SOLAR SOLUTION FOR NETWORK PROBLEM

By

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213-15-4525

FINAL YEAR DESIGN PROJECT REPORT

This Report Presented in Partial Fulfillment of the Requirements for

the **Degree of Bachelor of Science in Computer Science and Engineering**

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APPROVAL

This Project titled **"Solar Solution for Network Problems"**, submitted by Sajid Mahamood, ID No: **213-15-4525** to the Department of Computer Science and Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on **17 September, 2025**.

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DECLARATION

We hereby declare that this project has been done by us under the supervision of **Md. Sazzadur Ahamed, Assistant Professor,** Department of Computer Science and Engineering, Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for the award of any degree or diploma.

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Finally, I must acknowledge with due respect the constant support and patience of my parents.

ABSTRACT

This project proposes an IoT-based dual power mobile network monitoring system designed to ensure continuous connectivity during power outages. It involves two network towers—one connected only to the grid and the other integrated with both grid and solar power sources. A physical switch is used to simulate load shedding conditions. Upon load shedding, both towers initially drop from 4G to 2G. The tower equipped with solar power automatically recovers and restores the network from 2G back to 4G using solar energy. The system includes a display that visually represents the current network status and power source. It also features an IoT platform that updates the real-time condition of each tower, showing messages such as "LOAD SHEDDING, Taking Power From Solar Panel" or "NO LOAD SHEDDING, Taking Power From Grid." This project demonstrates an efficient approach to power redundancy, network stability, and remote monitoring for future-ready telecom infrastructure.

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Chapter 1

Introduction

This chapter provides a comprehensive introduction to the project, establishing the background and problem statement for the project. It will describes the objectives, motivation, methodology and outcomes of the project.

1.1 Introduction

With the rapid increase in mobile data traffic, energy consumption in cellular networks has surged significantly, particularly due to the operation of base stations (BSs), which are responsible for the majority of power usage. In regions with unreliable electrical grids or frequent power outages, mobile network operators often rely on diesel generators (DGs) to maintain network availability. However, this approach results in high operational expenditure (OPEX), environmental degradation through carbon emissions, and noise pollution. According to research, the global OPEX on electricity for cellular networks exceeded $22 billion in 2014 alone, and this number continues to rise as the demand for wider coverage and faster connectivity increases (Han et al., 2017).

To address these challenges, integrating renewable energy sources—especially solar photovoltaic (PV) systems—has become a promising solution. Solar energy is not only sustainable and clean, but it is also abundant during daytime hours, which typically align with peak data usage periods. This project proposes a hybrid power model for mobile network towers, where one tower operates with a solar fallback system. During load shedding, the system automatically switches from grid to solar power, restoring network performance from 2G to 4G within a few seconds. An IoT-based monitoring platform also displays the network status and power source usage in real-time.

This approach enhances energy efficiency, reduces dependency on fossil fuels, and ensures reliable connectivity in rural and urban areas alike. By leveraging solar

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energy, the proposed system contributes toward green communication and a more sustainable telecommunication infrastructure.

1.2 Motivation

In many developing countries, frequent power cuts or load shedding disrupt mobile communication services, especially in rural or low served areas. Since cellular connectivity is vital for emergency response, online education, business operations, and social connectivity, ensuring uninterrupted 4G network service has become a significant need. Traditional network towers rely solely on the main power grid, making them vulnerable during outages.

This motivated us to design a smart, sustainable solution that integrates solar energy with IoT-based monitoring to maintain seamless mobile communication even during power failures. By using a buck converter for voltage regulation, a relay-based auto switching mechanism, and real-time monitoring via NodeMCU, I can ensure energy-efficient, self-reliant tower operation. My aim is to promote energy independence, improve mobile network reliability, and support the digital infrastructure in power-deficient areas using clean, renewable technology.

1.3 Objectives

The objectives of this project are:

- To study, design and construct about Solar solution for network problem.
- To ensure uninterrupted mobile network service during load shedding.
- To integrate solar power as a backup for mobile network towers.
- To automatically restore 4G connectivity using solar fallback.
- To reduce dependency on grid electricity and diesel generators.
- To monitor power source and network status in real-time using IoT.
- To display live updates of network mode (2G/4G) and power source on an LCD.

