

“Power Storage Substation”

Submitted By

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ABSTRACT

A **Power Storage Substation** is an electrical facility designed to store electrical energy and supply it to the power grid when required. With the increasing use of renewable energy sources such as solar and wind, power storage substations play an important role in maintaining the stability and reliability of the power system. These substations typically use large-scale battery energy storage systems (BESS) to store excess electricity generated during periods of low demand or high renewable generation and release it during peak demand periods.

The main components of a power storage substation include battery banks, power conversion systems (inverters/rectifiers), transformers, switchgear, and an energy management system. The power conversion system converts alternating current (AC) from the grid into direct current (DC) for storage in batteries and converts it back to AC when energy is discharged to the grid. The energy management system monitors and controls the charging and discharging process to ensure efficient operation and grid stability.

Power storage substations help improve power quality, reduce energy losses, support renewable energy integration, and provide backup power during outages. They also assist in peak load management and frequency regulation in modern smart grids. As power demand continues to increase, energy storage substations are becoming a key technology for building reliable, sustainable, and efficient electrical power systems.

CHAPTER NO.1

INTRODUCTION

A Power Storage Substation is a facility that stores electrical energy during periods of low demand or excess generation and supplies it back to the power grid during peak demand. These substations are commonly equipped with Battery Energy Storage Systems (BESS), which allow electrical energy to be stored in batteries and used when required. This technology helps improve the flexibility and reliability of the electrical power system.

The main components of a power storage substation include battery banks, power conversion systems, transformers, control system, and protection equipment. The power conversion system converts alternating current (AC) from the grid into direct current (DC) to charge the batteries and converts it back to AC when the stored energy is supplied to the grid. Power storage substations play a crucial role in supporting renewable energy integration, maintaining grid stability, reducing power fluctuations, and improving power quality. They also help in peak load management, frequency regulation, and providing backup power during emergencies.

As modern power system continues to evolve toward smarter and more sustainable grids, power storage substations are becoming an essential technology for ensuring efficient energy management and reliable electricity supply.

The electrical power system plays a vital role in modern society by supplying electricity for residential, commercial, and

industrial applications. In traditional power systems, electricity generated at power plants must be used immediately because storing large amounts of electrical energy was difficult and expensive. However, with the increasing demand for electricity and the growing use of renewable energy sources such as solar and wind power, the need for efficient energy storage systems has become more important.

A power storage substation is a facility designed to store electrical energy and deliver it to the power grid whenever required. These substations mainly use Battery Energy Storage Systems (BESS) to store electricity in large battery banks. The stored energy can be supplied to the grid during peak demand periods or when power generation from renewable sources is low.

A typical power storage substation consists of several components such as battery units, power conversion systems, transformers, switchgear, control systems, and protection equipment. The power conversion system converts alternating current (AC) from the grid into direct current (DC) to charge the batteries, and during discharge, it converts the stored DC power back into AC so that it can be supplied to the grid.

Power storage substations help improve the reliability, efficiency, and stability of the electrical power system. They also support renewable energy integration, reduce power fluctuations, and help in peak load management. In addition, these systems provide backup power during emergencies and contribute to the development of modern smart grids.

With the continuous growth of renewable energy technologies and increasing electricity demand, power storage substations are becoming an essential part of future power systems, ensuring a more stable, efficient, and sustainable electricity supply

In modern electrical power systems, maintaining a balance between electricity generation and consumption is very important. Traditionally, electrical energy generated at power plants must be used immediately because storing large amounts of electricity was difficult. However, the rapid growth in electricity demand and the increasing use of renewable energy sources such as solar and wind power have created a need for efficient energy systems.

CHAPTER NO.2

LITERATURE SURVEY

A number of researchers have studied energy storage technologies and their applications in electrical substations and power systems. The following literature review summarizes key contributions related to Battery Energy Storage Systems (BESS), grid stability, renewable integration, and substation applications.

1. Battery Energy Storage Systems for Power Grid Applications

Several studies highlight the importance of Battery Energy Storage Systems (BESS) in improving the performance of modern power grids. Energy storage helps balance electricity supply and demand by storing excess power and supplying it during peak demand periods. It also improves reliability, power quality, and grid flexibility. Advanced battery management systems (BMS) are used to monitor battery health and control charging and discharging processes to ensure safe and efficient operation.

2. Integration of BESS with Renewable Energy

Recent research focuses on integrating lithium-ion battery storage with renewable energy sources such as photovoltaic (PV) systems in power substations. Studies show that combining PV systems with battery storage improves the reliability of auxiliary power supply and enhances grid resilience, especially in remote or high-voltage substations. However, challenges such as system cost, regulatory frameworks, and long-term performance still need further research.

