectifier

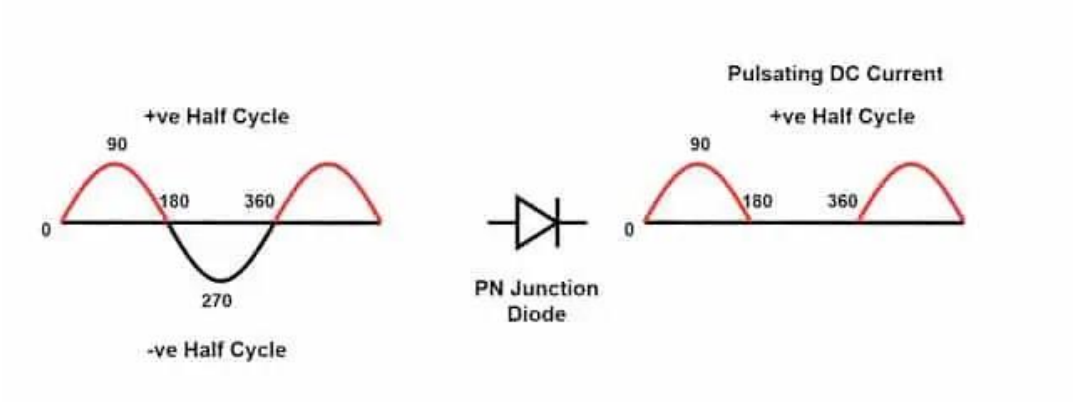
The half wave rectifier passes one half cycle of the alternating current and blocks the other half cycle. Thus in one complete cycle of the AC waveform, the half-cycle is passed. In a half wave rectifier, only one diode is used to convert AC into DC.

Single Phase Half Wave Rectifier Theory

Now, we will discuss the theory of single phase half wave rectifier.

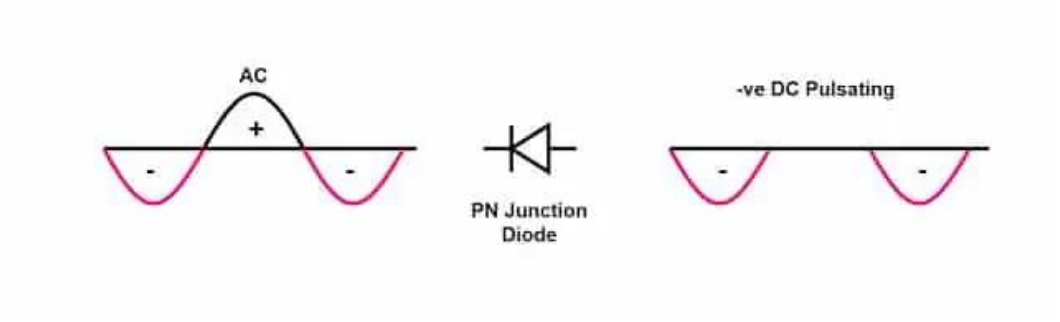
How does Single Phase Half-Wave Rectifier functions?

The main part of half wave rectifier is the diode. The diode conducts if the anode voltage is more than the cut-in voltage of the diode. The cut-in voltage of silicon and germanium diode is 0.7 and 0.3 Volts respectively. If the anode voltage is more than 0.7 volts, the diode starts conducting. In power electronics, silicon diodes are generally used because they have a low forward resistance which makes them suitable for delivering high forward current.



During one positive half cycle, the diode conducts and passes the waveform for the period from o to π. The diode does not conduct for the period from π to 2π because the anode potential is less than the cut-in voltage of the diode. The output waveform of the diode is the DC voltage since it has positive pulses. The output DC waveform has more ripples and it is not smooth.

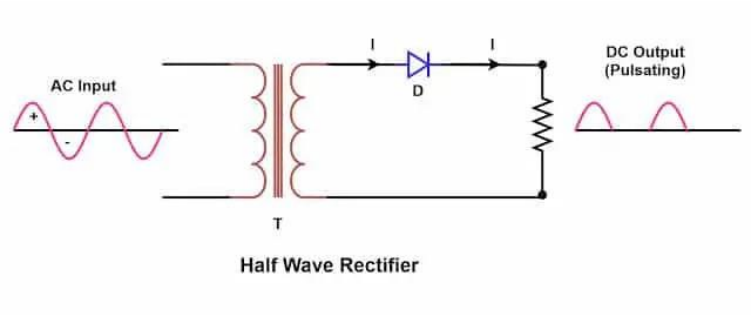
We can get negative DC voltage by making the diode conduct during the negative half cycle of the AC waveform.



The diode conducts during the negative half cycle of the AC waveform. During the positive half cycle, the diode is in reverse bias and no current flows through the diode.

Circuit Diagram of Half Wave Rectifier

The circuit diagram of Half wave rectifier is as shown below.



Half Wave Rectifier

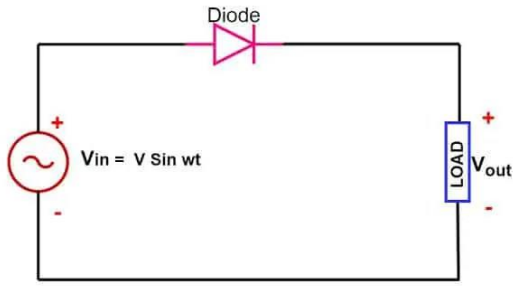
The half wave rectifier circuit consists of three main parts.

Transformer

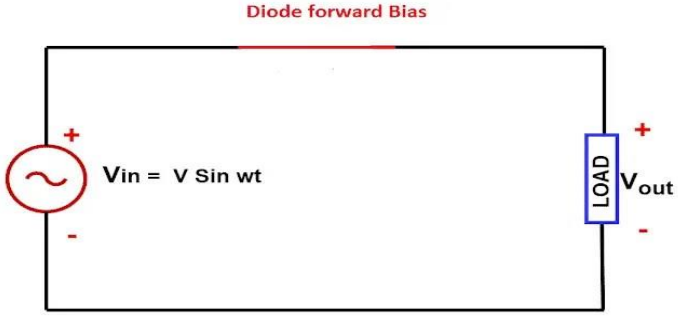
Diode

Resistive Load

The voltage is applied at the primary side of the transformer. The low voltage is induced in the secondary of the transformer according to the turns ratio of the transformer. The voltage is reduced to get desired DC voltage. The simplified equivalent secondary circuit of the rectifier is as below.



During the positive half cycle of the AC waveform, the voltage at the anode of the diode is more than its cut-in voltage and the diode becomes forward biased and starts conducting. Thus in the positive half cycle diode remains in the conducting state and current flows through the diode. The diode has very low forward resistance during its forward biasing state, and the diode behaves as a short circuit, considering zero forward resistance.



The diode stops conducting when the AC waveform crosses zero and goes towards the negative half cycle. During the negative half cycle, the diode is in reversed bias and no current flows through the diode. During the negative half cycle, the diode is an open circuit. The half wave rectifier equivalent circuit is as given below.



During the negative half cycle, the reverse resistance of the diode is very high and it acts as an open circuit and, the diode does not allow current to pass through it.

Single Phase Half Wave Rectifier Formulas

We will discuss how the various formulas of half wave rectifier used for assessing the rectifier performance.

Average value or DC value of Single Phase Half Wave Rectifier

We can calculate the average or effective DC output of half wave rectifier by taking the average of the DC output voltage. The instantaneous value of current at the output of the rectifier is $i=I_m Sin\omega t$. The average load current across the load resistance is equal to:

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} I_m Sin\omega t$$

$$I_{dc} = \frac{I_m}{2\pi}\int_0^{2\pi} Sin\omega t$$

$$I_{dc} = \frac{I_m}{\pi}$$

Or

$$V_{dc} = \frac{V_m}{\pi}$$

RMS Value of Single Phase Half Wave Rectifier

For a half-wave rectifier, the RMS load current (Irms) is equal to the average current (IDC) multiple by π/2. Hence the RMS value of the load current (Irms) for a half wave rectifier is:

$$I_{rms} = \frac{I_m}{2}$$

I_{rms} is the peak instantaneous current across the load.

Ripple Factor of single Phase Half Wave Rectifier

The ripple factor shows the effectiveness of rectification. The output of the rectified DC has an AC component as well. The AC component is undesirable in the rectified DC output and the AC component available in the rectified DC is ripple. It is practically impossible to eliminate the AC component in the rectified DC output. However, the lesser ripples in the rectified waveform make the output DC smoother.

Ripple factor is the ratio of AC component available in the rectifier output to the average value of DC output.

$$Ripple\ Factor\ \gamma = \frac{RMS\ Value\ of\ AC\ component\ availble\ in\ Rectifier\ output}{Average\ Value\ of\ DC\ Output}$$

We can express the ripple Factor of the Half Wave Rectifier by the following mathematical expression.

$$\textbf{Ripple Factor } \gamma = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

$$I_{rms} = \frac{I_m}{2}$$

$$I_{dc} = \frac{I_m}{\pi}$$

$$\textbf{Ripple Factor } \gamma = \sqrt{\left(\frac{\frac{I_m}{2}}{\frac{I_m}{\pi}}\right)^2 - 1}$$

$$\textbf{Ripple Factor } \gamma = 1.21$$

The ripple factor of the half wave rectifier is 1.21. It is possible to lower the ripples by the installation of a capacitor and inductor as a filter circuit.

Form Factor

The ratio of RMS value and the average value is the form factor.

$$\textbf{Form Factor} = \frac{V_{rms}}{V_{av}} \text{ or } \frac{I_{rms}}{I_{av}}$$

$$\textbf{Form Factor} = \frac{V_{rms}}{V_{av}}$$

$$\textbf{Form Factor} = \frac{\frac{Vm}{2}}{\frac{V_m}{\pi}}$$

$$\textbf{Where } V_m \textbf{ is the peak value of AC volatge}$$

$$\textbf{Form Factor} = \frac{\pi}{2} = 1.57$$

Efficiency of Half Wave Rectifier

The ratio of output DC power to the input AC power is the rectifier efficiency. The formula for the efficiency is equal to:

$$\eta = \frac{P_{dc}}{P_{ac}}$$

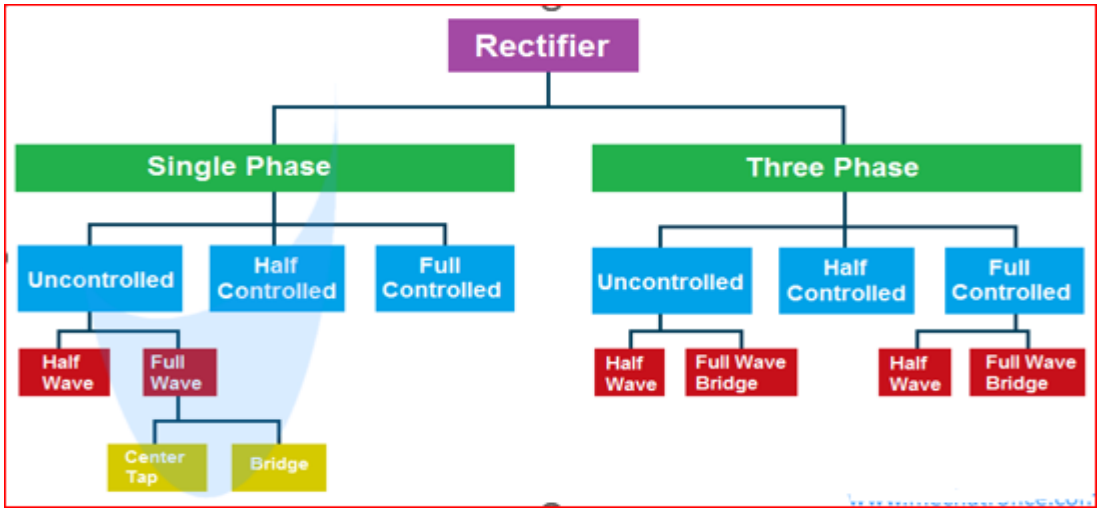
The efficiency of half wave rectifier is equal to 40.6%.

Peak Inverse Voltage of Half Wave Rectifier

The peak inverse voltage of the diode is the maximum voltage that a diode can withstand during reverse bias conditions. If the diode gets voltage above peak inverse voltage(PIV), the diode is apt to fail.

Different Types of Rectifiers – Single & Three Phase

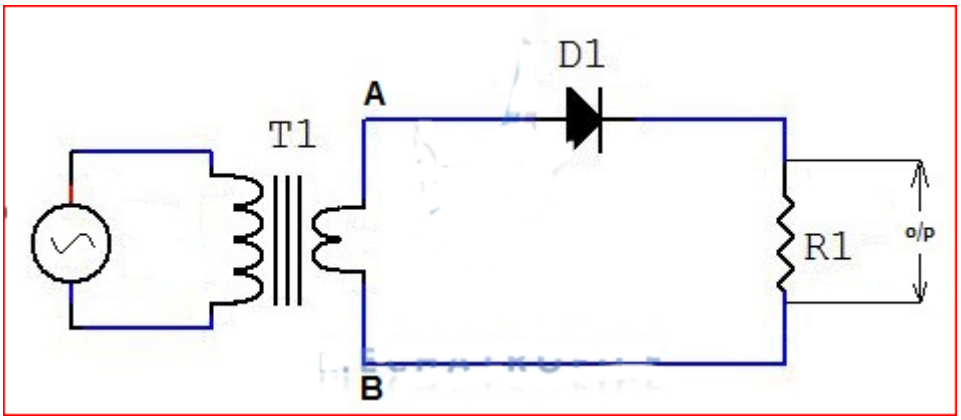
A rectifier is an electronic circuit which converts Alternating Current into Direct Current. Based on the type of input supply, rectification and output it can be classified into different types.



Single Phase Rectifier

Single phase rectifiers are used to convert AC single phase supplies to DC. That is a single phase transformer is used to provide input to the rectifier. Single phase rectifiers are mainly used for low power application like a household appliance, consumer electronic devices, etc.