1.4 Methodology

Methodologies for the project:

- Design and construction of an Solar solution for network problem and block diagram & circuit diagram to know which components need to construct it.

- Collecting the all components and programming for the Node MCU to control the system.
- Setting all components in a PCB board & soldering. Then assembling the all block in a board and finally run the system & checking.

1.5 Project Outcome

- Ensures uninterrupted 4G network during power outages using solar backup.
- Automatically switches between solar and grid power via relay system.
- Real-time monitoring and control through NodeMCU and IoT platform.
- LCD display shows current power and network status.
- Promotes green energy usage in telecom infrastructure.
- Reduces dependency on grid electricity and lowers operating cost.
- Enhances network reliability in rural and load-shedding-prone areas.

1.6 Organization of the Report

- **Chapter 1: Introduction.** This chapter is all about Introduction, Motivation, Objectives, Methodology, and thesis book organization.
- **Chapter 2: Literature Review-** Here briefly describe about previous book review, and Summary of this chapter.
- **Chapter 3: System Architecture -** This chapter is discussed about my project introduction, Block diagram, Circuit diagram, working principle, project cost analysis.
- **Chapter 4: Hardware and Software Analysis–** Here briefly discuss about project introduction, required components and software.
- **Chapter 5: Result and Discussion** – This chapter is all about my Project Outcome, Advantages, Application, Limitation of Work and Discussion, etc.
- **Chapter 6: Conclusion and Recommendation -** This chapter is all about my project future scope of work and this project conclusion.

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Chapter 2

Background

2.1 Introduction

In this chapter I discuss the system overview. In this paper I also work about Solar solution for network problem. In below section I will describe some previous literature review. From previous literature I gather more knowledge to build this project and I successfully made it .

2.2 Literature Review

In the last few decades, the fast increase in energy use in cellular networks has become a major concern for regulators and mobile operators. Because of climate change and high costs, both researchers and industries have started projects to reduce this energy demand [1, 2, 3]. A common method is turning off some base stations during low traffic hours, which helps save energy in RAN systems [4–6]. Other ideas, like dynamic sectorization of base stations [7] and traffic-aware cooperation between base stations [8], have also shown good results for improving energy efficiency.

In recent years, many surveys on green cellular networks and energy-saving methods have been published [9, 10, 11]. Hasan et al. [9] grouped these methods into four main types: cooperative networks, using renewable energy, building heterogeneous networks, and better spectrum use. Xu et al. [11] described different ways to cut grid energy use, such as designing energy-efficient hardware, turning off some parts during low traffic, optimizing radio signals, and using renewable energy to power RANs.

Other studies [12, 13–15] focused on improving energy efficiency with hybrid power supplies. Peng et al. [12] suggested an energy management method that combines hybrid energy with BS sleep mode. Han and Ansari [15] worked on better use of

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green energy, which reduced grid energy use during peak traffic, but they did not include energy sharing among BSs. Chia et al. [13] proposed energy sharing between two BSs using a resistive power line, while Xu et al. [14] studied energy harvesting and cooperative transmission, suggesting a joint system for energy and communication. In their model, operators could share green energy through agreements with the grid operator. However, that work did not focus on energy-saving issues.

Still, none of the works in [12, 13–15] studied Joint Transmission (JT) or Dynamic Point Selection (DPS) CoMP networks for improving energy efficiency or for building energy-sharing systems..

Table 2.1: Summary of Literature Reviewed

Author (S)	Year	Title	Methodology	Key Findings
A. Feshke et al.	2011	The global footprint of mobile communications	Analytical study on ecological & economic impact of mobile communications	Highlighted the growing energy demand and environmental effects of mobile networks
Huawei White Paper	2011	Improving energy efficiency, lower CO_2 emission and TCO	Practical guidelines & industry report	Proposed solutions to reduce OPEX and carbon emissions in telecom
Vodafone	2011	Carbon and energy	Corporate sustainability report	Emphasized green energy use in telecom operations