3. Voltage Regulation and Power Quality Improvement

Some research examines the role of battery storage systems in voltage regulation and power quality improvement at substations. By responding quickly to fluctuations in load demand, BESS can regulate voltage levels and prevent voltage drops during peak load conditions or disturbances in the grid. Simulation studies using software tools such as ETAP demonstrate that installing BESS at substations can significantly improve voltage stability and grid reliability.

4. Energy Storage Technologies and Hybrid Systems

Researchers have also investigated different energy storage technologies, including batteries, supercapacitors, flywheels, and fuel cells. Hybrid systems that combine batteries with supercapacitors can improve energy storage performance by providing high energy density and high-power density simultaneously. These systems can extend battery life, reduce operational stress, and enhance the efficiency of power storage systems.

5. Economic and Operational Considerations

Several studies analyze the economic feasibility and operational strategies of energy storage systems in power networks. Research shows that energystorage can support grid services such as frequency control, peak load management, and energy arbitrage. However, economic viability often depends on factors such as battery cost, system efficiency, and market conditions. Future studies are focusing on optimization techniques and advanced energy management systems to improve the economic benefits of BESS deployment.

Summary

From the reviewed literature, it can be concluded that power storage substations using battery energy storage systems play a crucial role in modern power systems. They support renewable energy integration, improve voltage regulation, enhance grid stability, and provide reliable backup power. However, further research is required to address challenges related to cost, system optimization, and long-term operational performance.

CHAPTER NO.3

SCOPE OF THE PROJECT

3.1. Project Overview

A power storage substation project, typically referred to as a **Battery Energy Storage System (BESS)** project, is a multi-phase engineering undertaking aimed at enhancing grid reliability and integrating renewable energy. These projects transition from initial feasibility studies through detailed electrical design to physical construction and commissioning

3.2 Objectives

The primary objective of a Power Storage Substation project is to establish a robust and flexible Energy Storage System (ESS) that bridges the gap between power generation and consumer demand. By integrating high-capacity battery technology with existing grid infrastructure, the project aims to enhance grid stability through instantaneous frequency regulation and voltage control, ensuring a steady supply even during sudden fluctuations. Furthermore, it serves as a critical enabler for renewable energy integration, capturing surplus power from intermittent sources like solar and wind to prevent energy wastage and allow for "time-shifting" of clean energy to peak hours.

3.3 Scope of Work

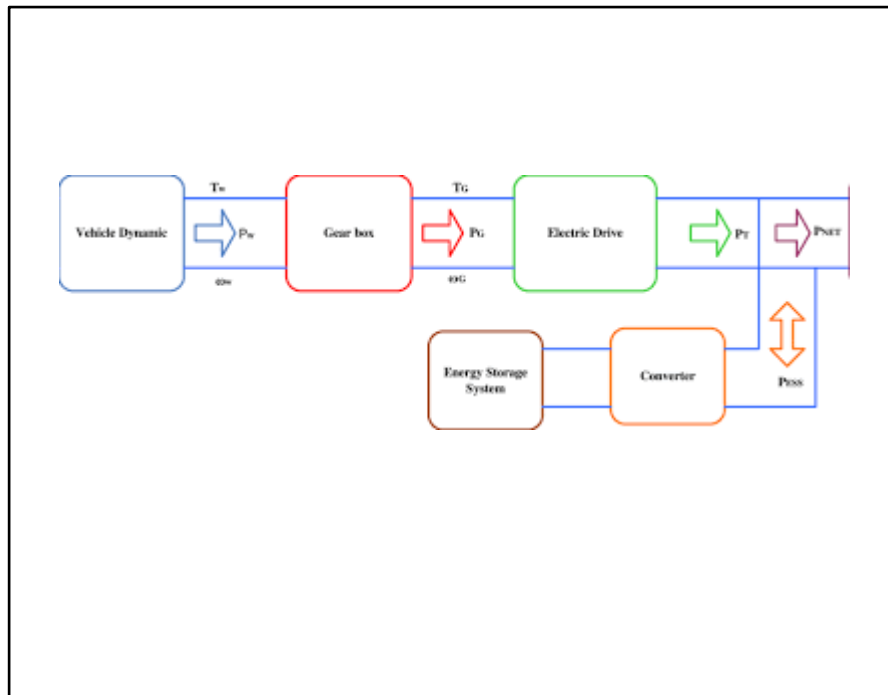
The Scope of Work for a power storage substation project encompasses the complete engineering, procurement, construction, and commissioning (EPCC) of a fully integrated Battery Energy Storage System (BESS). It begins with comprehensive site preparation and civil works, including the construction of reinforced foundations for battery containers, inverter units, and transformers. The Scope of Work for the power storage substation project encompasses the complete engineering, procurement, construction, and commissioning (EPCC) required to deliver a fully operational Battery Energy Storage System (BESS). This begins with detailed civil and structural engineering, including site grading, the construction of reinforced concrete foundations for battery containers and inverter units, and the installation of essential perimeter security and drainage infrastructure.

