CHAPTER THREE

DESIGN METHODOLOGY

3.0 INTRODUCTION

This section outlines the comprehensive design methodology adopted for the successful installation of a 10kVA inverter at the Institute of Technology. The project was aimed at providing an alternative and sustainable power supply to the central administrative building of the Institute of Technology (I.O.T), ensuring uninterrupted power for essential administrative tasks. The design takes into consideration the energy requirements of the central administrative building, including the Director's office, Deputy Director's office, Institute Secretary, Financial Officer, security personnel, and clerical staff, as well as the four external departmental HOD offices. The building is a two-storey facility, with management offices on the upper floor and support staff offices, including the conference room and the general exam office, on the ground floor.

3.1 BLOCK DIAGRAM

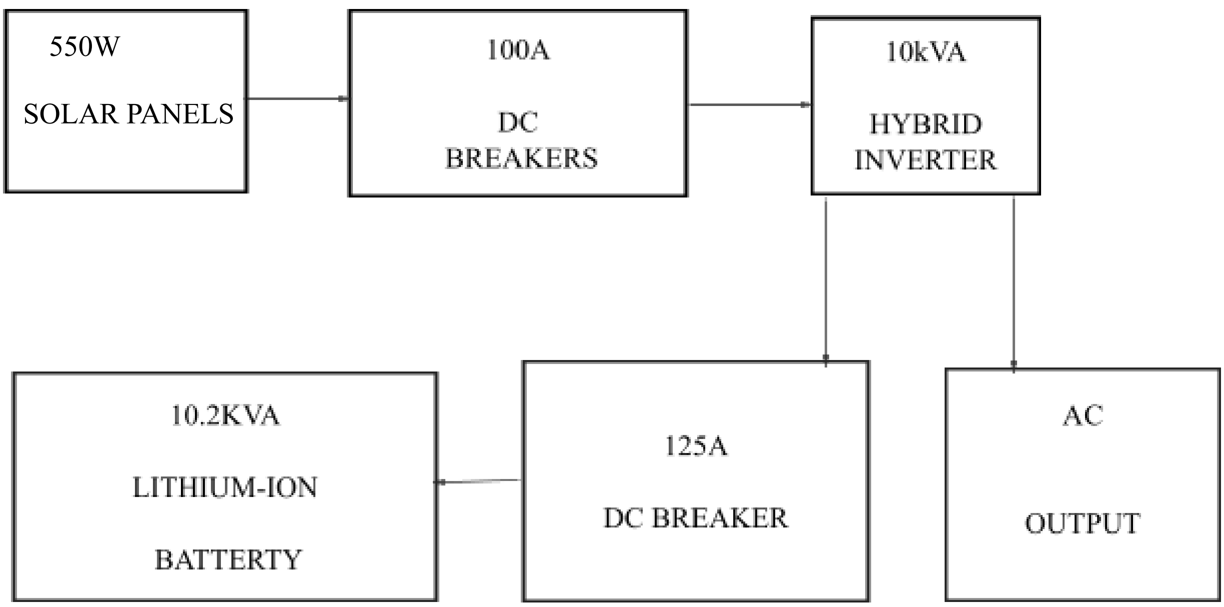

Fig. 1 The Block diagram of the project

a) 10kVA Hybrid Inverter

A 10kVA hybrid inverter is a smart energy device that combines the functions of a solar inverter and a battery inverter. It can draw power from solar panels, the battery bank, or the grid and intelligently switch between these sources. It ensures uninterrupted power supply, provides energy management features, and often includes MPPT charge controllers and backup capabilities.

b) 10.2kW Lithium-Ion Battery

This high-capacity lithium-ion battery stores up to 10.2 kilowatt-hours (kWh) of electrical energy. Known for their long life, high efficiency, and low maintenance, lithium-ion batteries are ideal for solar applications. They supply stored energy to the inverter during periods without sunlight or grid power, ensuring continuous operation.

c) DC Breakers

DC breakers are protective devices used in solar power systems to disconnect and isolate the direct current (DC) circuits safely. They prevent damage due to overcurrent, short circuits, or system faults by automatically breaking the circuit when current exceeds the rated value. They are essential for battery and solar panel safety.