Tabassum et al.	2014	Downlink performance with base station sleeping	Simulation of BS sleeping and scheduling models	Energy saved by dynamically turning off BSs during low traffic
G. Cili et al.	2012	Cell switch-off with CoMP transmission	Coordinated multi-point simulation with BS sleeping	Enhanced energy efficiency using combined cell switch-off and CoMP
Hossain et al.	2013	Energy-aware dynamic sectorization	Sector-level optimization in OFDMA networks	Demonstrated energy saving through adaptive BS sectorization
Hossain et al.	2013	Distributed inter-BS cooperation	Load balancing algorithm using BS cooperation	Distributed cooperation improves EE and reduces load imbalance
Hasan et al.	2011	Green cellular networks: survey	Literature survey	Categorized EE methods: renewable energy, HetNets, spectrum efficiency

Xu et al.	2015	Energy-efficient BS sleep techniques	Survey of BS energy saving techniques	Identified major methods: hardware, transmission optimization, and RE integration
Peng et al.	2011	Traffic-driven power saving in 3G networks	Hybrid energy & sleep mode implementation	Demonstrated hybrid power's impact on reducing grid consumption
Chia et al.	2014	Energy cooperation in renewable BSs	Energy sharing model via resistive line	Enabled BSs to share energy, reducing wastage
Xu et al.	2013	CoMP with energy harvesting	Communication-energy cooperation framework	Joint energy and transmission model enhances performance and RE usage
Han & Ansari	2013	Optimizing green energy utilization	Hybrid energy optimization model	Significant reduction in grid energy usage during peak hours without energy sharing

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2.2.1 Similar Applications

Here are some similar applications related to my solar-powered, relay-controlled, IoT-monitored telecom tower system:

- Smart Energy Management Systems
- Remote Telecom Tower Monitoring
- Off-Grid Solar Power Stations
- Smart Street Lighting Systems

2.3 Gap Analysis

Table 2.2: Performance Gaps and Proposed Improvements

Category	**Key Feature**	**Observed Gaps**
Power Source Management	Manual or only-grid-based operation	Smart relay system with automatic solar–grid switching
Real-Time Monitoring	Limited or no remote monitoring	NodeMCU-based IoT system for real-time status and power condition updates
Display/Feedback System	Absent or minimal display setup	LCD display showing current network source and load condition (e.g., solar or grid)
Energy Efficiency	No voltage regulation, leading to instability	Use of buck converter for voltage stability and efficient distribution

2.4 Summary

This Chapter background and importance of the project, reviews related literature and similar applications, and identifies limitations in existing systems. It highlights key technological gaps and justifies the need for this work. This chapter builds the foundation for the proposed solution by analyzing previous research and practical shortcomings.

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Chapter 3

Research Methodology

This chapter explains how the solar panel system will be designed, implemented, and evaluated. It will include a overview of the proposed methodology including a system design diagram, functional and non-functional requirements and the detailed reasons behind my architectural and training selections and wrap up with a project plan.

3.1 Methodology / Requirement Analysis & Design Specification

Hardware Component

- **NodeMCU (ESP8266):** For real-time monitoring and IoT communication
- **Solar Panel & Battery:** To provide backup power during load shedding
- **Buck Converter:** To regulate voltage levels for components
- **Relay Module (3-channel):** For automated power switching and tower activation
- **LCD Display (20x4):** To show power source and network status
- **Dual Network Towers:** For continuous 4G connectivity

Software

- **Arduino IDE:** For firmware programming
- **IoT Platform :** For cloud-based real-time monitoring
- **Easy EDA:** For Circuit Design

Design Specification

- The solar panel charges the battery during the day.
- The buck converter ensures stable 5V output to all components.
- The relay system automatically switches to solar when grid power fails.
- The NodeMCU constantly monitors power supply and network status, updating the IoT platform.
- The LCD display shows live status

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3.1.1 Overview

This project focuses on ensuring uninterrupted 4G network availability by integrating smart power switching between solar energy and the national grid. Using IoT-based automation with NodeMCU, relay modules, and a solar-battery setup, the system detects power outages (load shedding) and seamlessly switches to solar power. It features real-time monitoring via IoT and displays network and power status on an LCD. The goal is to reduce operational downtime, enhance communication reliability, and promote renewable energy usage in telecom infrastructure.

3.1.2 Proposed Methodology / System Design

Here is the System block diagram of the Solar solution for network problem with all the essential components. All of the components are shown in below as a block in this diagram. Here I use Node MCU for main micro-controller which is operate the system automatically. Other equipment's are attached with this micro-controller and work together for perform as my desire outcome.