The technical core involves the **procurement and installation** of high-capacity lithium-ion battery modules, power conversion systems (PCS), and high-voltage switchgear required for grid synchronization. A critical component of the scope is the **electrical integration**, which includes laying specialized medium-voltage cabling and establishing a robust grounding and lightning protection network. Furthermore, the work extends to the deployment of advanced **Energy**

Management Systems (EMS) and SCADA platforms to automate charging cycles and monitor system health in real-time. The project concludes with rigorous **testing and commissioning** phases to ensure the facility meets all utility standards for frequency response and safety before being officially handed over for commercial operation.

CHAPTER NO.4

METHODOLOGY



4.1 Block Diagram:

Fig 4.1 Block Diagram

The methodology describes the **step-by-step process** used to design and implement the power storage system.

1. System Planning and Design
2. Identify the **power requirement** and storage capacity needed.
3. Select appropriate **energy storage technology** such as batteries.
4. Design the **overall system layout** including solar panel, battery, inverter, and control unit.

A power storage substation is an important part of the electrical power system that stores energy and supplies it when needed. It collects electricity from sources like solar panels, wind turbines, or the main grid and converts it into a suitable form for storage, usually as DC power in batteries. When the demand for electricity increases, the stored energy is converted back into AC power and supplied to the grid. This helps in balancing supply and demand, improving grid stability, and reducing power interruptions. Power storage substations are especially useful in renewable

CHAPTER NO.5

DESIGN, WORKING AND PROCESSES

5.1 Circuit Diagram

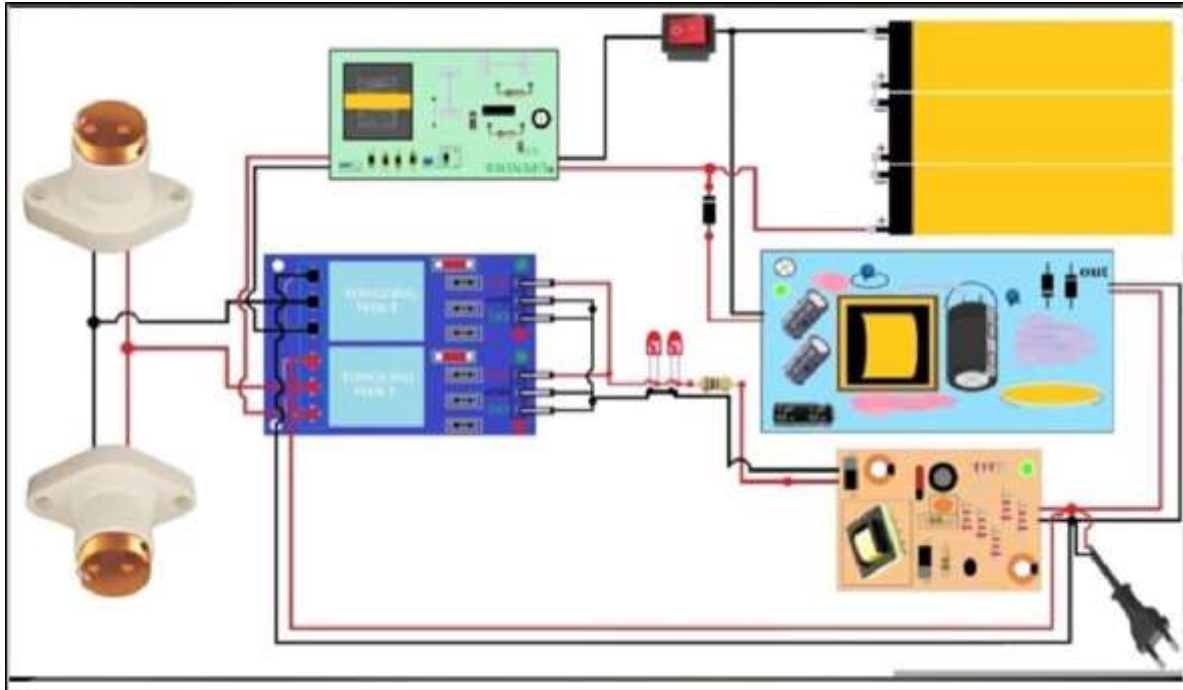


Fig. 5.1 Circuit Diagram

A **Power Storage Substation** is a facility designed to **store electrical energy and supply it to the power grid when required**. The basic principle behind it is that electricity generated from sources like solar, wind, or the main grid can be **stored in batteries** during periods of low demand and then released during peak demand or when the grid requires additional support.