1φ half-wave rectifier circuit

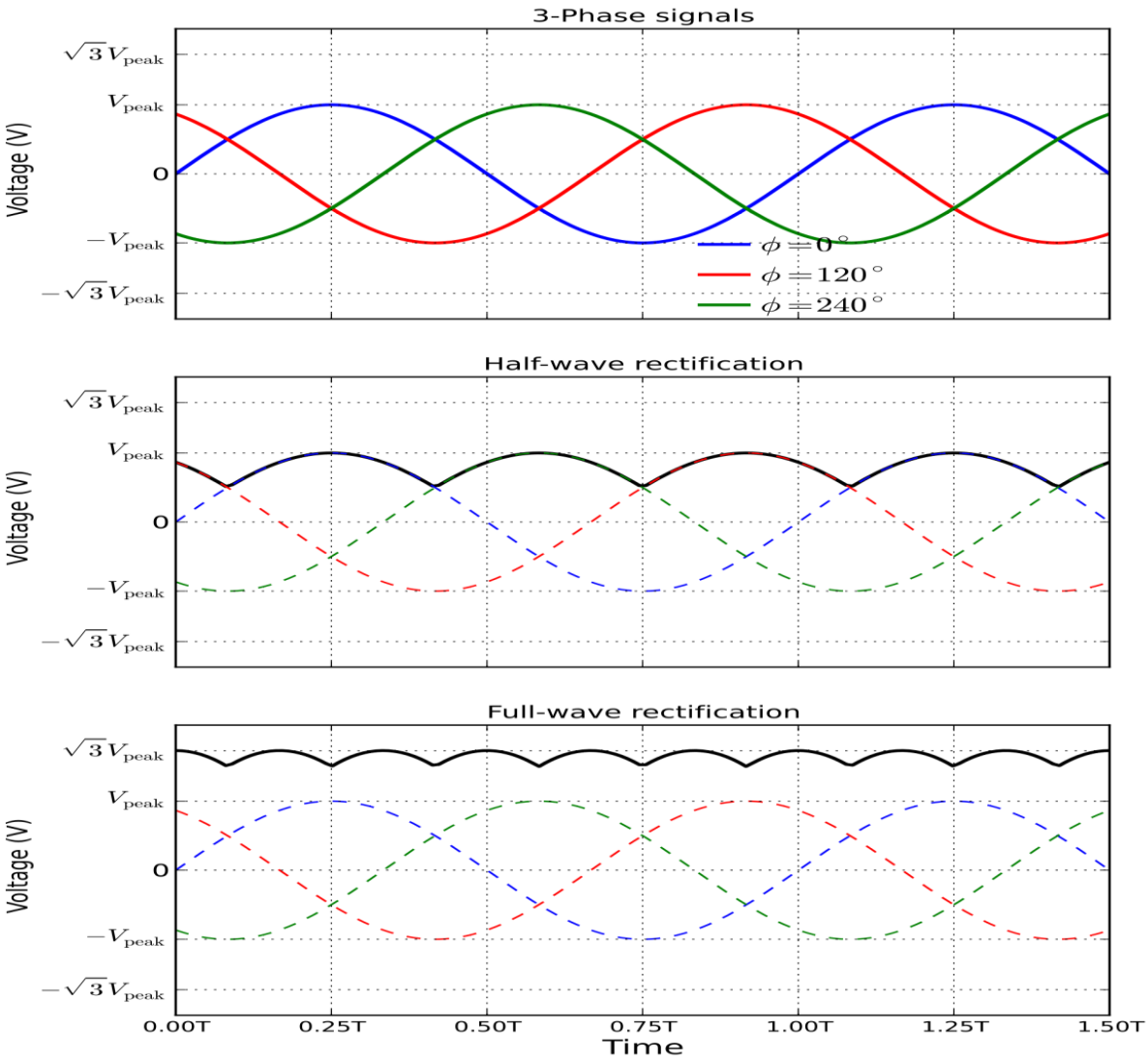


Three Phase Rectifier

A 3Φ Rectifier is an electronic circuit that converts three-phase AC supply into unidirectional DC output. 3 phase rectifiers are mainly used in industrial and high power applications.

In a three-phase electric power, an alternating current of the same frequency and voltage amplitude are carried through three conductors with a phase difference of 120^{o} degrees between each phase. Whereas a single phase supply is one of the three phases with respect to a neutral or common reference point of the 3 phase lines.

In three phase rectification, the output is obtained from the three phases fed into the rectifier circuit.


3-Phase signals
Voltage (V)
$\sqrt{3}V_{peak}$
V_{peak}
0
$-V_{peak}$
$-\sqrt{3}V_{peak}$
$\phi = 0°$
$\phi = 120°$
$\phi = 240°$
Half-wave rectification
Full-wave rectification
0.00T
0.25T
0.50T
0.75T
1.00T
1.25T
1.50T
Time

Single phase & Three phase rectifier comparison

Single Phase Rectifier	Three Phase Rectifier
▪ Input is a two-wire supply. ▪ Low power delivery. ▪ Low efficiency. ▪ Ripple factor is high. ▪ The maximum output voltage is the maximum phase to neutral potential. ▪ Less TUF (Transformer Utilization factor). ▪ Additional filters are required. ▪ Low PIV (peak inverse voltage).	▪ Input is three wire or four wire supply(3 phase line and one neutral). ▪ High power delivery. ▪ High Efficiency. ▪ Ripple factor is less. ▪ The maximum output voltage is the maximum phase to phase potential. ▪ More TUF. ▪ No additional filters are required. ▪ High PIV.

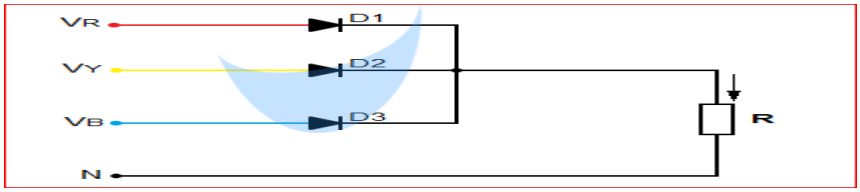
Uncontrolled

An uncontrolled rectifier circuit is the general purpose rectifier circuits using diodes only. The diode rectifiers have no control over the output voltage hence called uncontrolled rectifiers.

Half Wave

A half wave rectifier is a type of rectifier which converts only positive half cycle of the input AC into pulsating DC.

An uncontrolled 3 Phase half-wave rectifier circuit



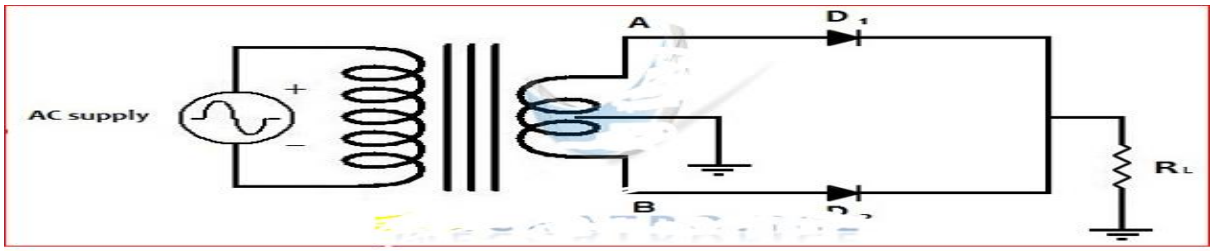
Here in the circuit 3 phase are connected to the anode of three diodes D1, D2, and D3. The cathode of all three diodes is connected to the one terminal of the load. The other terminal of the load is connected to the neutral. Hence, the maximum output voltage across the load is the maximum peak voltage of the phase line with respect to the neutral point which is ideally zero volts.

The diodes D1, D2, D3 alternatively conducts in respective to the phase change. The instantaneous output voltage will be equal to the voltage of the phase line which has the highest potential.

Full Wave

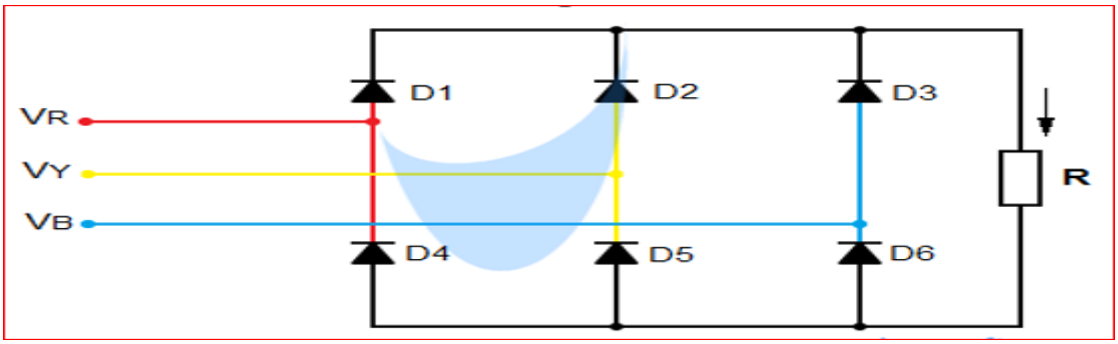
A Full Wave Rectifier is a rectifier circuit which converts both half cycles of the AC input into a pulsating DC.

Uncontrolled single phase full wave center tap rectifier circuit



The below 3 phase bridge rectifier circuit consists of six diodes. In a full wave rectifier, the voltage across the load is the voltage between two phases.

3φ Uncontrolled full wave bridge rectifier circuit



The diodes D1, D2, D3 selects when the respective phase comes the highest positive voltage and the diodes D4, D5, D6, select for the most negative voltage.

Half Controlled

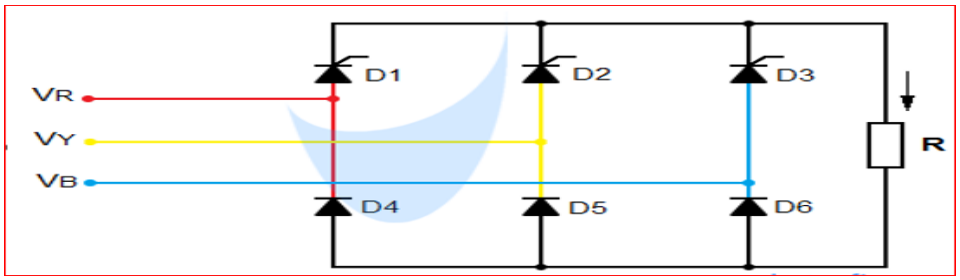
Controlled rectifiers are a type of Phase controlled rectifiers which has control over the output using thyristors or SCRs. In this type of rectifiers, the output voltage of the rectifier can be regulated by controlling the triggering of the thyristor.

A thyristor or SCR is a multi-layer semiconductor device consists of three terminals anode, cathode, and gate. It functions as an electrically controlled switching device. It conducts only in one direction and always blocks the reverse current.

During reverse bias, a thyristor blocks the reverse current in the same way as a reverse biased diode works. But during the forward bias, it does not conduct as like a normal diode. In order to switch ON or trigger the SCR into conduction, a small amount of current is needed to be applied at its gate terminal. And on triggering the current starts to flows from Anode to Cathode.

The gate pulse is required just for triggering the device, once the SCR is triggered it remains in the conducting state regardless of the gate current after that. The SCR turns OFF when the forward current drops below its threshold value or by a negative gate current. In the rectifier circuit, the SCR turns off as the voltage reverses in the next half cycle.

Half Controlled 3 phase full wave bridge rectifier circuit

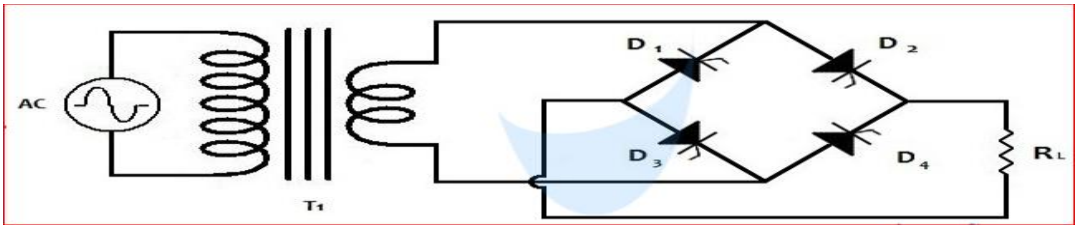


A half controlled rectifier consists of an equal number of thyristors and diodes, that is the total number of rectifier components are included of half number of SCR and half number of diodes. It means, a single phase half controlled bridge rectifier is made of 2 diodes and 2 SCRs; that is simply 2 diodes in an uncontrolled rectifier is replaced by two thyristors.

Full Controlled

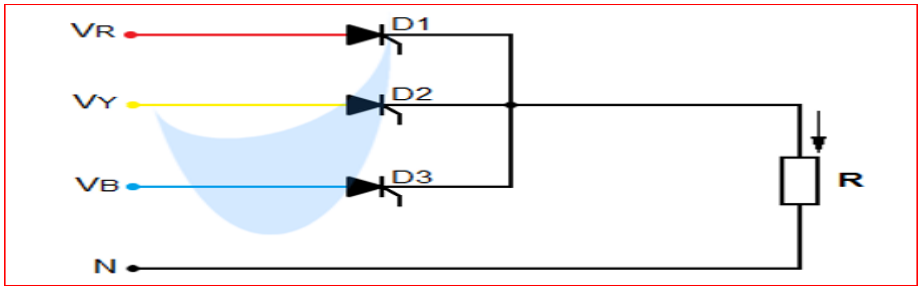
In a Full Controlled Rectifier, all the components in the rectifier are switching devices which are controlled by an external pulse.

A full Controlled single phase full wave bridge rectifier circuit



The output regulation in a controlled rectifier is done by adjusting the firing angle or the time delay of the triggering pulse. By controlling the gate pulse the SCR can be switched ON at different angles of the phase and thereby phase of each half cycles can be controlled.

Full Controlled 3 phase half wave rectifier circuit



Half Wave Diode Rectifier Applications

Power rectification: We use Half wave rectifier for rectification of AC to get DC Voltage.

Signal demodulation: Through process of demodulation, it is possible to recover the original signal sent from the transmitter end. A half wave rectifier is the best choice for demodulation of modulated signals.

Signal peak detector: The simple half wave diode detector can detect the peak value of a waveform. Therefore, we use it as a peak detector.

Advantages of Half Wave Rectifier

The half wave rectifier is very simple in construction. The half wave rectifier has very few numbers of components.

Lower number of components

Cheaper

Disadvantages of Half Wave Rectifier

It rectifies only half wave of AC, and it filters the the other half- cycle. Therefore, its efficiency is very low about (40%).

The output DC voltage is low.

The output DC contains more ripples and thus the output is not purely DC.