d) 550W Solar Panels

These high-efficiency solar panels convert sunlight into electrical energy with a power output of up to 550 watts under standard conditions. In a solar system, they supply the primary energy input, especially during peak sun hours. When installed in arrays, they generate enough electricity to charge batteries and power connected loads.

e) AC Output

AC output refers to the alternating current supplied by the inverter to power conventional electrical devices and appliances. In this system, the inverter converts DC from the solar panels or battery into 230V AC, the standard voltage for office and residential use. This output is distributed to all connected offices and utilities.

3.2 SITE SURVEY AND LOAD ASSESSMENT

The first step in the design methodology involved conducting a detailed site survey to understand the power requirements, existing electrical infrastructure, and physical constraints of the central building. The survey identified all electrical appliances and devices used in the offices, including lighting fixtures, fans, computers, printers, photocopiers, and refrigerators.

3.2.1 LOAD IDENTIFICATION AND CATEGORIZATION

Loads were categorized into essential and non-essential loads. Essential loads include lighting, computers, communication devices, and security systems, while non-essential loads include air conditioners and high-power-consuming appliances which are not powered by the inverter system. The following load estimation was derived:

i. Lighting: 30 units of 20W = 600W
ii. Fans: 15 units of 75W = 1,125W
iii. Computers and accessories: 20 units of 200W = 4,000W
iv. Printers and photocopiers: 3 units of 600W = 1,800W
v. Refrigerator: 1 unit of 250W = 250W
vi. Miscellaneous: 500W
vii. Total estimated load: 8,275W

A 20% margin was added for safety and future expansion, leading to a design load of approximately 9,930W, making a 10kVA inverter an ideal choice.

3.3 SYSTEM DESIGN SPECIFICATIONS

3.3.1 INVERTER SPECIFICATION

a. Rating: 10kVA Pure Sine Wave Inverter

b. Input: 48V DC

c. Output: 230V AC

d. Frequency: 50Hz

e. Efficiency: >90%

f. Protection: Overload, short-circuit, and over-temperature protection

3.3.2 BATTERY BANK

* Capacity: 10.2kWh (Rated at 48V)

* Type: Lithium-ion/AGM (based on chosen configuration)

* Configuration: Single battery unit with DC breaker for isolation and protection

3.3.3 SOLAR PANELS

a. Quantity: 10 Panels

b. Rating: 550W each

c. Total Capacity: 5.5kW (actual dissipation up to 570W/panel during peak sun)

d. Orientation: South-facing with a tilt angle optimized for maximum sun exposure

3.3.4 SOLAR CHARGE CONTROLLER

a) Type: MPPT (Maximum Power Point Tracking)

b) Input Voltage: Compatible with panel output

c) Output Voltage: 48V DC

d) Features: LCD display, programmable settings, overload and overcharge protection

3.3.5 CABLING AND PROTECTION

a. DC Cables: $6mm^2$ rated, UV resistant, and flame retardant

b. AC Cables: $4mm^2$ for distribution to offices

c. Protection: DC breakers at battery and inverter inputs, AC breakers for each output branch, surge protectors

3.4 DISTRIBUTION SYSTEM

The output of the inverter is connected to a distribution box that supplies power to the central building and to the external departmental offices. Sub-switches are installed for each section with preset maximum current values, programmed to disconnect the circuit in case of overcurrent.

3.5 INSTALLATION PROCESS

3.5.1 Pre-Installation Preparations

a) Procurement of equipment and components

b) Site preparation and structural assessment for solar panel mounting

c) Cable routing plans

3.5.2 INSTALLATION OF SOLAR PANELS

a. Installation on a secure, elevated platform with optimized tilt

b. String configuration for optimal voltage and current balance

c. Connection to the charge controller

3.5.3 INVERTER AND BATTERY SETUP

a) Inverter installed in a well-ventilated, moisture-free control room

b) Battery placed in a stable, temperature-controlled environment

c) Interconnection with appropriate cable terminations and DC breakers

3.5.4 WIRING AND PROTECTION IMPLEMENTATION

a. DC cabling from panels to charge controller and from controller to battery bank

b. DC cabling from battery bank to inverter with inline DC breakers

c. AC output wiring to distribution board and to various sub-circuits

d. Installation of circuit breakers, surge protectors, and earthing systems

3.5.5 LOAD CONNECTION AND TESTING

a) Each office's load connected and tested sequentially

b) Sub-switches configured to disconnect on overcurrent conditions

c) System tested for voltage stability, inverter switchover delay, and response time