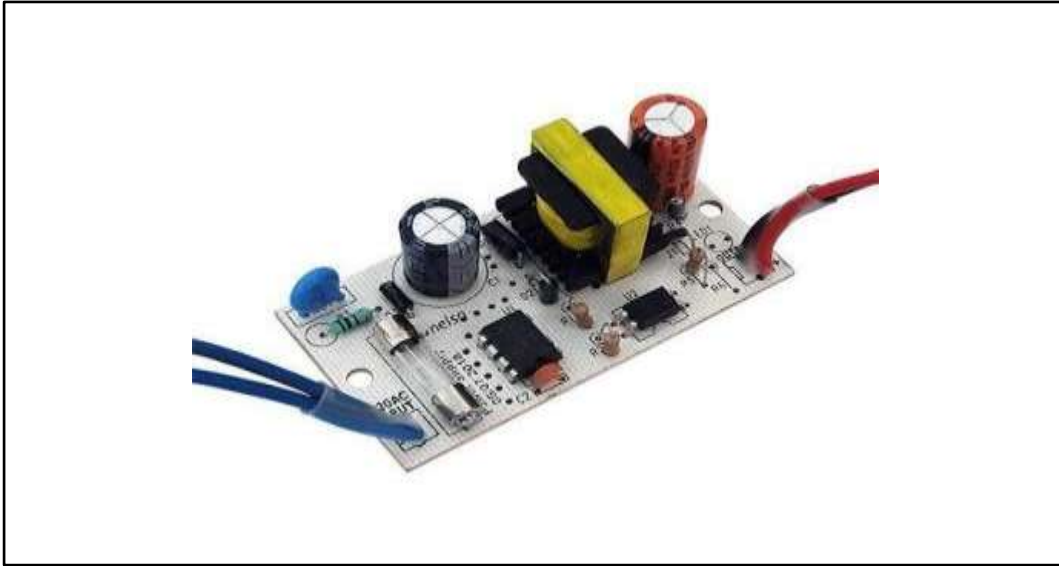
The circuit diagram of the power storage substation shows the connection between the power source, conversion units, storage system, and load. The input power is obtained from sources such as solar panels, wind energy, or the electrical grid. This AC power is first passed through a rectifier, which converts it into DC power suitable for storage.

The DC power is then stored in the energy storage system, typically batteries. When required, the stored energy is supplied through an inverter, which converts DC back into AC power. Transformers are used to step up or step down the voltage as needed for efficient transmission

1.1 Component Used:

1.1.1 AC to DC Converter

The **AC to DC converter** is an essential component of a **power storage substation**, because the main function of the substation is to store electrical energy in batteries. Since **batteries can store energy only in direct current (DC)** form, any alternating current (AC) coming from the **grid or renewable sources** like solar panels or wind turbines must first be converted to DC.



1.1.1 Fig.5.2.1. AC to DC Converter

An AC to DC converter, also known as a rectifier, is an essential component in a power storage substation. Its main function is to convert alternating current (AC) from the power source into direct current (DC), which is suitable for energy storage systems such as batteries.

The AC supply obtained from the grid or renewable sources is first fed into the rectifier circuit. This circuit typically consists of diodes that allow current to flow in only one direction, thereby converting AC into pulsating DC. In many cases, filters such as capacitors are used to smooth the output and reduce ripples, producing a more stable DC voltage.

The converted DC power is then supplied to the energy storage system for charging. Efficient AC to DC conversion is important to minimize energy losses and ensure proper functioning of the storage system.

1.1.2 Battery

Solar cell module produces electricity only when the sun is shining. They do not store energy. It is necessary to store some of the energy produced. So we use battery to store electrical energy generated by the solar panel. It is also used for the powering operation system. The battery is of 12V DC Batteries are available in different voltages and ampere hour range. To determine the battery selection, consideration was given to the rating of the voltage and current. Since the solar panel is 12V, then a 12V battery was selected. The ampere hour is used to measure the time the battery will take to discharge while it's not charging. A 7 Ampere battery was selected and will give 7 amps of current of battery for one hour before it fully discharges.