Solved Problems on Single Phase Half wave Rectifier

Example No. 1

The applied input power to a half wave rectifier is 200 watts. The DC power output of the rectifier is 80 Watts. What is the efficiency of the rectifier? Rectification efficiency =pout/pin*100=80/200=40

Example No. 2

An ac supply v= 60 Sin ωt is applied to half wave rectifier. The internal resistance of the diode(r_f)is 20 Ω and load resistance is 600 Ω. Calculate – (1) Ac Power Input (2) DC power Output (3) Efficiency of rectification

$$Maximum\ or\ Peak\ Value\ Voltage\ , V_m = 60\ Volts$$

$$Maximum\ or\ Peak\ Value\ Current, I_m = \frac{V_m}{r_f + r_l}$$

$$Maximum\ or\ Peak\ Value\ Current, I_m = \frac{60}{20 + 600} = 0.0967\ Amp.$$

$$Maximum\ or\ Peak\ Value\ Current, I_m = 96.77\ mA$$

$$DC\ Current, I_{dc} = \frac{I_m}{\pi} = \frac{96.77}{\pi} = 30.81\ mA$$

$$RMS\ Current, I_{rms} = \frac{I_m}{2} = \frac{96.77}{2} = 48.38\ mA$$

$$ac\ power\ input = I_{rms}^2\ X\ (r_f + r_l) = \left(\frac{48.38}{1000}\right)^2 X(20 + 600)$$

$$= 1.45\ Watts$$

$$dc\ power\ input = I_{dc}^2\ X\ (r_f + r_l) = \left(\frac{30.81}{1000}\right)^2 X(20 + 600)$$

$$= 0.58\ Watts$$

$$Rectification\ Efficiency = \frac{P_{dc}}{P_{ac}} = \frac{0.58}{1.45} = 40\ \%$$

Example No. 3 an ac supply of 230 volt is applied to step down transformer of 230/15 volts whose secondary is connected to the half wave rectifier.

Find (1) the output dc voltage

(2) PIV of diode

$$RMS\ value\ of\ Tr.Secondary\ Voltage, Vrms = 15\ Volts$$

$$Peak\ or\ Max.Secondary\ Voltage, V_m = V_{rms}\ X\sqrt{2} = 15\ X\sqrt{2}$$

$$= 21.21\ V$$

$$\boldsymbol{DC\ output = \frac{V_m}{\pi} = \frac{15\ X\ \sqrt{2}}{\pi} = 6.75\ Volts}$$

$$\boldsymbol{Peak\ Inverse\ Voltage\ (PIV) of\ diode = V_m = 21.21\ Volts}$$

Classification of Rectifiers

Rectifiers have evolved to a mature state. There have been many rectifier topologies since the evolution of diodes and thyristors. Uncontrolled or line-commutated rectifiers usually consist of diodes. Most diode rectifiers have fixed frequency input AC voltages, fixed DC output

voltage. Controlled rectifiers or Phase-control rectifiers have control on switching devices and usually

consist of thyristors where the thyristors act as a switch and have two states: ON state and OFF state (i.e. achieved by providing suitable gate trigger pulse). In the case of diode rectifiers, load current flows when diodes conduct and in the case of phase rectifiers, the load current flows when the thyristors conduct. Fig. 2.2 shows an attempt to classify the rectifiers based on their operational control **.**

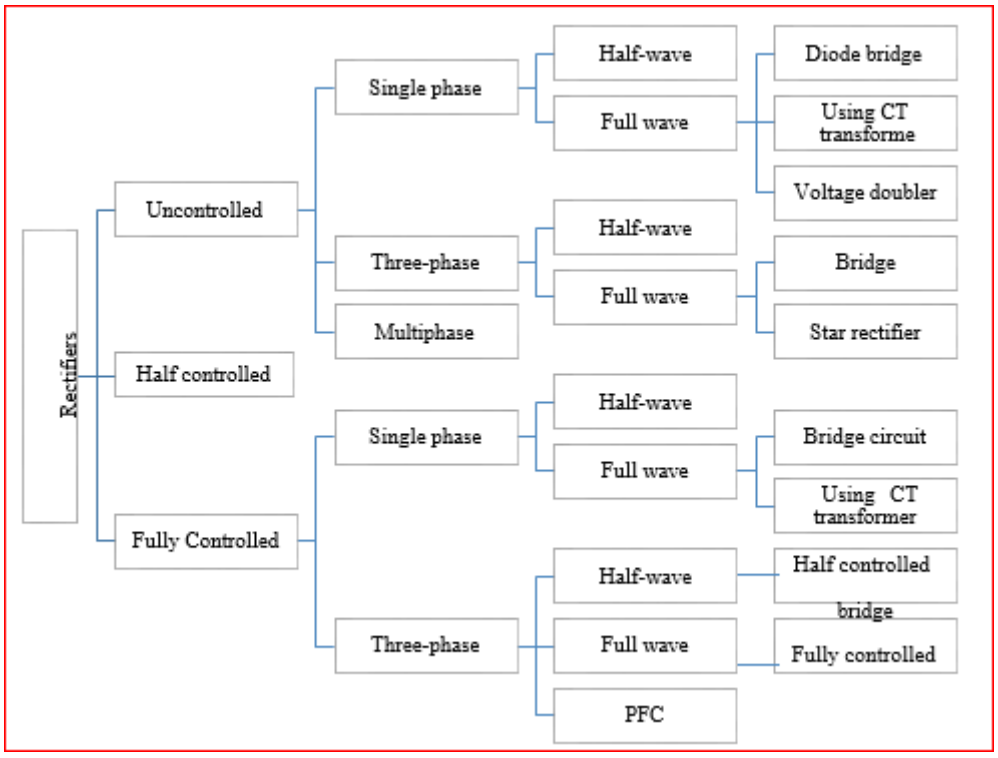


Fig. 2.2: Rectifier Classification

as part from these two categories shown Fig. 2.2, there are many hybrid rectifier constructions proposed by researchers, which are popular in the industry. Traditional rectifiers are usually constructed using diodes. These diode rectifiers are also vital in the home and in industrial equipment to feed in- between DC link to electronic circuitry. problems in single /three electronic power control circuits

problems in single/three-phase half-controlled bridge rectifier are listed as followed

1.4.1. Voltage ripple:

Half-controlled bridge rectifiers can produce high voltage ripple due to the presence of harmonics in the rectified output waveform. This can lead to poor voltage regulation and increased stress on downstream components.

Voltage ripple refers to the fluctuation or variation in the output voltage of a power supply or rectifier circuit. It is characterized by periodic oscillations or small amplitude variations superimposed on the **DC voltage**. Voltage ripple is typically undesirable, as it can affect the performance and reliability of electronic devices connected to the power supply. Here's some information on voltage ripple:

Causes of voltage ripple: Voltage ripple can be caused by various factors, including the switching action of semiconductor devices (such as diodes or thyristors) in the rectifier circuit, the filtering characteristics of capacitors used to smooth the output, and the load conditions. Inadequate filtering or high-frequency components in the input power can also contribute to voltage ripple.

Ripple frequency: The frequency of the voltage ripple depends on the rectifier circuit design and the power system frequency. In a full-wave rectifier using diodes or thyristors, the ripple frequency is twice the power system frequency (i.e., 100 Hz for a 50 Hz power system). In other rectifier topologies, such as half-wave rectifiers or bridge rectifiers, the ripple frequency can be the same as the power system frequency.

Ripple amplitude: The amplitude of the voltage ripple is measured as the peak-to-peak variation in voltage. It is typically expressed as a percentage of the DC voltage or as a voltage value. The acceptable ripple amplitude depends on the specific application and the sensitivity of the connected devices. Generally, lower ripple amplitudes are desired for sensitive electronic circuits.

Ripple reduction techniques: To reduce voltage ripple, various techniques can be employed:

Filtering: Adding filtering elements, such as capacitors or inductors, to the output of the rectifier can help smooth out the voltage ripple by attenuating the high-frequency components. The choice of filter components and their values should be selected based on the desired ripple reduction.

Increasing capacitor value: Increasing the capacitance of the output capacitor in the rectifier circuit can improve ripple reduction. A larger capacitor can store more energy and provide better smoothing of the output voltage.

Active ripple control: Using active control techniques, such as feedback control or pulse-width modulation (PWM), can actively compensate for voltage ripple by dynamically adjusting the switching operation of the rectifier circuit.

Multiple stages of filtering: Employing multiple stages of filtering, such as LC filters or cascaded capacitor filters, can further reduce the voltage ripple.

Ripple measurement: Voltage ripple can be measured using an oscilloscope or a power quality analyzer. The instrument should be connected across the output terminals of the power supply or rectifier circuit to capture the voltage waveform. The ripple amplitude and frequency can be determined by analyzing the waveform.

Standards and specifications: Different applications may have specific requirements for voltage ripple. For example, electronic devices like computers or audio equipment may have standards or specifications that define the acceptable level of voltage ripple. It's important to refer to the relevant specifications or guidelines to ensure compliance and optimal performance.

Reducing voltage ripple is crucial in applications where stable and clean power is required, especially in sensitive electronic circuits. Proper design, component selection, and filtering techniques can help minimize voltage ripple and ensure reliable operation of connected devices.

1.4.2. Current harmonics

The use of half-controlled devices introduces harmonics in the input current waveform, which can cause interference with other electronic devices and lead to power quality issues. Additional filtering may be required to mitigate these harmonics.

Identifying current harmonics problems in a system can be done through the following methods:

Power quality monitoring: Conducting power quality monitoring using power analyzers or power quality meters can help identify current harmonics. These devices measure and record various parameters, including total harmonic distortion (THD) of the current. High THD values indicate the presence of significant current harmonics.

Harmonic spectrum analysis: Utilize a spectrum analyzer or harmonic analyzer to analyze the current waveform and identify the presence of harmonics. These instruments provide a detailed breakdown of the harmonics present in the current waveform, including their magnitude and frequency components.

Current waveform analysis:

Use an oscilloscope to capture the current waveform and visually inspect it for any distortion, non-sinusoidal behavior, or irregularities. Harmonics appear as additional frequency components superimposed on the fundamental frequency.

Harmonic distortion calculation:

Calculate the THD value by measuring the RMS (root mean square) value of the harmonic currents and comparing it to the RMS value of the fundamental current. The THD is expressed as a percentage and provides an indication of the severity of current harmonics.

Compliance with standards:

Compare the measured current harmonics with the limits specified in relevant standards or guidelines, such as IEEE 519 or IEC 61000-3-2. These standards define acceptable levels of harmonics in power systems and can help determine if the current harmonics are within acceptable limits.

Equipment malfunction or overheating:

Current harmonics can lead to equipment malfunctions, overheating, and increased losses. Monitoring the performance and temperature of equipment connected to the system can reveal signs of harmonic-related problems.

Harmonic impedance measurement:

By injecting a known harmonic voltage signal into the system and measuring the resulting harmonic currents, the harmonic impedance can be determined. Higher harmonic impedance values indicate a higher sensitivity to harmonic currents and can help identify potential problem areas.

1.4.3. Commutation overlap

In half-controlled rectifiers, there is a brief period during each half-cycle where both the upper and lower devices of a phase-leg are simultaneously conducting. This overlap can cause high currents to flow through the devices, leading to increased losses and potential device failure if not properly managed.

current harmonics problems in a system can be done through the following

Identifying commutation overlap problems in a fully controlled rectifier can be done through the following methods:

(a) Observing the thyristor currents:

Use current probes or current sensors to monitor the individual thyristor currents during the commutation process. If there is commutation overlap, you will observe a period where both the upper and lower devices of a phase-leg are conducting simultaneously, resulting in a higher total current than expected.

(b) Voltage waveform analysis:

Analyze the voltage waveform across the thyristors during the commutation process using an oscilloscope. Look for any overlapping periods where both the incoming and outgoing thyristors are conducting simultaneously. This can indicate commutation overlap.

(c) Gate signal monitoring:

Monitor the gate signals applied to the thyristors during the commutation process. If there is commutation overlap, you may observe instances where the gate signals of both the incoming and outgoing thyristors overlap, causing both devices to conduct simultaneously.

(d) Power loss analysis:

Measure the power losses in the rectifier circuit during the commutation process. Excessive losses or higher-than-expected losses can indicate commutation overlap. This can be done by measuring the voltage and current waveforms across various components, such as the thyristors and snubber circuits, and calculating the power losses using appropriate formulas.

(e) Temperature monitoring

Use thermal sensors or thermal imaging cameras to monitor the temperature of the thyristors and associated components during operation. If there is commutation overlap, it can lead to increased heat generation, resulting in higher temperatures in the affected components.

(f) Simulation and modeling

Utilize simulation software, such as circuit simulation tools or power system analysis software, to model the rectifier circuit and simulate the commutation process. By analyzing the simulated waveforms and parameters, you can identify instances of commutation overlap and evaluate its effects on the system.

It's important to note that commutation overlap can have adverse effects on the performance and reliability of the rectifier circuit, such as increased losses, higher current stresses, and potential device failure. If commutation overlap is identified, it is crucial to review the control and firing angle settings, gate drive circuitry, and overall circuit design to rectify the issue.

1.4.4. Thyristor failure:

Thyristors used in half-controlled bridge rectifiers are susceptible to failure due to overvoltage or overcurrent conditions. Incorrect triggering, voltage transients, or short circuits in the load can cause excessive stress on the thyristors, resulting in their failure.

Temperature monitoring: Use thermal sensors or thermal imaging cameras to monitor the temperature of the thyristors and associated components during operation. If there is

commutation overlap, it can lead to increased heat generation, resulting in higher temperatures in the affected components.

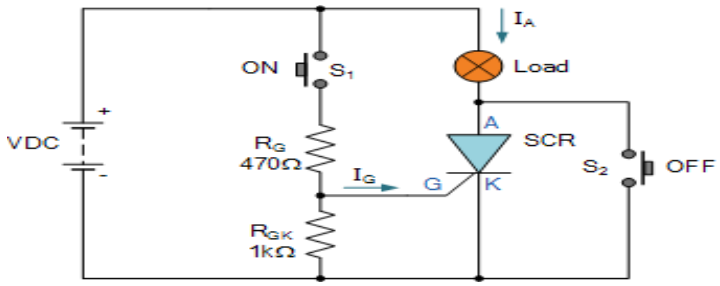


Fig Thyristor Circuit

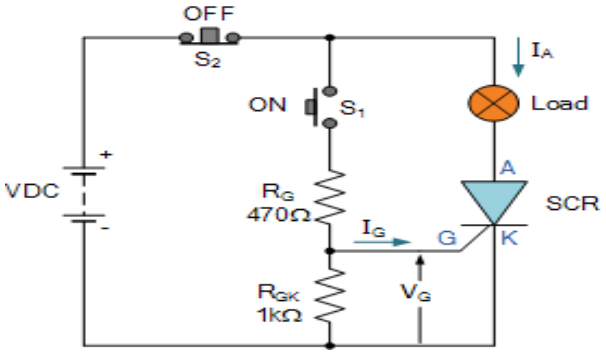
Thyristors are high-speed solid-state devices which can be used to control motors, heaters and lamps

Thyristors are semiconductor devices that are specifically designed for use in high-power switching applications and do not have the ability of an amplifier. Thyristors can operate only in a switching mode, acting like either an open or closed switch. Once triggered into conduction by its gate terminal, a thyristor will remain conducting (passing current) always. Therefore in DC circuits and some highly inductive AC circuits the current has to be artificially reduced by a separate switch or turn off circuit.