3.6 EXTENSION TO EXTERNAL OFFICES

To enhance productivity and ensure continuity of service in all departments, the inverter's AC output was extended to four external HOD offices (Mechanical, Agriculture, Metallurgy, and Mining Engineering).

3.6.1 CABLING AND ROUTING

a. Overhead AC cabling was used for safety and durability

b. Proper routing through conduits to protect from weather and physical damage

c. Separate breakers installed at the extension points for fault isolation

3.6.2 LOAD ANALYSIS AT EXTERNAL OFFICES

Each office has:

a) 1 printer (600W)

b) 2 computers (400W total)

c) Lighting (100W)

d) Fan (75W)

e) Miscellaneous (100W)

Total: 1,275W per office; Total external load: 5,100W

3.7 MONITORING AND CONTROL SYSTEM

A monitoring system was installed to log and display performance metrics:

i. Solar generation per day

ii. Battery State of Charge (SOC)

iii. Load consumption

iv. Inverter status (input/output voltage, current, overload warnings)

3.8 SAFETY AND COMPLIANCE MEASURES

i. All equipment used complies with relevant IEC and national standards

ii. Fire extinguishers and warning signage installed

iii. Staff sensitized on safety and maintenance practices

iv. Earthing systems tested and verified

3.9 MAINTENANCE STRATEGY

a. Routine visual inspections for dust accumulation on panels

b. Monthly checkups on battery health and inverter functionality

c. Biannual professional servicing of the system

d. Prompt replacement of damaged components

3.10 CHAIN OF CONNECTION

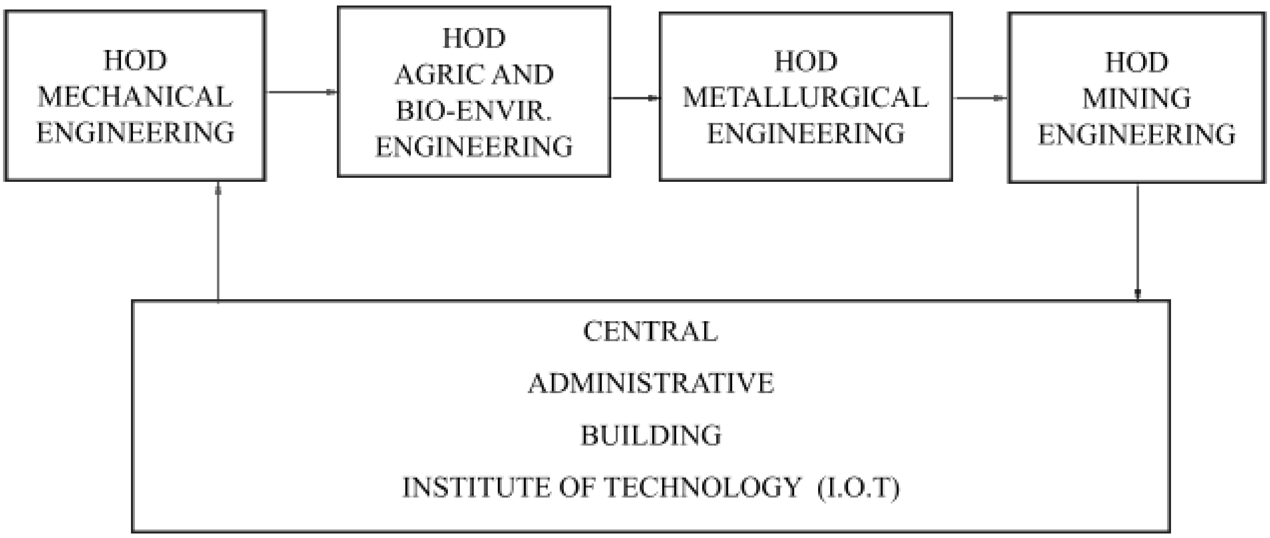

Fig.3.2 Chain of Connection

This refers to the systematic distribution of power from the main solar energy installation at the Central Administrative Building to the various satellite offices it supports. This configuration demonstrates a thoughtful and strategic power extension architecture, enabling the smooth operation of critical departmental units within the Institute of Technology. The installation of a 10kVA hybrid inverter system not only addresses the central building's energy demands but also extends its service reach to four major departments, ensuring a seamless supply of electricity for both administrative and academic operations.

1. Central Administrative Building – Power Generation Hub

At the heart of the system lies the Central Administrative Building, which houses the entire renewable energy infrastructure. This includes:

a. 10kVA hybrid inverter – converts DC power from the battery and solar panels into usable AC output.

b. 10.2kWh lithium-ion battery – stores excess energy generated during peak sunlight hours for later use.

c. 10 × 550W solar panels – generating up to 5.5kW, and in favorable conditions, even 5.7kW.

d. DC breakers and protection devices – ensure the safety of all components by preventing overcurrent and short circuits.

This central node is responsible for powering the offices of top management staff including the Director, Deputy Director, Institute Secretary, Financial Officer, security personnel, and clerical staff. The building also contains a large conference room and the general examination office of the institute.

Once stabilized AC output is produced by the hybrid inverter, the power is distributed through properly rated electrical cables and protective sub-switches, enabling a structured connection chain to external buildings.