Fig. 1.1.2. Battery

Function

- A battery is a device that stores chemical energy and converts it to electrical energy. The chemical reactions in a battery involve the flow of electrons from one material (electrode) to another, through an external circuit. The flow of electrons provides an electric current that can be used to do work.

1.1.3 DC to AC Converter

A **DC to AC converter** is an electronic device that converts **direct current (DC)** electricity into **alternating current (AC)** electricity. This is essential because most household appliances and the power grid operate on AC, while sources like batteries, solar panels, and fuel cells provide DC.

Key Components

1.DC Input Source

Provides the direct current (e.g., battery, solar panel, or DC power supply).

Oscillator

Generates a high-frequency signal that switches the DC into AC.

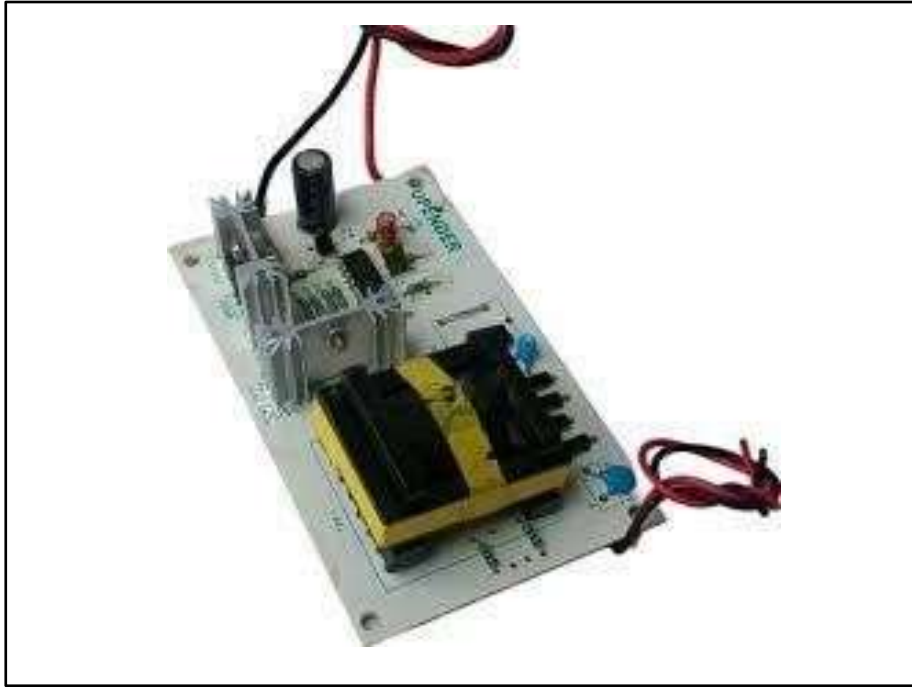


Fig 1.1.3 DC to AC Converter

Function

The main purpose is to **transform DC voltage from a source (like a battery or solar panel) into AC voltage** suitable for operating standard electrical appliances.

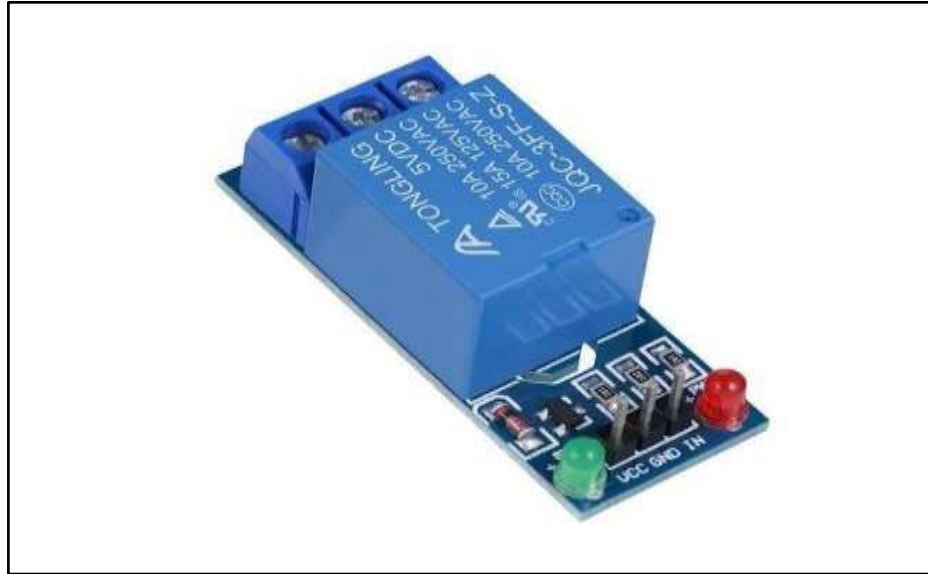
A DC to AC converter, commonly known as an inverter, is a key component in a power storage substation. Its main function is to convert the stored direct current (DC) energy into alternating current (AC), which can be used by electrical loads or supplied to the power grid.