DC Thyristor Circuit

When connected to a direct current DC supply, the thyristor can be used as a DC switch to control larger DC currents and loads. When using the Thyristor as a switch it behaves like an electronic latch because once activated it remains in the "ON" state until manually reset. Consider the DC thyristor circuit below.

DC Thyristor Switching Circuit



This simple "on-off" thyristor firing circuit uses the thyristor as a switch to control a lamp, but it could also be used as an on-off control circuit for a motor, heater or some other such DC load. The thyristor is forward biased and is triggered into conduction by briefly closing

the normally-open "ON" push button, S_1 which connects the Gate terminal to the DC supply via the Gate resistor, R_G thus allowing current to flow into the Gate. If the value of R_G is set too high with respect to the supply voltage, the thyristor may not trigger.

Once the circuit has been turned-"ON", it self latches and stays "ON" even when the push button is released providing the load current is more than the thyristors latching current.

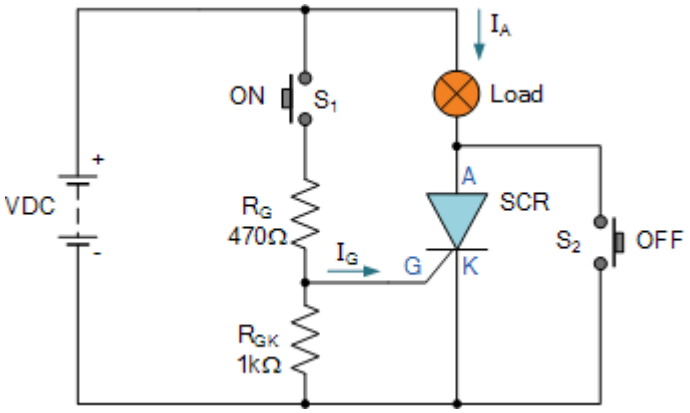
The Gate-cathode resistor R_{GK} is generally included to reduce the Gate's sensitivity and increase its dv/dt capability thus preventing false triggering of the device.

As the thyristor has self latched into the "ON" state, the circuit can only be reset by interrupting the power supply and reducing the Anode current to below the thyristors minimum holding current (I_H) value.

Opening the normally-closed "OFF" push button, S_2 breaks the circuit, reducing the circuit current flowing through the **Thyristor** to zero, thus forcing it to turn "OFF" until the application again of another Gate signal.

However, one of the disadvantages of this DC thyristor circuit design is that the mechanical normally-closed "OFF" switch S_2 needs to be big enough to handle the circuit power flowing through both the thyristor and the lamp when the contacts are opened. If this is the case we could just replace the thyristor with a large mechanical switch. One way to overcome this problem and reduce the need for a larger more robust "OFF" switch is to connect the switch in parallel with the thyristor as shown.

Alternative DC Thyristor Circuit



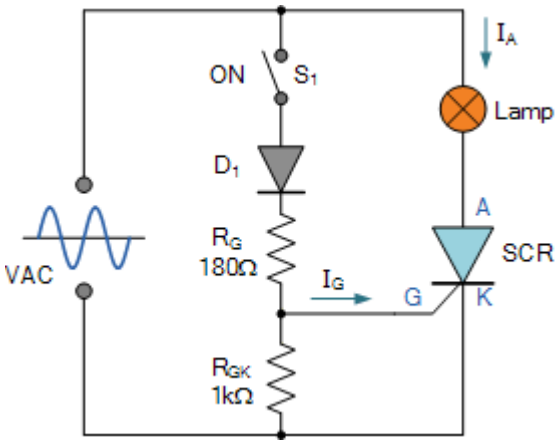
Here the thyristor switch receives the required terminal voltage and Gate pulse signal as before but the larger normally-closed switch of the previous circuit has be replaced by a smaller normally-open switch in parallel with the thyristor. Activation of switch S_2 momentarily applies a short circuit between the thyristors Anode and Cathode

stopping the device from conducting by reducing the holding current to below its minimum value.

AC Thyristor Circuit

When connected to an alternating current AC supply, the thyristor behaves differently from the previous DC connected circuit. This is because AC power reverses polarity periodically and therefore any thyristor used in an AC circuit will automatically be reverse-biased causing it to turn-"OFF" during one-half of each cycle. Consider the AC thyristor circuit below.

AC Switching Circuit



The above thyristor firing circuit is similar in design to the DC SCR circuit except for the omission of an additional "OFF" switch and the inclusion of diode D_1 which prevents reverse bias being applied to the Gate.

During the positive half-cycle of the sinusoidal waveform, the device is forward biased but with switch S_1 open, zero gate current is applied to the thyristor and it remains "OFF". On the negative half-cycle, the device is reverse biased and will remain "OFF" regardless of the condition of switch S_1.

If switch S_1 is now closed, at the beginning of each positive half-cycle the thyristor is fully "OFF" but shortly after there will be a sufficient increase in positive trigger voltage and therefore current present at the Gate to turn the thyristor full into conduction and the lamp "ON".

The thyristor is now latched-"ON" for the duration of the positive half-cycle with the Gate having no affect and effectively shorted to the Cathode. This condition continues until the thyristor automatically turns "OFF" again when the positive half-cycle ends as the sinusoidal waveform reaches zero volts at 180^o and the Anode current falls below the holding current value.

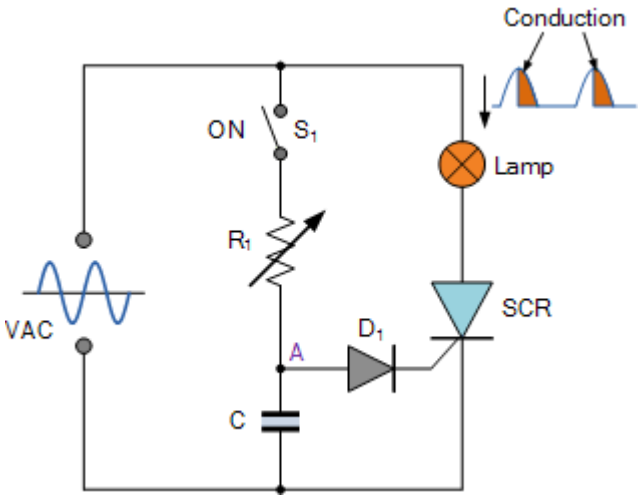
During the next negative half-cycle the device is fully "OFF" anyway until the following positive half-cycle when the process repeats itself and the thyristor conducts again as long as the switch is closed.

Then in this condition the lamp will receive only half of the available power from the AC source as the thyristor acts like a rectifying diode, and conducts current only during the positive half-cycles when it is forward biased. The thyristor continues to supply half power to the lamp until the switch is opened.

If it were possible to rapidly turn switch S_1 ON and OFF, so that the thyristor received its Gate signal at the "peak" (90^o) point of each positive half-cycle, the device would only conduct for one half of the positive half-cycle. In other words, conduction would only take place during one-half of one-half of a sine wave and this condition would cause the lamp to receive "one-fourth" or a quarter of the total power available from the AC source.

By accurately varying the timing relationship between the Gate pulse and the positive half-cycle, the **Thyristor** could be made to supply any percentage of power desired to the load, between 0% and 50%. Obviously, using this circuit configuration it cannot supply more than 50% power to the lamp, because it cannot conduct during the negative half-cycles when it is reverse biased. Consider the circuit below.

Half Wave Phase Control



Phase control is the most common form of thyristor AC power control and a basic AC phase-control circuit can be constructed as shown above. Here the thyristors Gate voltage is derived from the RC charging circuit via the trigger diode, D_1.

During the positive half-cycle when the thyristor is forward biased, capacitor, C charges up via resistor R_1 following the AC supply voltage. The Gate is activated only when the voltage

at point A has risen enough to cause the trigger diode D_1, to conduct and the capacitor discharges into the Gate of the thyristor turning it "ON". The time duration in the positive half of the cycle at which conduction starts is controlled by RC time constant set by the variable resistor, R_1.

Identifying thyristor failure in a rectifier circuit can be done through the following methods:

Visual inspection: Perform a visual inspection of the thyristors for any physical signs of failure, such as discoloration, burn marks, cracks, or visible damage. This can be done by examining the thyristors directly or by inspecting any heat sinks or cooling devices associated with them.

Current measurement: Measure the current flowing through each thyristor using current probes or current sensors. Comparing the currents of the individual thyristors in a phase-leg can help identify any significant deviations or imbalances, which may indicate a faulty thyristor.

Voltage waveform analysis: Analyze the voltage waveforms across the thyristors using an oscilloscope. Look for any abnormalities, such as distorted or asymmetrical waveforms, voltage spikes, or irregular switching behavior. These can be indicative of a thyristor failure.

Diode test: Use a multimeter with a diode test function to check the forward and reverse blocking characteristics of the thyristor. A healthy thyristor will exhibit a consistent behavior, while a faulty thyristor may show open or shorted conditions in one or both directions.

Insulation resistance measurement: Measure the insulation resistance of the thyristor terminals to the heatsink or mounting surface. A significant decrease in insulation resistance may indicate internal damage or breakdown, suggesting a thyristor failure.

Thermal imaging: Use a thermal imaging camera to inspect the temperature distribution across the thyristors during operation. If a thyristor is faulty, it may exhibit significantly higher temperatures compared to the others, indicating an internal problem.

Gate signal monitoring: Monitor the gate signals applied to the thyristors during operation. If a thyristor fails, it may not respond to the gate signal, resulting in a lack of conduction or abnormal behavior in the rectifier circuit.

Functional testing: Perform functional tests on the rectifier circuit, including load tests and performance evaluation, to identify any abnormal behavior that may be attributed to a faulty thyristor.

Fault indication circuit: Some thyristor modules or control systems may have built-in fault indication circuits that provide visual or audible alarms when a thyristor failure occurs. Check if such a circuit is present and monitor for any fault indications.

Current imbalance detection: Use a current transformer or current sensor to measure the current imbalance between the phases or within a phase-leg. Significant current imbalances may suggest a faulty thyristor in the affected phase or leg.

Voltage drop measurement: Measure the voltage drop across the thyristor during operation. A higher-than-normal voltage drop may indicate a faulty thyristor, as it may have increased forward voltage drop due to internal defects or shorted junctions.

Insulation integrity test: Perform an insulation integrity test using a megohmmeter or insulation resistance tester. This test measures the insulation resistance between the thyristor terminals and the heatsink or mounting surface. A low insulation resistance value could be an indication of a faulty thyristor.

Failure analysis: If a thyristor failure is suspected, it may be beneficial to perform a failure analysis on the failed component. This involves removing the faulty thyristor from the circuit and conducting visual inspections, electrical tests, or even destructive testing to determine the root cause of the failure.

Historical data analysis: If the system has a history of thyristor failures, analyze past failure events to identify any patterns or common factors. Look for recurring issues such as specific operating conditions, voltage spikes, overcurrent events, or inadequate cooling that may contribute to thyristor failures.

Expert consultation: If you are unable to identify the thyristor failure or if the rectifier system is complex, it is advisable to seek assistance from experts in power electronics or thyristor technology. They can provide specialized knowledge and diagnostic tools to accurately identify and address the thyristor failure.

1.4.5. Lack of reverse voltage blocking:

Half-controlled rectifiers do not provide reverse voltage blocking capability. Therefore, if a reverse voltage is applied to the rectifier, it can lead to a short circuit condition and damage the devices.

Lack of reverse voltage blocking in a thyristor can lead to a failure condition known as a "forward-biased condition." In this state, the thyristor fails to block the reverse voltage as intended, allowing current to flow in the reverse direction. Here are some indications that may suggest a lack of reverse voltage blocking in a thyristor:

Reverse current flow: Measure the current flowing through the thyristor when it is supposed to be blocking reverse voltage. If you observe a significant reverse current, it indicates a lack of reverse voltage blocking.

Voltage waveform analysis: Analyze the voltage waveform across the thyristor using an oscilloscope. If you see a high voltage drop across the thyristor in the reverse-biased state, or if the voltage waveform shows a forward voltage drop instead of blocking reverse voltage, it suggests a lack of reverse voltage blocking.

Functional testing: During functional testing, observe the behavior of the thyristor when reverse voltage is applied. If the thyristor conducts or allows current to flow in the reverse direction, it indicates a lack of reverse voltage blocking.

Reverse recovery time: Measure the reverse recovery time of the thyristor. This is the time it takes for the thyristor to block reverse voltage after being forward biased. If the reverse recovery time is significantly longer than expected or if the thyristor fails to block reverse voltage altogether, it suggests a lack of reverse voltage blocking.

Temperature monitoring: Monitor the temperature of the thyristor during operation. Excessive heating in the reverse-biased state may indicate a lack of reverse voltage blocking, as increased power dissipation occurs due to the reverse current flow.

Voltage stress analysis: Analyze the voltage stress across the thyristor under reverse-biased conditions. If the voltage stress exceeds the thyristor's rated reverse voltage, it can result in a lack of reverse voltage blocking and potential failure.

It's important to note that a lack of reverse voltage blocking in a thyristor can be caused by various factors, including manufacturing defects, excessive temperature, overvoltage conditions, or electrical stress. If a lack of reverse voltage blocking is suspected, it is recommended to consult with experts in power electronics or thyristor technology to accurately diagnose the issue and replace the faulty component. Additionally, implementing protective measures such as proper voltage clamping devices or snubber circuits can help mitigate the risk of reverse voltage-related failures.

1.4.6. Limited control range:

Half-controlled bridge rectifiers offer limited control over the output voltage by controlling the firing angle of the thyristors. This limitation can affect the ability to regulate the output voltage accurately, especially at low loads or during transient conditions.

1.4.7. Thermal management:

Half-controlled rectifiers generate significant heat during operation. Adequate thermal management, such as heat sinks and cooling systems, is necessary to prevent device overheating and ensure reliable operation.