2. Structured Power Distribution – Extending Beyond the Central Node

The second stage of the chain involves the extension of power to the departments outside the central building. From a central distribution board within the administrative building, dedicated AC lines are run to the offices of the following departments:

- HOD Mechanical Engineering
- HOD Agricultural and Bio-Environmental Engineering
- HOD Metallurgical Engineering
- HOD Mining Engineering

Each office not only houses the HODs but also their secretaries and departmental operations that rely on uninterrupted power to support:

- Administrative tasks (email communication, document processing)
- Office utilities (desktop computers, laptops, printers, photocopiers)
- Cooling appliances (fans, small fridges)
- Mobile gadget charging and academic research activities

The cable routes are installed using standard underground or overhead trunking, considering building layout and load requirement. Voltage drop and power loss are minimized by using high-quality 6mm² DC and appropriate AC cables, and protective sub-circuit breakers are installed at each terminal point to safeguard individual department systems from overload or short circuits.

3. Energy Efficiency and Load Management

An essential part of this chain of connection is load management. The hybrid inverter system includes intelligent energy management features that:

a. Monitor power distribution in syncronously.

b. Disconnect non-essential loads automatically if consumption approaches the inverter's 10kVA limit.

c. Prioritize essential services during low energy periods (e.g., cloudy days or high night-time usage).

To ensure balance, each department was surveyed for its power requirement prior to installation. The average departmental consumption was analyzed and matched against the capacity of the inverter system, taking into account both peak and off-peak operations. Load distribution ensures that no single department overloads the system.

4. Scalability and Future Provisions

The system is designed with scalability in mind. Extra conduits and sub-panels were laid out during installation to accommodate future connections or load expansions without disrupting current operations. The current configuration allows for additional battery or panel capacity, if needed. Each point in the connection chain is monitored for performance and fault detection, and maintenance checks are scheduled periodically to ensure long-term efficiency and safety.

5. Operational Impact

The successful implementation of this chain of connection has significantly:

Improved power reliability across the entire institute.

Reduced reliance on the public grid and fossil-fuel generators.

Enhanced productivity in administrative and departmental offices.

Provided a cleaner, quieter, and more sustainable working environment for both staff and students.

This energy architecture serves as a model for institutional power decentralization using renewable energy, proving that a well-designed hybrid inverter system can provide dependable energy across multiple buildings without compromising performance or safety.