The DC power stored in batteries is fed into the inverter circuit. The inverter uses electronic switching devices to convert the DC input into AC output. This output is then shaped into a proper sinusoidal waveform using filters, ensuring it is suitable for practical use. In advanced systems, the inverter also controls voltage and frequency to match grid requirements.

The AC power produced by the inverter is then passed through transformers if necessary and supplied to the distribution system. Efficient DC to AC conversion is important for reliable power delivery and minimizing energy losses.

1.1.4 Single module relay

A **Single Module Relay** is a **compact protection device** used in electrical systems (such as substations, control panels, or industrial circuits) to **detect faults and automatically operate a circuit breaker or alarm**. It contains **all relay functions in one module**, including sensing, processing, and tripping.



1.1.4 Single module relay

A **Single Module Relay** is used in electrical systems to **monitor electrical parameters and protect equipment by automatically controlling circuits during abnormal conditions**. A single module relay is an electrical switching device used to control a high-power circuit using a low-power signal. It consists of a relay, driver circuit, and protection components assembled in a single module, making it easy to use in control systems.

The relay works on the principle of electromagnetic induction. When a small control signal is applied to the input, it energizes a coil inside the relay. This creates a magnetic field that pulls the switch contacts, either opening or closing the circuit. In this way, the relay can control devices like motors, lights, or other electrical loads.

Single module relays are commonly used in automation, microcontroller projects, and power systems for switching operations. They provide electrical isolation between the control circuit and the high-power circuit, ensuring safety and reliability

1.1.5 230v To 5v converter

A **230V to 5V converter** is a power supply circuit that converts **high-voltage AC mains (230V)** into **low-voltage 5V DC** suitable for electronic devices such as microcontrollers, sensors, relays, and communication modules.



Fig. 1.1.5 230v To 5v converter

Function

A 230V to 5V converter is an electronic circuit used to step down high-voltage AC power (230V) to a low-voltage DC output of 5V. It is commonly used to power low-voltage electronic devices such as microcontrollers, sensors, and relay modules.

The conversion process involves several stages. First, the 230V AC supply is passed through a step-down transformer, which reduces the voltage to a lower AC level (e.g., 12V AC). This low AC voltage is then converted into DC using a rectifier circuit, usually made of diodes. After rectification, a filter (capacitor) is used to smooth the pulsating DC into a more stable form. Finally, a voltage regulator is used to provide a constant 5V DC output.

In modern systems, instead of bulky transformers, a switched-mode power supply (SMPS) is often used for efficient and compact conversion. This converter is essential in electronic systems to safely power low-voltage components from the main AC supply.

1.1.6 PCB Board

A **PCB (Printed Circuit Board)** is a flat board used to **mechanically support and electrically connect electronic components** using copper tracks, pads, and other conductive pathways.

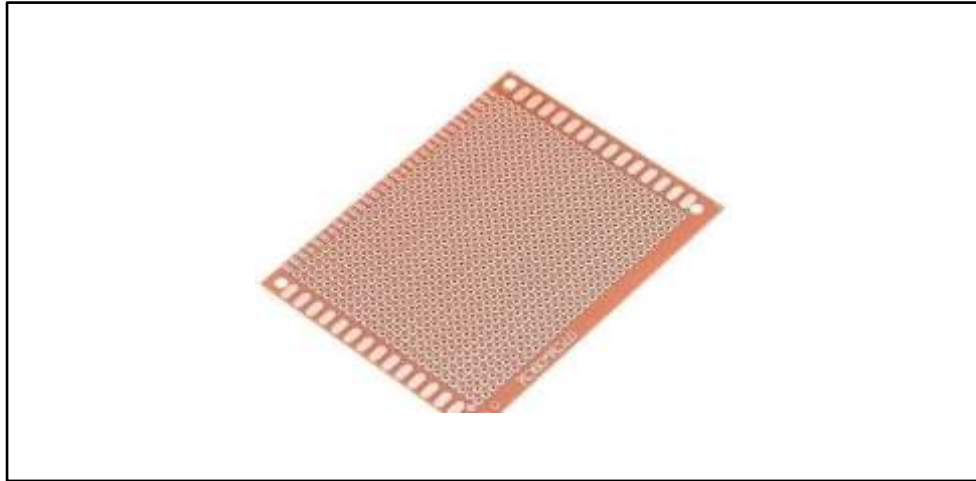


Fig. 1.1.6 PCB Board

Function

A **PCB (Printed Circuit Board)** is designed to **mechanically support electronic components and electrically connect them using conductive pathways**. Its main function is to create a **compact, reliable, and organized circuit** for electronic devices

A PCB (Printed Circuit Board) is a flat board used to mechanically support and electrically connect electronic components using conductive pathways, tracks, or signal traces. It is an essential part of almost all electronic devices and circuits.