1.4.8. Voltage transients:

Switching operations in the rectifier circuit can cause voltage transients or spikes, which may exceed the maximum voltage rating of the components. These transients can lead to device failures or induce noise in the power supply system.

1.4.9. Harmonic distortion:

The presence of harmonics in the rectified output voltage can cause distortion in the waveform and affect the performance of sensitive electronic equipment connected to the rectifier. Harmonic distortion can lead to increased heating, reduced efficiency, and interference with other devices.

1.4.10. Power factor correction:

Half-controlled bridge rectifiers typically have a poor power factor due to the non-sinusoidal input current waveform. This can result in higher reactive power consumption, lower system efficiency, and penalties from utility companies for low power factor operation.

1.4.11. Control complexity:

The control of half-controlled bridge rectifiers can be more complex compared to full-controlled rectifiers. Managing the firing angles of the thyristors accurately and controlling the output voltage requires sophisticated control algorithms and feedback systems.

1.4.12. Voltage unbalance (three-phase rectifiers):

In three-phase half-controlled bridge rectifiers, imbalances in the input voltage can lead to unequal sharing of power between phases, resulting in unbalanced output voltages and currents. This can affect the performance and reliability of the connected loads.

Voltage unbalance in three-phase rectifiers refers to an uneven distribution of voltage across the three phases of the input power supply. This can lead to several issues in the rectifier circuit and can affect the performance and reliability of the system. Here are some indications that may suggest voltage unbalance in a three-phase rectifier:

Voltage measurements: Measure the voltages of the three phases using a voltmeter or power quality analyzer. Significant differences in voltage magnitudes among the phases indicate voltage unbalance. Ideally, the voltages should be equal or have a small deviation from the nominal value.

Current imbalance: Monitor the current flowing through each phase of the rectifier using current sensors or current probes. Voltage unbalance often leads to current imbalance, where the currents in the phases differ significantly. Higher currents in certain phases can cause uneven loading and thermal stress on the rectifier components.

Overheating: If there is voltage unbalance, it can result in increased heat generation in the rectifier circuit. Monitor the temperatures of components such as thyristors, diodes, and heat sinks. Higher temperatures in specific phases or components may indicate voltage unbalance.

Power quality analysis: Conduct a power quality analysis using a power quality analyzer. This analysis can provide detailed information on the voltage and current waveforms, including harmonic distortion, voltage fluctuations, and interharmonics. Voltage unbalance can contribute to distorted waveforms and non-sinusoidal behavior.

Voltage unbalance factor: Calculate the voltage unbalance factor, which is a measure of the deviation from balanced voltages. It is typically expressed as a percentage or ratio. A high voltage unbalance factor indicates voltage unbalance. The formula for calculating the voltage unbalance factor is:

Unbalance Factor = [(Max Voltage Deviation) / (Average of Three Phase Voltages)] × 100%

System performance issues: Voltage unbalance can lead to various performance issues in the rectifier system, such as increased losses, reduced efficiency, poor power factor, and increased harmonic content. If there are recurrent malfunctions, unexpected behavior, or suboptimal performance, voltage unbalance could be a contributing factor.

If voltage unbalance is detected in a three-phase rectifier, it is important to identify the cause and address it appropriately. Potential causes of voltage unbalance include uneven loading, unequal impedance in the power supply, faulty connections, transformer issues, or supply line faults. Consulting with experts in power systems or electrical engineering can help diagnose the underlying causes and implement corrective measures, such as load balancing, voltage regulation, or compensating devices like static VAR compensators (SVCs) or active power filters (APFs), to mitigate the effects of voltage unbalance on the rectifier system.

1.4.13. EMI/RFI interference:

The switching operations and the presence of harmonics in the rectifier circuit can generate electromagnetic interference (EMI) and radio frequency interference (RFI). This interference can affect the performance of nearby electronic devices and may require additional shielding or filtering measures.

1.4.14. **Voltage sag and flicker**:

In systems with large loads or significant changes in load conditions, half-controlled bridge rectifiers can experience voltage sags or fluctuations, resulting in flickering of connected lights or disturbances in sensitive equipment.

1.4.15. **Compatibility with power factor correction capacitors**:

Half-controlled rectifiers may not be compatible with power factor correction (PFC) capacitors commonly used in power distribution systems. The nonlinear load characteristics of the rectifier can cause resonance issues and affect the operation of PFC systems.

It's important to address these problems through proper circuit design, component selection, protective measures, and control strategies. Consulting relevant standards and guidelines and conducting thorough testing and analysis can help ensure the reliable and efficient operation of the rectifier system.

1.5. equipment and testing devices

Electronic Testing Equipment and Their Types

The testing equipment used to detect faults in the operation of electronic devices by creating stimulus signals and capture responses from electronic devices under test is known as electronic test equipment. If any faults are detected, then identified faults can be traced an rectified using electronic testing equipment. Most often all electrical and electronic circuits are tested and troubleshooted to detect faults or abnormal functioning if any.



Fig. Basic Electronic Testing Equipments

Therefore, testing equipment is necessary to find and analyze the circuit conditions, for checking electronic test equipment and maintenance in various industries. Many industries

utilize different types of electronic test equipment ranging from the very simple and inexpensive to complex and sophisticated ones.

Types of Electronic Testing Equipments

The Basic Electronics Testing Equipments Under this Category Include the Following

Voltmeter

A basic electronics device or instrument used to measure voltage or electrical potential difference between two points in electrical circuits is known as voltmeter. There are two types of voltmeters: analog and digital. An analog voltmeter moves a pointer across a scale in proportional to the voltage of the electrical circuit. A digital voltmeter measures an unknown input voltage by converting the voltage to a digital value by using a converter and then displays the voltage in numeric form.



Fig.Voltmeter

Ohmmeter

An electrical instrument that measures electrical resistance is known as an ohmmeter. The instrument used to measure small value of resistance are micro-ohmmeters. Similarly meg-ohmmeters is used to make large resistance measurements. Resistance values are measured in ohms (Ω). Originally, ohmmeter is designed with a small battery to apply a voltage to a resistance.



Fig. Ohmmeter

It uses a galvanometer to measure the electric current through the resistance. The scale of the galvanometer was marked in ohms (Ω), because the fixed voltage from the battery assures that the resistance decreases and the current through the meter increases.

Ammeter

A measuring instrument which is used to measure the electric current in a circuit is known as an ammeter. The units of measurement for electric current is amperes (A) Earlier ammeters were laboratory instruments which depend on the earth's magnetic field for operation. In an era of the 19th century, improved instruments were designed which could be placed in any position and allows accurate measurements in electric power systems.



Fig. Ammeter

The smaller currents can be measured by using milliammeters or micro ammeters, units of measuring the smaller current are in the milliampere or micro-ampere range. There are different types of ammeters such as moving-coil, moving magnet and moving-iron, etc.

Multimeter

A multimeter is an electronic instrument used to measure the three basic electrical characteristics: voltage, current and resistance. It has multiple functions and acts like ohmmeter, voltmeter and ammeter and also used for household wiring, electric motors, testing batteries and power supplies. The multimeter is a handheld device with a needle over a numeric LCD digital display for indication purpose. It is also used to test continuity between two points in an electrical circuit. There are three types of multimeters made available in the market such as: digital multimeter, analog multimeter and fluke multimeter.



Fig. Multimeter

The Following are used for Testing Stimulus Signals of the Circuit Under Test

Power Supplies

A power supply is an electronic instrument that supplies electric energy to an electric load. Regulated power supplies refers to a power supply which supplies a variety of output voltages used for bench testing of electronic circuits, with the variation of output voltages or some preset voltages. Almost all the electronic circuits make use of a DC source of power for operation. A regulated power supply consists of various blocks such as an ordinary power

supply and a voltage regulating device. The output generated from ordinary power supply is fed to the voltage regulating device that provides the final output. The main function of a power supply is to convert one form of electrical energy into another.



Fig. Power Supplies

Signal Generator

A signal generator is also named as pitch generator, function generator or frequency generator is an electronic device used for generating electronic signals either in the analog or digital domains (repeating or non-repeating signals). Signal generators are used in testing, designing and repairing electro acoustic or electronic devices.



Fig. Signal Generator

In general no electronic device is suitable for all applications. There are various types of signal generators with different applications and purposes. During the development in technology, compared to signal generators there are flexible and programmable software tone generators with embedded hardware units are made available in the market.

Pulse Generator

A pulse generator is either an electronic circuit or a piece of electronic test equipment used to generate electrical pulses in different shapes: mostly used for tests at analog or electrical level. Pulse generators are used to control the width, frequency,delay based on the low and high voltage levels of the pulses and with respect to an internal and external triggering. There are three types of pulse generators namely optical pulse generator, bench pulse generators and microwave pulsers.



Fig. Pulse Generator

Digital Pattern Generator

A digital generator is an electronic testing equipment or software used to generate digital electronics stimuli. Digital electronics stimuli are a specific type of electrical waveform varying between two conventional voltages corresponding to two logic gates (either 1 or 0, low or high). The function of the digital pattern generator is to stimulate the inputs of a electronic device. For that purpose, the voltage levels are generated by a digital pattern generator are compared to I/O standards of digital electronics: TTL, LVTTL and LVDS. It is also known as a logic source because it is a source of synchronous digital stimulus.



Digital Pattern Generator

It generates a signal for testing digital electronics at logic level. This generator also produces a single shot or repetitive signals in which some sort of triggering source takes place (internally or externally)

The Following Equipments Analyze the Response of the Circuit Under Test

Oscilloscope

The oscilloscope is an electronic test instrument that constantly obverses varying voltage signals as a two dimensional plot of one or more signals as a function of time. The other names for oscilloscope are oscillograph, cathode ray oscilloscope or digital storage oscilloscope. It is also used for converting non electrical signals such as vibration or sound into voltages and then displays the result.

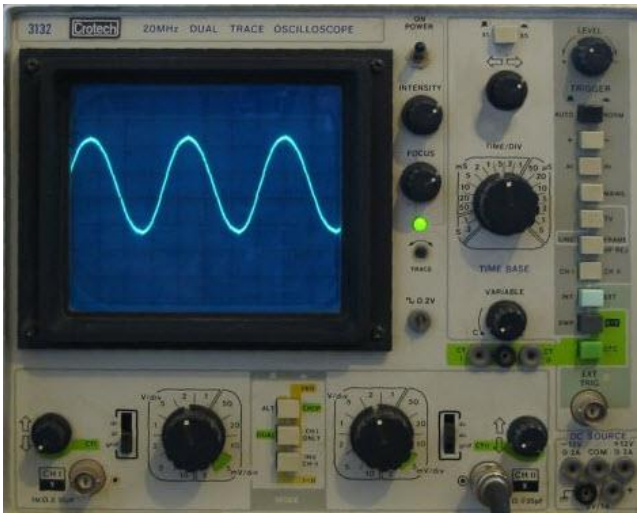


Fig. Cathode Ray Oscilloscope

Oscilloscopes are used to observe the change of an electrical signal based on time such that voltage and time describe a shape of the signals and graphed continuously compared with a

calibrated scale.The obtained waveforms can be considered for following properties such as frequency, amplitude, time interval, rise time and others. Modern digital instruments may calculate these properties directly and displays them.

Frequency counter

Digital frequency counter is an electrical test equipment used for measuring the frequency of repetitive signals and elapsed time between events. Digital frequency counters are also used to measure the radio frequency where it is important to measure the precise frequency of a particular signal.



Fig. Frequency Counter

There is a slight difference between the timers and frequency counters in the electronic industry. It is often possible to use both timers and frequency counters to perform the both functions: to measure the time and frequency. Frequency counters are mostly used as general purpose laboratory test equipment to measure higher frequencies.

Advanced or Less Commonly used Testing Equipment

LCR Meter

LCR Meter name itself indicates that it is used to measure the inductance, capacitance and resistance of electronics components. The inductance, capacitance and resistance are denoted by the letters L, C, and R so it is named as LCR Meter. A variety of meters are made available in the market, but simple versions of LCR meters indicates impedance only for converting the values to capacitance or inductance.

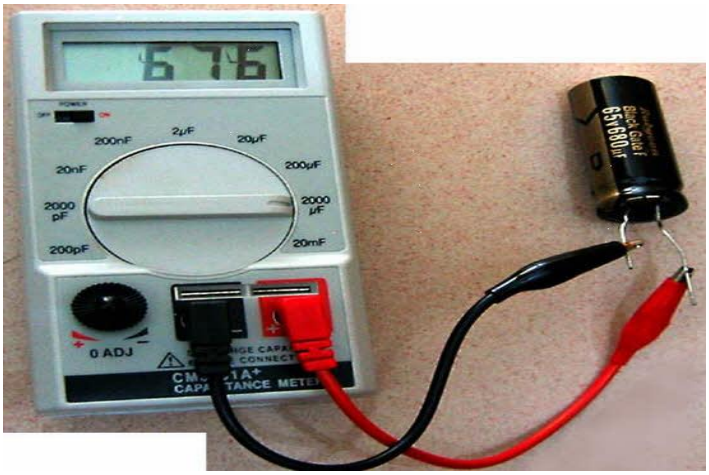


Fig. LCR Meter

More designs are available and used to measure the capacitance or inductance, and also the equivalent series resistance of capacitors and the Q factor of inductive components. These conditions make the LCR meters valuable for measuring the quality and overall performance of the component.

There are many advanced testing equipments developed using most innovative technologies and are being used almost all types of electrical and electronic industries for checking estimated results and operation of electronics projects or devices. For more information regarding the testing equipments and their working you can contact us by posting your queries in the comments section below.

1.6. Work plane

work plan for electro control power circuit problem solving, we should:

1. Gather information about the circuit. This includes the schematic diagram, the wiring diagram, and the bill of materials. You should also know the operating voltage and current of the circuit.
2. Identify potential problems. Once you have a good understanding of the circuit, you can start to identify potential problems. This can be done by looking at the circuit diagram and wiring diagram, and by considering the operating environment of the circuit.
3. Develop a troubleshooting plan. Once you have identified potential problems, you can develop a plan for troubleshooting them. This plan should include the steps that you will take to isolate the problem and to identify the cause of the problem.
4. Have the necessary tools and equipment. Before you start troubleshooting, make sure that you have the necessary tools and equipment. This includes safety gear, such as

insulated gloves and safety glasses. You should also have the necessary test equipment, such as a multimeter and an oscilloscope.