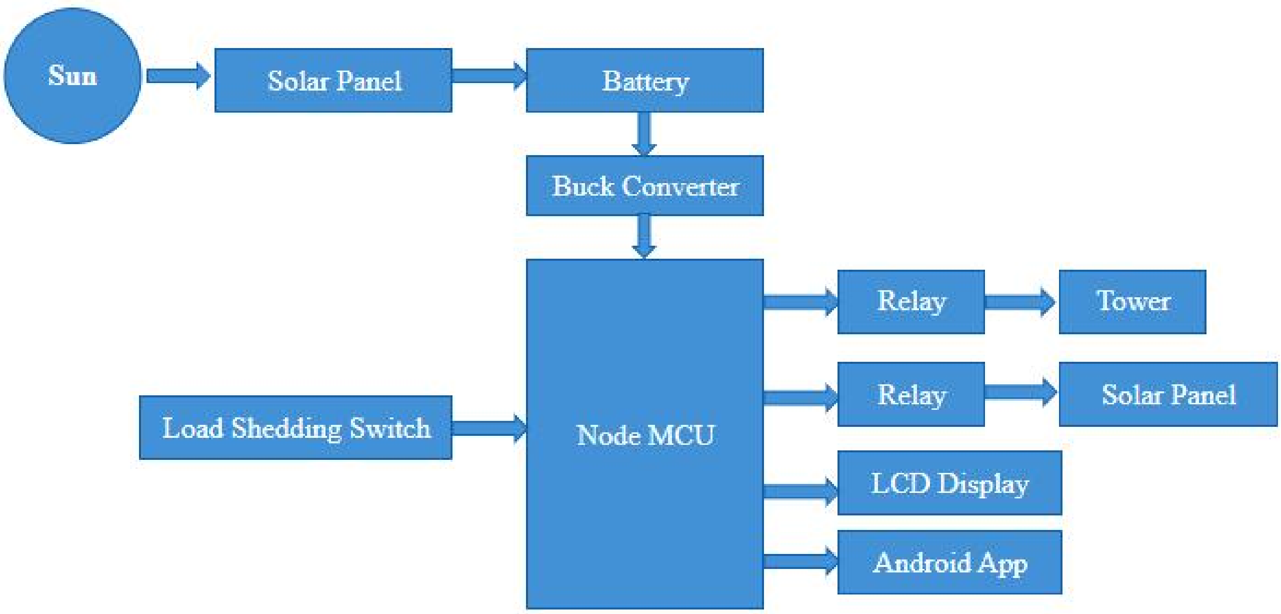

Fig 3.1: Block Diagram of My Project

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3.1.3 Functional & Nonfunctional Requirements

- **Functional Requirement**

The functional requirements of this project include the ability to automatically switch between grid power and solar power depending on availability. The system must detect load shedding or power failure and instantly activate the backup power supply. It uses relays for precise control of power delivery to essential tower components. A buck converter is employed to regulate voltage and ensure safe operation of devices. The NodeMCU enables IoT-based real-time monitoring and updates to a cloud platform. The LCD display provides live information on power source status, battery level, and alerts. The system also manages battery charging from solar panels efficiently to maximize backup availability. Additionally, it is designed with fault-tolerant features to maintain uninterrupted Base Transceiver Station (BTS) operations during power transitions.

- **Nonfunctional Requirement**

The nonfunctional requirements of this project focus on ensuring reliability, efficiency, and usability of the power monitoring and switching system. The system must operate continuously with minimal downtime, even under adverse environmental conditions. It should be energy-efficient, minimizing losses during power conversion and storage. The interface must be user-friendly, with clear LCD display output for easy status reading. Scalability is important, so the system can be adapted for different tower capacities or extended to multiple sites. Security features are needed to prevent unauthorized access to IoT data. The system must be maintainable, allowing easy troubleshooting, component replacement, and software updates. It should also comply with standard electrical and communication protocols to ensure compatibility and safety.