The PCB is made of insulating material such as fiberglass (FR4), with thin layers of copper laminated on its surface. The copper is etched to form pathways that connect different components like resistors, capacitors, ICs, and relays according to the circuit design.

PCBs help in reducing wiring complexity, improving reliability, and making the circuit compact and organized. Components are mounted on the PCB either by through-hole technology or surface mount technology (SMT).

CHAPTER NO.6

RESULTS AND APPLICATIONS

Result

The **results** section typically summarizes the findings of an experiment, study, or project. Its purpose is to present data and observations **without interpretation** (interpretation often comes in the discussion). Key elements include:

1. Data Presentation:

- a. Use tables, graphs, and charts to clearly show measurements, trends, or outcomes.
- b. Temperature vs. reaction rate in a chemistry experiment
- c. User engagement statistics in a software study

2. Observations:

- a. Highlight significant trends or unexpected outcomes. For instance:

- b. “The reaction was faster at higher temperatures.”
- c. “Users spent 30% more time on the updated interface.”

3. Quantitative Metrics:

- a. Report precise numbers, percentages, or statistical analyses:
- b. “Average growth increased from 5% to 12%.”
- c. “Error margin was $\pm 2\%$.”

4. Visual Evidence:

- a. Figures, photos, or diagrams support the results, making them easier to interpret at a glance.

Applications:

The **applications** section explains how the results can be **used in real life**, industry, or further research. It answers the question: “*Why does this matter?*” Key aspects include:

1) Practical Applications:

2) Describe how findings solve real problems. Examples:

- i. A new drug formulation → used in treating a specific disease
- ii. Efficient solar cell design → implemented in renewable energy systems

3) Theoretical Applications:

4) How the results contribute to knowledge or models:

- i. Improving climate prediction models
- ii. Advancing AI algorithms

5) Industrial or Commercial Applications: Explain market relevance or product integration:

- i. “The algorithm reduces processing time by 40%, suitable for cloud services.”

6) Future Research Directions: Suggest extensions or improvements:

- i. “Further studies can test performance under extreme conditions.”

CHAPTER NO.7

CONCLUSION AND FUTURE SCOPE

Future Scope

storage systems play a crucial role in modern energy management by storing excess electricity and supplying it when demand increases. These systems improve the reliability, stability, and efficiency of power grids while supporting the integration of renewable energy sources such as solar and wind.

Technologies like battery energy storage, pumped hydro storage, compressed air energy storage, and flywheel systems each offer unique advantages depending on the scale and application. Among them, battery storage systems are becoming the most widely used due to their fast response time, flexibility, and decreasing costs.

Overall, power storage systems help reduce energy waste, provide backup during power outages, and enable a more

sustainable and efficient energy infrastructure.

7.1 Future Scope:

The future of power storage systems is highly promising as the global demand for clean and reliable energy continues to grow. With advancements in technology, energy storage systems are expected to become more efficient, affordable, and environmentally friendly.

Key future developments include:

- **Advanced battery technologies** such as solid-state batteries and improved lithium-ion batteries with higher energy density.
- **Large-scale grid storage** to support renewable energy integration and stabilize power networks.
- **Hydrogen energy storage**, which can store energy for long durations and support green hydrogen production.

CONCLUSION

Conclusion

The automatic reverse braking system (ARBS) is a crucial advancement in vehicle safety, designed to prevent accidents while reversing. By automatically applying the brakes when the system detects an obstacle, ARBS significantly reduces the risk of back over accidents, which are common in parking lots or areas with limited visibility.

This technology works alongside other safety features, such as parking sensors and backup cameras, to provide a comprehensive layer of protection. While it enhances driver confidence and safety, particularly for those with limited experience or when manoeuvring in tight spaces, ARBS does have limitations, such as potential false positives or negatives due to sensor limitations.

However, as vehicle safety technology continues to evolve, ARBS is expected to become a standard feature in most vehicles, further contributing to the reduction of accidents and making

driving a safer, more intuitive experience.