5. Follow the troubleshooting plan. Once you have developed a troubleshooting plan, follow it carefully. This will help you to identify the problem quickly and efficiently.
6. Repair the problem. Once you have identified the cause of the problem, you can repair it. This may involve replacing a defective component or fixing a loose connection.
7. Test the circuit. Once you have repaired the problem, test the circuit to make sure that it is working properly.

- Document everything. As you troubleshoot the circuit, document everything that you do. This includes the steps that you take, the test results that you get, and the repairs that you make. This documentation will help you to troubleshoot the circuit in the future, and it will also help you to communicate your findings to others.
- Be safe. Electro control power circuits can be dangerous. Be sure to take all necessary safety precautions when troubleshooting these circuits.

Self-Check 1

Part-I: Choose the correct answer

Multiple Choice:

1What can excessive current draw in a load indicate in a power control circuit?

A. Proper functioning
B. Faulty control signals
C. Normal load behavior
D. Unbalanced power supply

2. Power factor issues in a power control circuit can result in:

a) Higher load efficiency
b) Balanced voltage levels
c) Reactive power consumption
d) Stable control signals

3. Voltage fluctuations in a load beyond acceptable limits can indicate:

a) Proper load response
b) Stable power control circuit
c) Faulty control components
d) Balanced three-phase system

4. Unintended load operation in a power control circuit may lead to:

a) Increased system efficiency
b) Proper load balancing
c) Abnormal load behavior
d) Improved power factor

5. Excessive heat generation in a power control circuit can be caused by:

a) Low current levels
b) Adequate cooling mechanisms
c) Faulty connections or components
d) Proper load response

6What is the purpose of power factor correction in a power control circuit?

a) Increase reactive power consumption
b) Balance voltage levels
c) Improve load efficiency
d) Reduce load current

Part-II: if the statement is correct say true if the statement is incorrect say false

1. True or False: Excessive current draw in a load is a normal characteristic of a well-functioning power control circuit.
2. True or False: Voltage fluctuations beyond acceptable limits are not a cause for concern in a power control circuit.
3. True or False: Unbalanced loads in a three-phase power control circuit can lead to voltage imbalances.
4. True or False: Power factor correction helps to reduce reactive power consumption in a power control circuit.
5. True or False: Excessive heat generation in a power control circuit can be caused by faulty connections or components.

Part-III: Answer the following questions accordingly

Short Answer:

1. What are some common OHS/WHS requirements and procedures that should be followed when working with power control circuits?
2. Explain the importance of proper grounding and bonding in a power control circuit.
3. Briefly describe the procedure for conducting a risk assessment before performing maintenance or troubleshooting tasks on a power control circuit.

Unit Two: Single/Three Phase Electronic Power Control Circuits Problem solving

This unit to provide you the necessary information regarding the following content coverage and topics:

- Troubleshoot and control problems solution
- Parameters, specifications and performance requirements
- unplanned situations.

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Understand the importance of troubleshooting in power control circuits.
- Acquire the ability to analyse and troubleshoot
- Develop skills to analyze the impact of unplanned situations
- Learn to identify and evaluate relevant parameters

2.1. troubleshoot and control problems solution

2.1.1. troubleshoot power electronics circuits

Power electronics circuits are widely used in various applications, such as renewable energy, electric vehicles, industrial drives, and smart grids. However, they can also encounter various faults and failures that can affect their performance, efficiency, and reliability. Therefore, troubleshooting power electronics circuits is an essential skill for electrical engineers who work with these systems. In this article, we will discuss some general steps and tips for troubleshooting power electronics circuits, as well as some common tools and methods that can help you diagnose and fix the problems.

A. Identify the symptoms

The first step in troubleshooting power electronics circuits is to identify the symptoms of the fault or failure. This means observing and measuring the input and output voltages, currents, and power of the circuit, as well as checking the status of the switches, sensors, and controllers. You should also look for any signs of physical damage, overheating, noise, or smoke that may indicate a serious problem. By identifying the symptoms, you can narrow down the possible causes and locations of the fault or failure, and decide what tests or actions to take next.

B. Check the components

The next step in troubleshooting power electronics circuits is to check the components of the circuit, such as diodes, transistors, capacitors, resistors, inductors, and transformers. You should inspect each component for any visible defects, such as cracks, burns, bulges, or leaks. You should also use a multimeter, an oscilloscope, or a logic analyzer to test the functionality and performance of each component. For example, you can measure the resistance, voltage, current, or frequency of the components, and compare them with the expected values or specifications. If you find any faulty or damaged components, you should replace them or repair them if possible.

C. **Check the connections**

The third step in troubleshooting power electronics circuits is to check the connections of the circuit, such as wires, connectors, terminals, and solder joints. You should inspect each connection for any loose, broken, corroded, or shorted wires or contacts. You should also use a continuity tester or a multimeter to verify the continuity and resistance of each connection. For example, you can check if there is any open circuit or short circuit between the input and

output terminals of the circuit, or between the ground and the power supply. If you find any faulty or poor connections, you should tighten them, clean them, or replace them if necessary.

D. Check the control

The fourth step in troubleshooting power electronics circuits is to check the control of the circuit, such as the switching signals, the feedback signals, and the control algorithm. You should inspect the control circuit for any errors, glitches, or malfunctions that may affect the operation of the power circuit. You should also use a signal generator, an oscilloscope, or a logic analyzer to test the quality and timing of the control signals. For example, you can check if the switching signals are synchronized with the input voltage or current, if the feedback signals are accurate and stable, or if the control algorithm is correct and robust. If you find any problems with the control circuit, you should debug it, calibrate it, or update it if possible.

E. Check the load

The fifth step in troubleshooting power electronics circuits is to check the load of the circuit, such as the motor, the battery, the lamp, or the converter. You should inspect the load for any abnormal behavior, such as excessive current, voltage, or power consumption, or poor performance or efficiency. You should also use a load tester, a power analyzer, or a scope meter to test the characteristics and response of the load. For example, you can check if the load is matched with the output voltage or current of the circuit, if the load is stable and linear, or if the load has any faults or failures. If you find any issues with the load, you should adjust it, replace it, or isolate it if possible.

F. Check the environment

The sixth step in troubleshooting power electronics circuits is to check the environment of the circuit, such as the temperature, humidity, vibration, or electromagnetic interference. You should inspect the environment for any factors that may affect the performance, reliability, or safety of the circuit. You should also use a thermometer, a hygrometer, an accelerometer, or an EMI tester to measure the environmental conditions and compare them with the recommended or acceptable ranges. For example, you can check if the temperature is too high or too low for the circuit, if the humidity is causing corrosion or condensation, if the vibration is causing mechanical stress or fatigue, or if the EMI is causing noise or distortion.

If you find any adverse environmental conditions, you should improve them, protect the circuit from them, or relocate the circuit if possible.

TROUBLESHOOT A CIRCUIT

These are the things we check before diving deep into troubleshooting a circuit:

- Does the PCB or breadboard match the circuit diagram?
- Does the circuit have power?
- Is the circuit getting the correct voltage?
- Is the power supply connected the right way around?
- Are all ICs, transistors, and diodes the correct type?
- Are all resistors and capacitors the correct value?
- Are all polarized components (electrolytic capacitors, diodes, LEDs, etc.) connected the right way around?
- Do all of the solder joints have a good electrical connection?
- Are there any broken traces on the PCB?

2.1.2. Voltage ripple trouble shoot

Half-controlled bridge rectifiers can produce high voltage ripple due to the presence of harmonics in the rectified output waveform. This can lead to poor voltage regulation and increased stress on downstream components.

Ripple and Ripple Factor with Formula of Ripple Factor

Ripple

Ripple is the fluctuating AC component present in rectified DC output. The output of a rectifier may either be DC current or voltage. In view of this, AC fluctuating component present in DC output voltage is called voltage ripple and that in DC current output is called current ripple.

Why Ripple is Present?

Ripple is always present in the rectifier output. This is because of the behavior of circuit elements like diode or thyristor. Let us consider an example of single phase full wave rectifier to better understand the reason for presence of ripple. The output current waveform of single phase full wave rectifier is shown below.

The expected output from full wave rectifier should be a pure DC but actually the output current is different. Since the average value of output current is the pure, therefore the ripple present is equal to the difference of output current or load current minus average current.

What is Ripple Factor

Ripple Factor is the ratio of rms value of ac component present in the rectified output to the average value of rectified output. It is a dimensionless quantity and denoted by γ. Its value is always less than unity.

$$\text{Ripple Factor}, \gamma = \frac{\text{RMS value of AC component present in Rectifier Output}}{\text{Average Value of Rectifier Output}}$$

$$\gamma = \frac{I'_{rms}}{I_{dc}} = \frac{V'_{rms}}{V_{dc}}$$

where I'_{rms} and V'_{rms} are the rms value of alternating component of load current and voltage respectively.

This is basically a measurement of ripple which denotes the purity of rectified output. The more the ripple factor, the lesser will be the purity of rectifier DC output. This means more will be fluctuating AC component. Thus every effort is made to reduce the ripple factor. Here we will not discuss the ways to reduce the ripple factor.

Ripple factor is generally denoted in percentage like 3 % or 4 %. Percentage ripple factor is obtained by just multiplying γ by 100. 3 % ripple content in output current means that 3 A rms alternating component of current is present against the actual 100 A DC current output. Similarly, 3 % ripple content in output voltage means that 3 V rms alternating component of voltage is present against the actual 100 V DC voltage output.

Ripple Factor Formula

The formula for ripple factor is given in terms of rms value and average value of rectifier output.

Derivation of Ripple Factor Formula

The ripple factor formula can easily be derived from its definition. As per definition, we need to find two parameters: rms value of ripple present in rectifier output current or voltage and average value of output of rectifier for one time period T. For calculating rms value of ripple I_{rms}, first we need to find the ripple. Ripple is equal to the difference between the actual output minus expected DC output. Thus,

Ripple = $i_L - I_{dc} = v_L - V_{dc}$

Here, i_L and v_L are the output current and voltage through the load connected at the terminals of rectifier. Similarly, V_{dc} and I_{dc} are the average value of load voltage and current.

Let us now find the rms value of current ripple. Though rms value of voltage ripple can also

be used for deriving the formula for ripple factor but here we are using current ripple.

$$RMS\ Value\ of\ Ripple = \sqrt{\left(\frac{1}{T}\right)\int_0^T (\text{iL} - \text{Idc})^2\, d(\omega t)}$$

$$= \sqrt{\left(\frac{1}{T}\right)\int_0^T [(\text{iL})^2 + (\text{Idc})^2 - 2(\text{iL})(\text{Idc})]d(\omega t)}$$

But the effective or rms value of load current is given as

$$(I_{rms}) = \sqrt{\left(\frac{1}{T}\right)\int_0^T (iL)^2 d(\omega t)}$$

Therefore.

$$RMS\ Value\ of\ Ripple = \sqrt{\left(\frac{1}{T}\right)\int_0^T [(\text{iL})^2 + (\text{Idc})^2 - 2(\text{iL})(\text{Idc})]d(\omega t)}$$

$$= \sqrt{(Irms)^2 + \left(\frac{1}{T}\right)\int_0^T [(\text{Idc})^2 - 2(\text{iL})(\text{Idc})]d(\omega t)}$$

$$= \sqrt{(Irms)^2 + \left(\frac{1}{T}\right)\int_0^T (\text{Idc})^2\, d(\omega t) - \left(\frac{2Idc}{T}\right)\int_0^T (\text{iL})\, d(\omega t)}$$

Since the average value is given as

$$I_{dc} = \sqrt{\left(\frac{1}{T}\right)\int_0^T (iL)\, d(\omega t)}$$

Therefore, the second integration will become equal to I_{dc}.

$$RMS\ Value\ of\ Ripple = \sqrt{(Irms)^2 + \left(\frac{1}{T}\right)\int_0^T (\text{Idc})^2\, d(\omega t) - 2(Idc)^2}$$

$$= \sqrt{(Irms)^2 + \frac{(\text{Idc})^2}{T}[\omega t - 0] - 2(Idc)^2}$$

But $\omega t = T$, therefore

$$RMS\ Value\ of\ Ripple = \sqrt{(Irms)^2 + (Idc)^2 - 2(Idc)^2}$$

$$= \sqrt{(Irms)^2 - (Idc)^2}$$

Since the ripple factor is equal to the ratio of rms value of ripple content and average value of rectifier output, therefore its formula becomes

$$\textbf{Ripple Factor}, \gamma = \frac{\sqrt{(Irms)^2 - (Idc)^2}}{Idc}$$

$$= \frac{\sqrt{(Vrms)^2 - (Vdc)^2}}{Vdc}$$

Testing switching power supplies includes many different tests, one of them being the output-voltage peak-to-peak ripple. Output-voltage ripple is the alternating current (AC) component of the direct current (DC) output voltage. It's generated by a combination of factors,

including the output capacitor's equivalent series resistance (ESR), the voltage drop across the output capacitance, duty cycle and switching frequency.

Because it impacts the overall voltage tolerance of the rail, the peak-to-peak output-voltage ripple is a target specification in many processor, field-programmable gate array (FPGA), application-specific integrated circuit (ASIC) and system-on-chip (SoC) data sheets and design guides.

Figure 1 shows a typical output-voltage ripple probe setup.

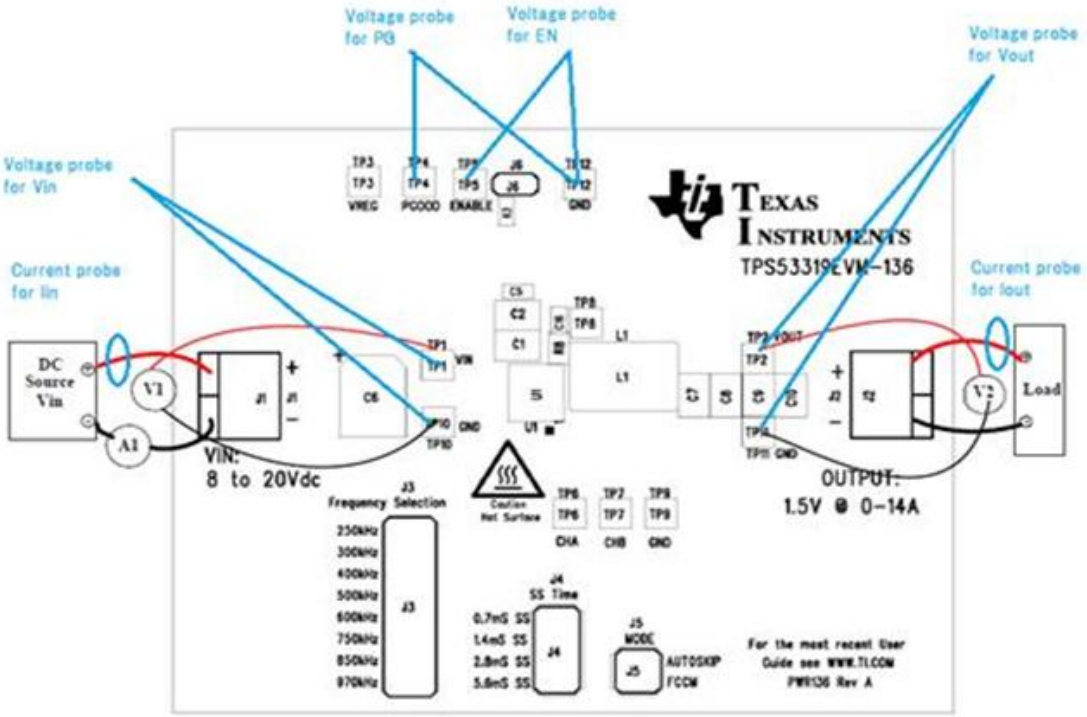


Figure 1: Output-voltage ripple probe setup

Probing using a clip-on probe shows an increased ripple that may be partly the result of the ground-wire loop picking up noise, as shown in Figure 2.