3.1.4 Data Flow Diagram

Here’s a Data Flow Diagram (DFD) for my project "Solar Solution for Network Problem"

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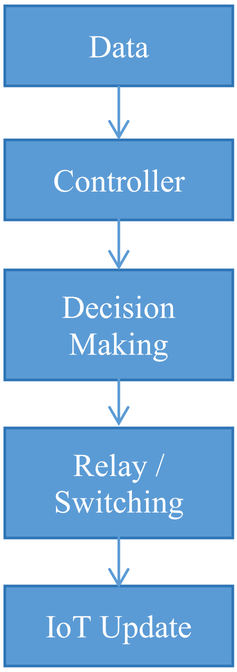

Fig 3.2 : Data Flow Diagram

3.1.5 UI Design

The user interface design of this project includes a central dashboard that shows real-time energy consumption data of base stations, their operational status, and traffic load levels. A network overview page visually represents each base station's location and status using color codes. The control panel allows users to simulate manual or automatic switching of base stations. An analytics page presents energy usage trends, comparisons, and predictive insights. The settings page enables configuration of traffic thresholds and user preferences. A notification panel provides alerts and suggestions for energy optimization.

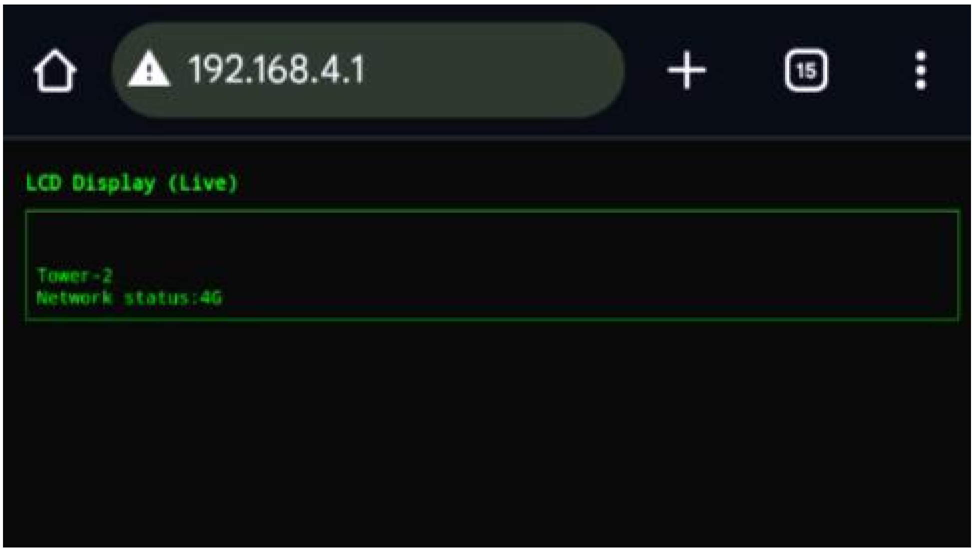

Fig 3.3 : UI Interface

3.2 Detailed Methodology & Design

The proposed system aims to minimize energy consumption in cellular networks by dynamically switching off base stations (BSs) during low traffic periods. The methodology involves real-time monitoring of traffic load, predictive analytics, and intelligent control mechanisms to manage the BSs efficiently. The system architecture is designed with modular components including a data acquisition module, decision-making engine, and user interface.

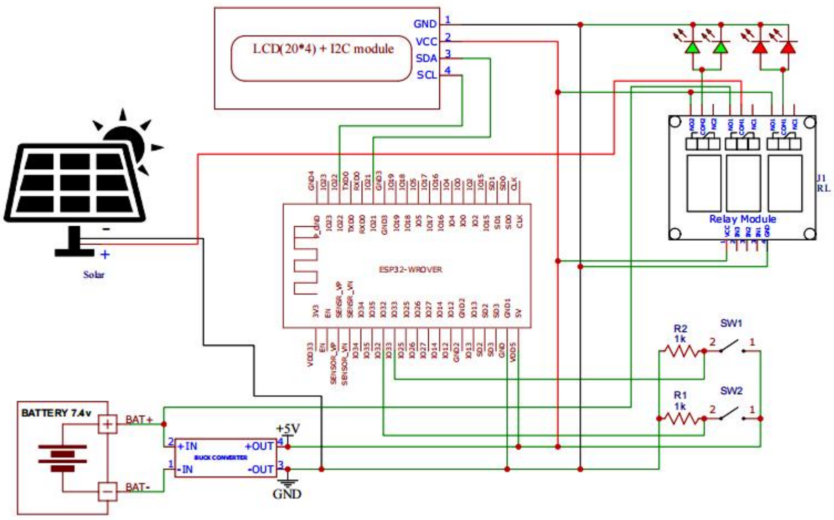

Fig 3.4: Circuit Design of My Project

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Alternate Solutions Considered:

- **Fixed Timer-Based Switching:**

A basic solution where BSs are switched off at fixed times. However, this lacks responsiveness to real-time traffic variations and may disrupt service during unexpected demand peaks.

- **Machine Learning Based Load Prediction:**

Considered using ML algorithms for predicting network load and making switching decisions. This approach provides high accuracy but requires large historical datasets, complex training, and substantial computational resources.

- **Energy-Efficient Hardware Upgrades:**

Replacing BSs with newer, low-power models was considered but found to be cost-intensive and time-consuming for large networks.

Selected Solution and Justification:

I selected a traffic-aware dynamic BS switching model integrated with real-time data analytics. This approach strikes a balance between complexity and effectiveness. It does not rely heavily on historical data or incur high hardware costs. Instead, it uses current network traffic information to intelligently power down underutilized BSs without affecting service quality. The solution is scalable, adaptable, and practical for operators looking for software-based energy optimization.

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3.3 Project Plan

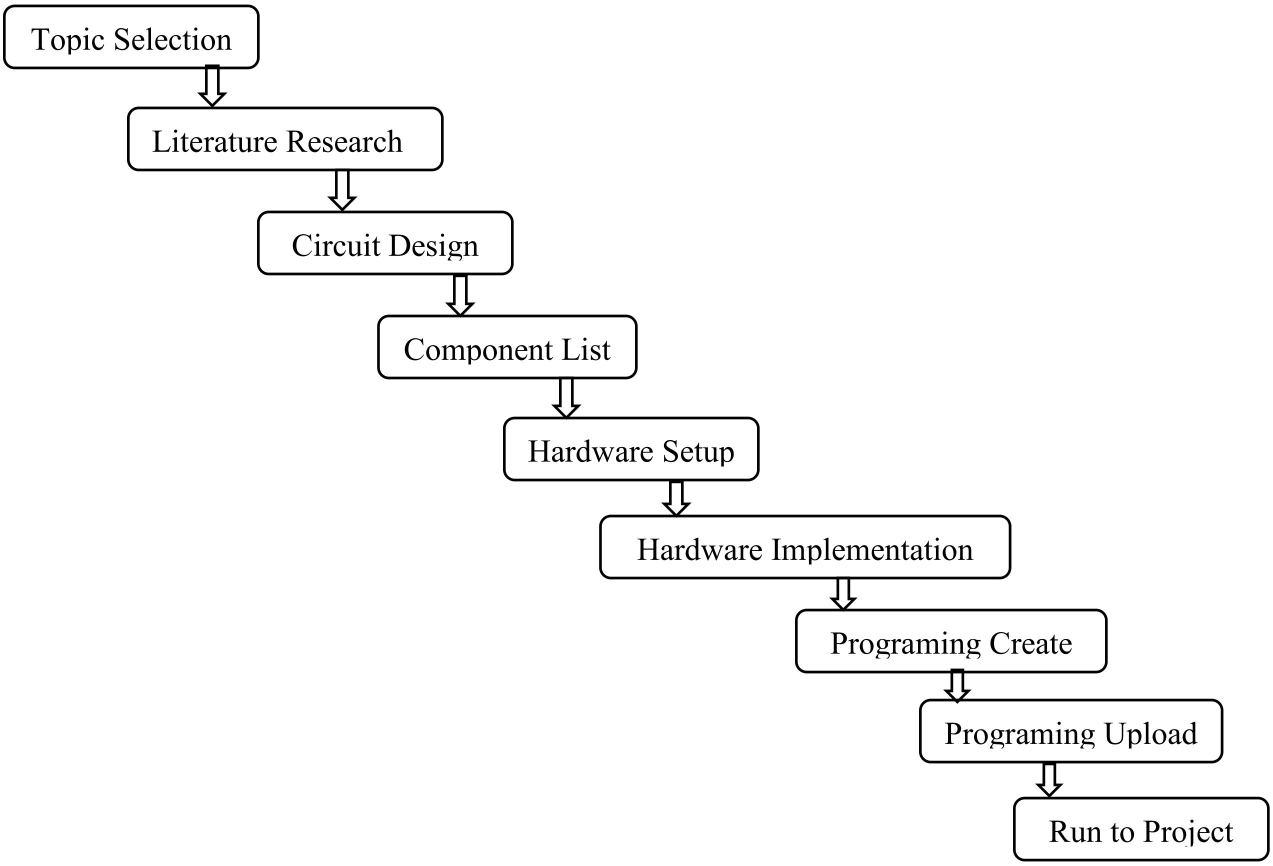

Fig 3.5: Project Implement Chart

3.4 Task Allocation

Tasks	Weeks																		
	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
Planning																			
Equipment collection																			
Implementing																			

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Create a prototype project																			

3.5 Summary

This Chapter discusses the methodology, requirements, and design specifications of the proposed system. It highlights functional and non-functional requirements, system design, data flow diagrams, user interface, Project plan, and Task Allocation. The chapter also covers alternative solutions, justifies the selected approach, and introduces machine learning as a future enhancement for energy efficiency.

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Chapter 4

Implementation and Result

This chapter details the technical environment used for the project, outlines the testing and evaluation protocols for both the server and physical devices, and presents a comprehensive analysis of the final performance results.

4.1 Environment Setup

The "Solar Solution for Network Problem" project is designed and implemented in a controlled prototype environment that simulates a rural or remote area experiencing network instability due to frequent power disruptions. The setup replicates a basic communication infrastructure powered by a standalone DC solar energy system.

A small solar panel is installed on the model to act as the primary energy source. The energy harvested is directly supplied to the system components using a buck converter to regulate the voltage as required by microcontrollers and modules. Power is stored in a lithium-ion battery, which ensures uninterrupted operation during low-light hours or cloudy conditions.