COST ESTIMATION AND HARDWARE

8.1 Cost Estimation:

Table 8.1 Cost Estimation

Sr. No.	DISCRIPTIONS	PRICE
1	AC to DC Converter	750/-
2	DC to AC Converter	680/-
3	Rechargeable battery	550/-

4	230V to 5v converter	340/-
5	Single module relay	270/-
6	switch	20/-
7	Diode	20/-
8	ResisterS	20/-
9	wire	150/-
10	LED	100/-
11	PCB board	150/-
	Total	3,050/-

8.1 Hardware Design:

This Model is fabricated in workshop.

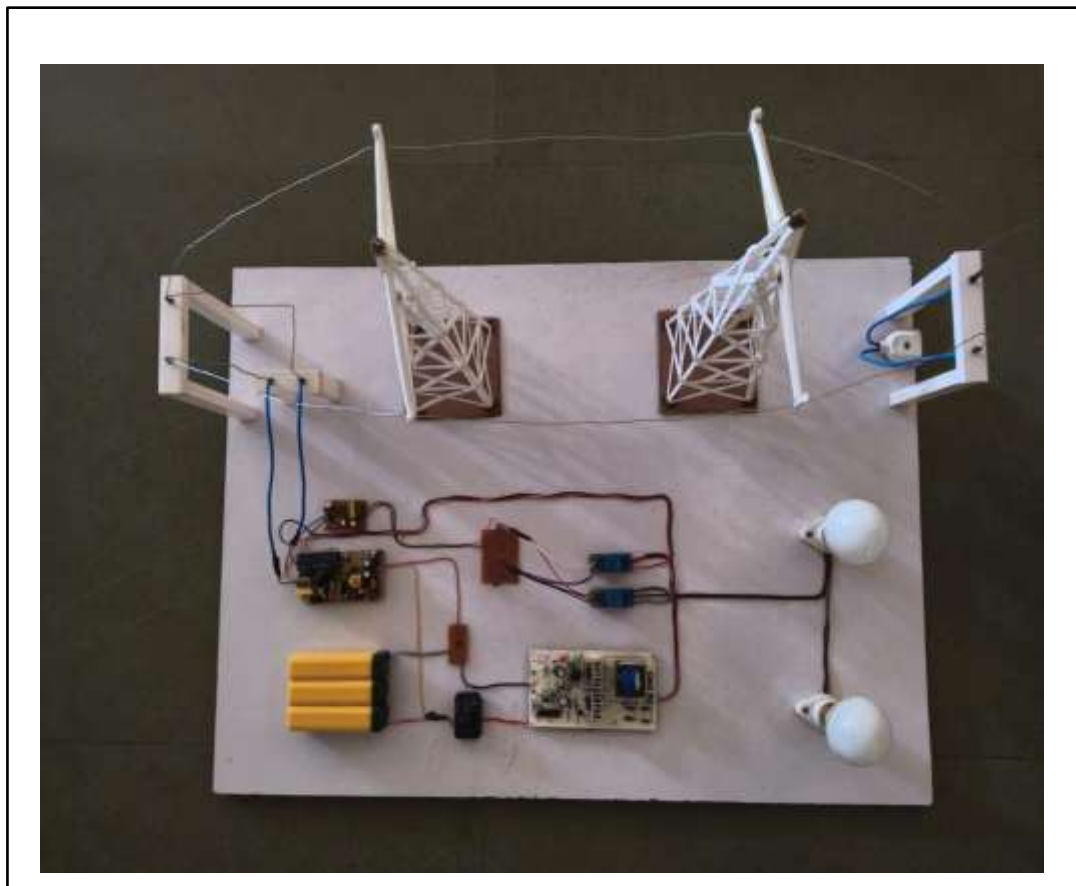


Photo 8.1 Hardware Design

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APPENDIX

Appendix

The Automatic Reverse Braking System (ARBS) is a critical safety feature designed to prevent collisions when reversing a vehicle. It uses a combination of sensors, such as ultrasonic, radar, and cameras, to detect obstacles in the vehicle's path.

These sensors send data to an Electronic Control Unit (ECU), which processes the information and activates the braking system if an obstacle is detected within a critical range, usually about one meter or less.

The system works seamlessly with the vehicle's existing braking infrastructure, ensuring smooth and rapid intervention without driver involvement. While the initial cost of installing ARBS varies depending on the vehicle model and sensor type, it is generally considered a valuable addition for improving safety, particularly in tight spaces like parking lots.

As technology evolves, future advancements in sensor fusion, machine learning, and autonomous parking integration are expected to enhance the system's effectiveness and reliability even further.