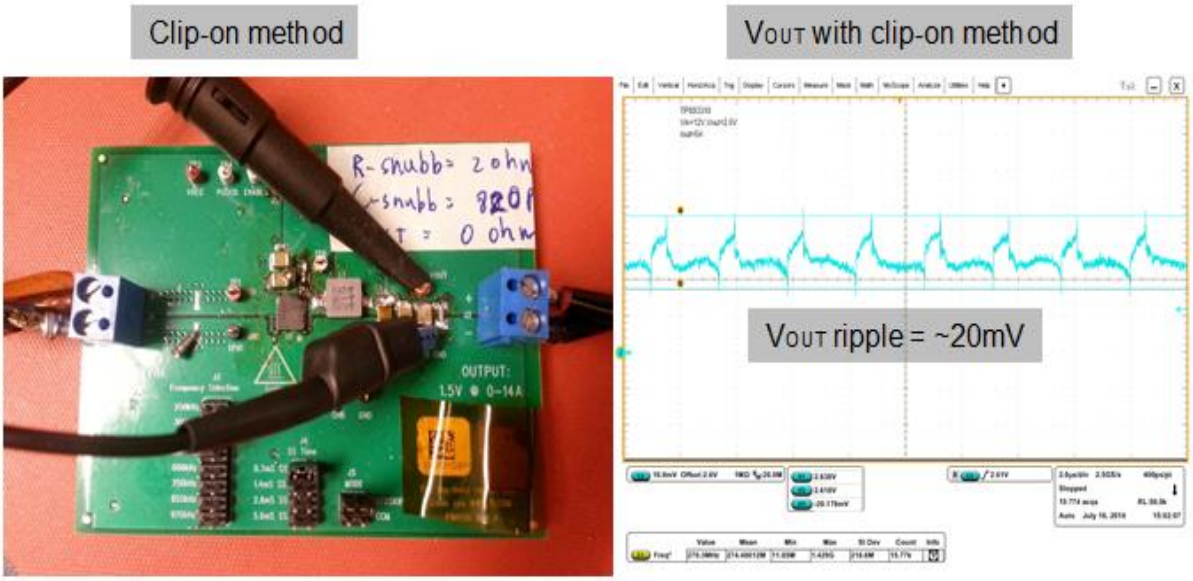


Figure 2: Output voltage ripple probe with a clip-on probe and ground wire fully extended, picking up noise from the nearby switch node

Probing using the pigtail method improves ripple, even though the tip is again near the switch node, as Figure 3 shows. The ground loop is much shorter; thus the noise pickup is less severe.

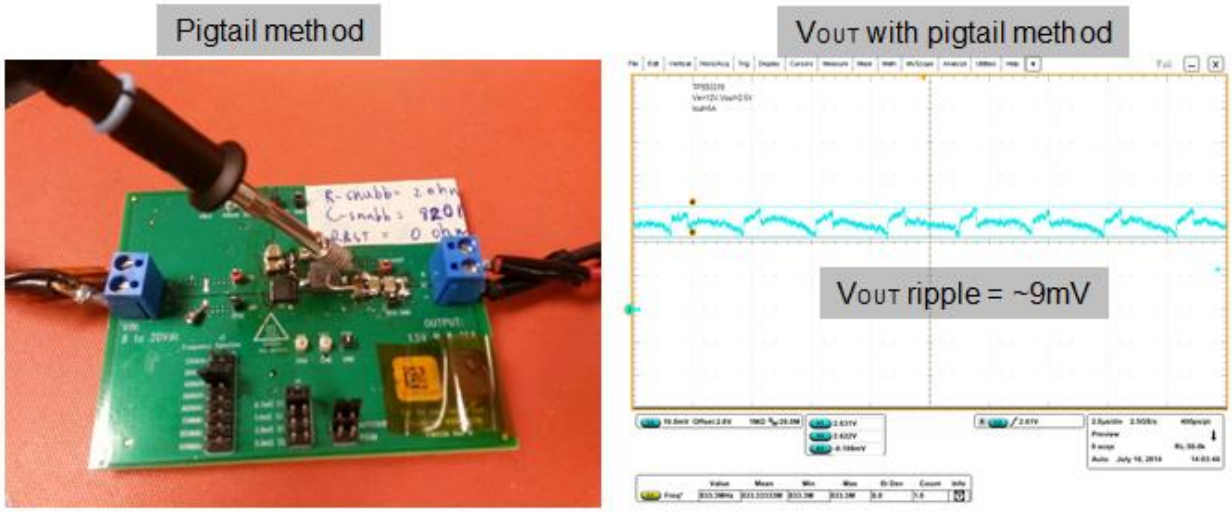


Figure 3: Output-voltage ripple probe using the pigtail method; the probe ground is in contact with the pigtail, which is connected to the board ground

Using a coaxial cable method improves results even more, as Figure 4 shows. Directly soldering the woven copper shield on the board ground minimizes the ground loop further.

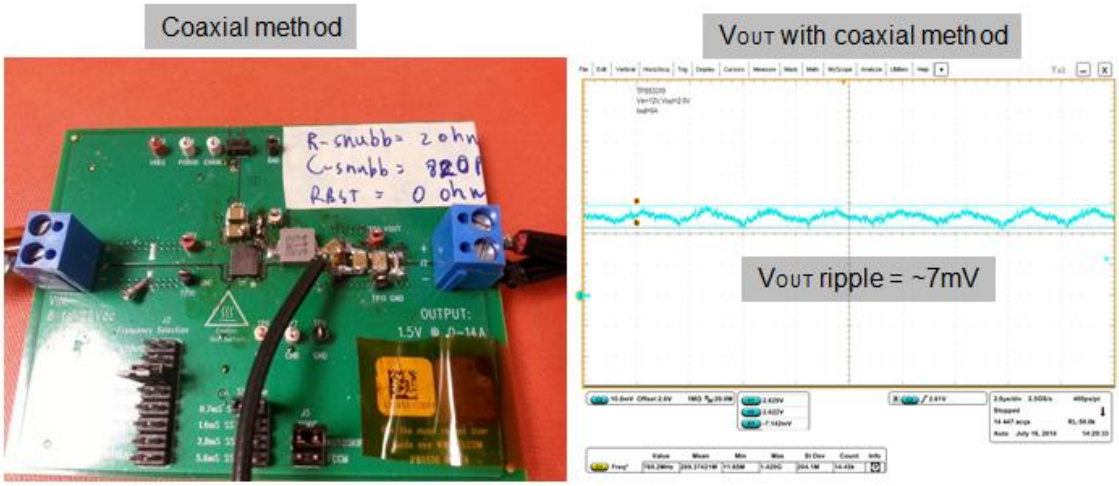


Figure 4: Output-voltage ripple probe using coaxial method

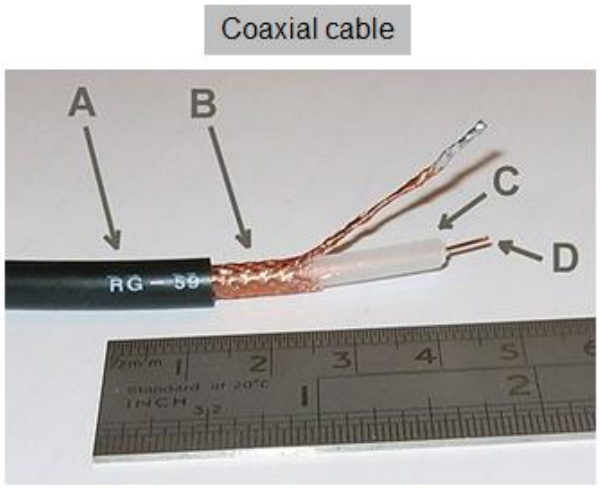


Figure 5: Coaxial cable close-up: the outer plastic sheath

(a); woven copper shield (ground) (b); inner dielectric insulator (c); and copper core (V_{OUT}) (d Another similar measurement method is to use a probe jack like that shown in Figure 6. The outside jacket is the ground connected directly on the board while allowing the probe tip to connect to the voltage test point.

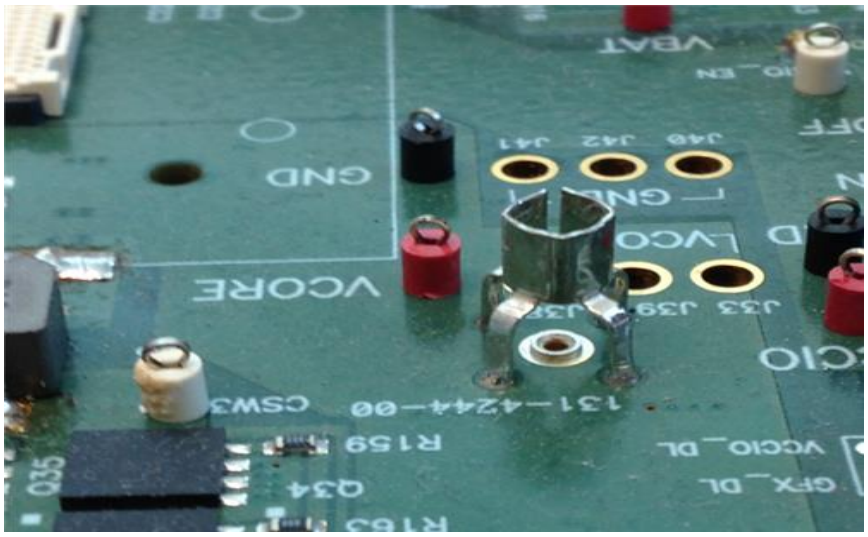


Fig: Probe jack

Of all of these methods, using a differential probe is probably the best way to measure ripple accurately. It can eliminate the ground-loop noise pickup error, especially when connecting other electronic equipment to the same board ground (such as electronic loads and multimeters).

2.2. parameters, specifications and performance requirements

1. Thyristors

thyristors are a type of semiconductor device used in power electronics applications. Here are some common parameters for thyristors:

Blocking Voltage (VDRM/VRRM): The maximum reverse voltage that a thyristor can withstand in its off-state without experiencing breakdown.

On-State Voltage Drop (VTM): The voltage drop across the thyristor when it is conducting current in its on-state.

Holding Current (IH): The minimum current required to maintain the thyristor in the conducting state after it has been triggered.

Gate Trigger Voltage (VGT): The minimum voltage applied to the gate terminal of the thyristor to initiate the switching from the off-state to the on-state.

Gate Trigger Current (IGT): The minimum current required at the gate terminal to trigger the thyristor.

Turn-On Time: The time it takes for a thyristor to switch from the off-state to the on-state after the gate trigger signal is applied.

Turn-Off Time: The time it takes for a thyristor to switch from the on-state to the off-state after the gate current is removed.

Peak Surge Current (ITSM): The maximum surge current that a thyristor can handle for a short duration without causing damage.

Maximum Operating Junction Temperature (Tjmax): The maximum temperature at which the thyristor can operate safely without exceeding its specified limits.

Forward Blocking Capability (dV/dt): The maximum rate of change of voltage that a thyristor can withstand in its off-state without triggering unintentionally.

These parameters can vary depending on the specific type and model of the thyristor. Thyristors are available in different configurations such as silicon-controlled rectifiers (SCRs), gate turn-off thyristors (GTOs), and insulated gate bipolar transistors (IGBTs). Each configuration may have its own set of parameters and specifications. It's important to refer to the datasheet or manufacturer's documentation for the specific thyristor being used for accurate parameter values.

2. Diodes

Diodes are semiconductor devices that allow current to flow in one direction while blocking it in the opposite direction. Here are some common parameters for diodes:

Forward Voltage Drop (VF): The voltage drop across a diode when it is forward-biased and conducting current. It depends on the type of diode and the current flowing through it.

Reverse Breakdown Voltage (VR): The voltage at which a diode experiences a reverse breakdown and starts conducting in the reverse direction. It indicates the maximum reverse voltage the diode can withstand.

Reverse Current (IR): The current that flows through a diode when it is reverse-biased. Ideally, this current should be very low, indicating a high reverse resistance.

4. Transistors

Current Gain (hFE or β): For instance, a common NPN bipolar junction transistor (BJT) may have a current gain of 100, meaning that the output current is 100 times the input current.

Collector-Emitter Saturation Voltage: Let's consider an NPN BJT with a collector-emitter saturation voltage of 0.2 V. When the transistor is fully turned on and saturated, the voltage drop across the collector-emitter terminals will be around 0.2 V.

Maximum Power Dissipation: Suppose a power transistor has a maximum power dissipation of 2 watts (W). It means that it can handle a maximum power of 2 W without exceeding its specified temperature limits.

5. **Inverters**

Input Voltage Range: For instance, a DC-to-AC inverter may have an input voltage range of 10 to 15 volts DC, meaning it can accept DC input voltages within that range for conversion to AC output.

Output Voltage Regulation: Consider a grid-tied inverter with an output voltage regulation of ±2%. It means that it can maintain the AC output voltage within 2% of the desired value, even with changes in the input voltage or load conditions.

Total Harmonic Distortion (THD): Let's say a sine wave inverter has a THD of 3%. It indicates that the distortion in the output waveform, caused by harmonics, is limited to 3%.

6. **Converters**

Input Voltage Range: Take, for example, a buck converter with an input voltage range of 12 to 24 volts DC. It can accept input voltages within that range and convert them to a lower output voltage.

Output Voltage Regulation: Consider a boost converter with an output voltage regulation of ±1%. It means that it can maintain the output voltage within 1% of the desired value, even with changes in the input voltage or load conditions.

Conversion Efficiency: Suppose a flyback converter has a conversion efficiency of 90%. It indicates that it can convert 90% of the input power to the desired output power, with 10% of the power being lost as heat.

2.3. unplanned situations.

Electro-power control circuits can be susceptible to a variety of unplanned situations, such as: Unexpected situations in power electronic circuits can arise due to various factors and can include:

Voltage or Current Surges: Sudden increases in voltage or current levels can occur due to external factors like lightning strikes, power grid fluctuations, or equipment malfunctions. These surges can potentially damage components or disrupt the operation of the power electronic circuit.

Environmental Factors: Environmental conditions, such as temperature extremes, humidity, dust, or vibrations, can affect the performance and reliability of power electronic circuits. They can cause unexpected behaviour or premature aging of components.

Electromagnetic Interference (EMI): External electromagnetic interference, such as radio frequency interference (RFI) or electromagnetic radiation from nearby equipment, can

introduce noise or distort signals in power electronic circuits, leading to unexpected behaviour or malfunctions.

Software or Firmware Errors: Errors or bugs in the control software or firmware used in power electronic systems can cause unexpected behaviour or incorrect operation of the circuit.

Grounding Issues: Poor or improper grounding practices can introduce ground loops, noise, or voltage potential differences, leading to unexpected circuit behaviour or safety hazards.

Circuit Design or Layout Issues: Flaws or oversights in the circuit design or layout can result in unexpected interactions between components, inadequate thermal management, or improper signal routing, affecting the performance and reliability of the circuit.

Changes ran Load Conditions: Sudden changes in the load connected to the power electronic circuit, such as variations in resistance, inductance, or capacitance, can impact the circuit's stability or cause unexpected voltage or current behaviour.

Human Error: Mistakes made during installation, maintenance, or operation of the power electronic circuit can lead to unexpected situations. Examples include incorrect wiring, incorrect component selection, or improper configuration of control parameters.

External Events: Natural disasters, accidents, or power outages can cause unexpected situations in power electronic circuits. These events can result in sudden interruptions, damage to components, or unsafe operating conditions.

Transient Voltage or Current Spikes: Transient voltage or current spikes, also known as voltage or current transients, are sudden and short-duration increases in voltage or current levels. These spikes can be caused by events such as lightning strikes, switching operations in nearby circuits, or electromagnetic interference. Transients can cause damage to sensitive components, disrupt the operation of the circuit, or trigger protective devices like surge suppressors or transient voltage suppressors.

Harmonic Distortion: Harmonic distortion refers to the presence of unwanted harmonic frequencies in the power supply waveform. It can occur due to nonlinear loads, such as electronic devices or power converters, which inject harmonic currents into the system. Harmonic distortion can lead to increased losses, reduced power factor, interference with other equipment, and overheating in power electronic circuits.

Ground Faults: Ground faults occur when an unintended connection is made between a live conductor and the ground or earth. This can happen due to insulation breakdown, damaged

cables, or faulty connections. Ground faults can result in abnormal current flow, voltage imbalances, electrical shock hazards, and system failures.

Electrostatic Discharge (ESD): Electrostatic discharge is the sudden flow of electricity between two objects with different electrical potentials. ESD can occur when a person or object comes into contact with sensitive electronic components or circuits. It can cause damage to the components, alter their characteristics, or lead to circuit malfunctions.

Voltage or Current Regulation Errors: Errors in voltage or current regulation can occur due to faulty control circuits, incorrect feedback signals, or improper calibration. These errors can result in voltage or current levels deviating from the desired values, affecting the performance or protection of the power electronic circuit.

Resonance and Oscillation: Resonance and oscillation can occur in power electronic circuits due to parasitic elements, such as stray capacitance and inductance. These phenomena can cause voltage or current amplification, instability, or unwanted high-frequency oscillations, leading to circuit malfunction or failure.

Inadequate Cooling: Insufficient cooling or inadequate heat dissipation can result in excessive temperatures in power electronic components. This can degrade their performance, reduce their lifespan, or trigger thermal protection mechanisms that limit their operation.

Voltage or Current Regulation Hunting: Voltage or current regulation hunting refers to the continuous fluctuation or oscillation of the control signal in an attempt to maintain the desired voltage or current level. This can occur due to improper control loop tuning, instability in the feedback system, or incorrect parameter settings. Regulation hunting can lead to instability, inefficient operation, or even damage to the power electronic circuit.

It's important to address these unexpected situations through proper circuit design, robust protection mechanisms, effective grounding techniques, regular maintenance, and adherence to safety standards. Additionally, thorough testing, simulation, and analysis during the design and development stages can help identify and mitigate potential issues before they occur in practical applications.

Self-Check-2

Part-I: Choose the correct answer

1. Which parameter of a diode indicates the maximum reverse voltage it can withstand?

a) Forward Voltage Drop

b) Reverse Breakdown Voltage

c) Reverse Recovery Time

d) Holding Current

2. What does the gate trigger voltage of a thyristor represent?

e) The minimum voltage required to initiate switching from the on-state to the off-state.

f) The minimum voltage required to initiate switching from the off-state to the on-state.

g) The voltage drop across the thyristor when it is conducting current.

h) The minimum voltage required for the thyristor to maintain its conducting state.

3. In an inverter, what does the output voltage regulation refer to?

a) The ability to maintain a stable DC input voltage.

b) The ability to maintain a constant output voltage regardless of variations in the input voltage or load conditions.

c) The ability to convert AC input voltage to DC output voltage.

d) The ability to adjust the output voltage based on the desired load requirements.

4. What does the conversion efficiency of a power converter indicate?

a) The percentage of power lost as heat during the conversion process.

b) The ability of the converter to handle high surge currents.

c) The ability of the converter to handle high peak voltages.

d) The ability of the converter to withstand high ambient temperatures.

What is the purpose of troubleshooting in power control circuits?

a) To identify and resolve faults or malfunctions in the system.

b) To optimize the performance of the power control circuit.

c) To design new power control circuits.

d) To measure the power consumption of the circuit.

7. What is the main objective of control problem solutions in power control circuits?

a. To adjust the control parameters to improve system performance.

b. To design new power control circuits.

c. To troubleshoot and identify faults in the system.

d. To measure the power consumption of the circuit.

Part-II Answer the following question based on the statement is correct say True if not say False

1. The forward voltage drop of a diode remains constant regardless of the current flowing through it.
2. The gate trigger voltage of a thyristor is the minimum voltage required to initiate switching from the on-state to the off-state.
3. In an inverter, the output voltage regulation refers to the ability to maintain a stable DC input voltage.
4. The conversion efficiency of a power converter indicates the percentage of power lost as heat during the conversion process.

Part-III explain the following question

1. List three key parameters to consider when selecting a diode for a specific application.
2. How can the performance requirements of a power control circuit be determined and specified?
3. Describe a situation where an unplanned event or fault in a power control circuit can occur and affect its operation.
4. What are some common troubleshooting techniques used in power control circuits when identifying and resolving issues?
5. Provide an example of a control problem in a single/three-phase electro power control circuit and suggest a potential solution to address it
6. Discuss the applications of single/three-phase half-controlled bridge rectifiers in various industries or electrical systems.
7. Highlight the limitations and constraints associated with their usage in terms of power factor, harmonic content, and control range.
8. Advantages and Disadvantages:
9. List and explain the advantages of using single/three-phase half-controlled bridge rectifiers in power control applications.
10. Discuss the disadvantages or challenges associated with their implementation, such as increased complexity or cost.

Operation sheet 2.1:

Objective: Practice analyzing a single-phase rectifier circuit and measuring key output parameters.

Instructions:

Given a single-phase rectifier circuit with a resistive load, analyze the circuit and determine the following parameters:

a. Circuit configuration: Identify the type of single-phase rectifier circuit (half-wave or full-wave bridge).

b. Output voltage waveform: Sketch the waveform of the rectified output voltage.

c. Ripple voltage: Calculate the ripple voltage magnitude and frequency.

d. Peak reverse voltage: Determine the peak reverse voltage across the diode.

Assume the following circuit specifications:

Input voltage: 220V RMS, 50Hz

Load resistance: 10Ω

Diode forward voltage drop: 0.7V

Calculate the following parameters:

a. Output voltage magnitude: Determine the peak and average output voltage values.

b. Ripple voltage: Calculate the peak-to-peak ripple voltage and ripple percentage.

c. Peak reverse voltage: Determine the peak reverse voltage across the diode.

Verify your calculations using simulation software or a circuit simulator. Simulate the circuit using the given specifications and compare the measured values with your calculated results.

Operation sheet 2.2:

Objective: Practice analyzing a three-phase rectifier circuit and measuring key output parameters.

Instructions:

Given a three-phase rectifier circuit with an inductive load, analyze the circuit and determine the following parameters:

a. Circuit configuration: Identify the type of three-phase rectifier circuit (6-pulse or 12-pulse).

b. Output voltage waveform: Sketch the waveform of the rectified output voltage.

c. Ripple voltage: Calculate the ripple voltage magnitude and frequency.

d. Peak reverse voltage: Determine the peak reverse voltage across the diodes.

Assume the following circuit specifications and Drow circuit diagram

Input voltage: 400V RMS, 50Hz

Load inductance: 5mH

Diode forward voltage drop: 1V

Calculate the following parameters

a. Output voltage magnitude: Determine the peak and average output voltage values.

b. Ripple voltage: Calculate the peak-to-peak ripple voltage and ripple percentage.

c. Peak reverse voltage: Determine the peak reverse voltage across the diodes.

Verify your calculations using simulation software or a circuit simulator. Simulate the circuit using the given specifications and compare the measured values with your calculated results.

Note: In this operation sheet, you can use appropriate formulas and equations related to single-phase and three-phase rectifier circuits to perform the calculations. Ensure you have a good understanding of rectifier operation and measurement techniques to successfully complete the operation sheet.

Operation sheet 2.3:

Operation Title: Maximum Output Voltage and Efficiency of Single Phase Half Wave Rectifier

Objective: To understand the effect of the firing angle on the output voltage and current of a single-phase half wave-controlled rectifier with a resistive load.

Materials and tools:

- Single phase half wave-controlled rectifier circuit
- Resistive load
- Power supply
- Variac
- Oscilloscope
- Multimeter

Procedure:

1. Connect the single phase half wave-controlled rectifier circuit according to the schematic diagram.
2. Connect the resistive load to the output of the rectifier.
3. Apply a fixed AC voltage to the input of the rectifier using the variac.
4. Adjust the firing angle of the thyristor using the firing circuit.
5. Observe the output voltage and current waveforms using the oscilloscope.
6. Measure the average output voltage and current using the multimeter.
7. Repeat steps 4-6 for different values of firing angle.

Analysis:

1. Plot the average output voltage and current versus the firing angle.
2. Discuss the relationship between the firing angle and the average output voltage and current.
3. What is the maximum average output voltage that can be obtained from the rectifier?
4. What is the efficiency of the rectifier at different firing angles?

Operation sheet 2.4:

Objective: To compare the output voltage and current waveforms of a single phase half wave-controlled rectifier with a resistive load and a three phase half wave-controlled rectifier with a resistive load.

Materials and tools:

- Single phase half wave-controlled rectifier circuit
- Three phase half wave-controlled rectifier circuit
- Resistive load
- Power supply
- Variac
- Oscilloscope
- Multimeter

Procedure:

1. Connect the single phase half wave-controlled rectifier circuit according to the schematic diagram.
2. Connect the resistive load to the output of the rectifier.
3. Apply a fixed AC voltage to the input of the rectifier using the variac.
4. Adjust the firing angle of the thyristor using the firing circuit.
5. Observe the output voltage and current waveforms using the oscilloscope.
6. Measure the average output voltage and current using the multimeter.
7. Repeat steps 3-6 for the three phase half wave-controlled rectifier circuit.

Analysis:

1. Compare the output voltage and current waveforms of the single and three phase half wave-controlled rectifiers.
2. Discuss the advantages and disadvantages of three phase half wave-controlled rectifiers.

Lap Tests

Lab Test for Single/Three-Phase Half-Controlled Bridge Rectifier:

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks accordingly.

Lab Test for Single/Three-Phase Half-Controlled Bridge Rectifier:

Circuit Configuration and Connections:

- Construct a single/three-phase half-controlled bridge rectifier circuit using thyristors.
- Connect the appropriate diodes, thyristors, resistive loads, and inductive loads as per the circuit diagram.
- Ensure proper isolation and safety measures are in place.
- Rectifier Output - Resistive Loads:
- Connect a resistive load (e.g., a resistor) to the rectifier output.
- Gradually increase the input voltage and measure the output voltage across the resistive load.
- Record the voltage readings for different input voltage levels.
- Output Voltage - Resistive Loads:
- Calculate the average and peak output voltage using the voltage readings obtained in the previous step.
- Compare the measured values with the expected values based on the input voltage and the rectifier configuration.

Rectifier Output - Inductive Loads:

- Disconnect the resistive load and connect an inductive load (e.g., an inductor or RL load) to the rectifier output.
- Apply the same input voltage as in the previous step and measure the output voltage across the inductive load.
- Record the voltage readings for different input voltage levels.

Output Voltage - Inductive Loads:

1. Calculate the average and peak output voltage using the voltage readings obtained in the previous step.
2. A Compare the measured values with the expected values based on the input voltage, load characteristics, and the rectifier configuration.

3. Flywheel Diode and Output Voltage Calculations:
4. Introduce a flywheel diode in the circuit parallel to the inductive load.
5. Measure the output voltage across the inductive load while the flywheel diode is in action.
6. Compare the output voltage readings with and without the flywheel diode and analyze the impact.

OBSERVATION

1. Input Parameter
    a. Input voltage
    b. Frequency
    c. Cycle time period
2. Observation Table

Half wave controlled rectifier with R - load

S.N.	Triggering Time (t)	Firing Angle (α)	Observed Output voltage		Theoretical Output Value	
			Avg. voltage	rms voltage	Avg. Voltage	rms voltage
1						
2						
3						
4						
5						

Half wave controlled rectifier with RL - load

S.N.	Triggering Time (t)	Firing Angle (α)	Observed Output voltage		Theoretical Output Value		Extinction Angle (β)	
			Avg. voltage	rms voltage	Avg. Voltage	rms voltage	Observed	Calc
1								
2								
3								
4								
5								

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