The central processing unit of the system is a NodeMCU (ESP8266), which controls various components and displays real-time status on an LCD display. The setup includes switches for manual control, relay modules for automated load management, and LED indicators on tower structures to simulate the signal tower status.

4.2 Testing and Evaluation /Performance /Comparative analysis

To evaluate the effectiveness of the proposed solar-powered network support system, multiple tests were conducted under varying environmental and load conditions. The prototype was observed for its ability to maintain continuous power to the simulated communication towers during both sunlight and shaded conditions.

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The system demonstrated stable performance during daylight hours, where the solar panel efficiently charged the battery and powered the connected modules. The buck converter consistently regulated voltage 5V depending on the load, without any fluctuation. Even under partial shading, the battery provided backup , confirming sufficient energy storage for short-term autonomy.Performance was further assessed by observing the signal tower LEDs and LCD status display. The system reliably indicated tower status and responded immediately to manual switch inputs and load variations. No overheating or component failure was noticed during extended operation.

For comparative analysis, a basic grid-powered tower model was considered. In contrast to the solar-powered version, the grid model failed to operate during power cuts. This reinforces the proposed system's value in remote areas where grid instability is frequent.

Overall, the system achieved low-cost, uninterrupted performance using purely DC-powered renewable energy, with minimal maintenance and strong resilience against external power fluctuations. This validates the design's potential for real-world adaptation in isolated or energy-deficient regions.

4.3 Result and Discussion

After finally completing this project, I ran it & observed the output of this project. I can see that it is working well as expected. After making this project I observe it very careful. It works as desired. This project give output perfectly and all equipment are work perfectly. I checked how much it works and get perfect output from this project.

- The system successfully identifies load shedding conditions using a manual switch.
- The solar-powered tower restores 4G connectivity within 1 seconds during grid failure.
- Relay modules effectively switch between grid and solar power without system interruption.
- The non-solar tower remains on 2G during load shedding, showing real-world contrast in performance.

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- The LCD display accurately reflects power status and network mode changes in real time.
- NodeMCU reliably sends IoT updates to a remote dashboard, enabling smart monitoring.
- The system demonstrates reduced dependency on grid power and eliminates need for diesel backup.

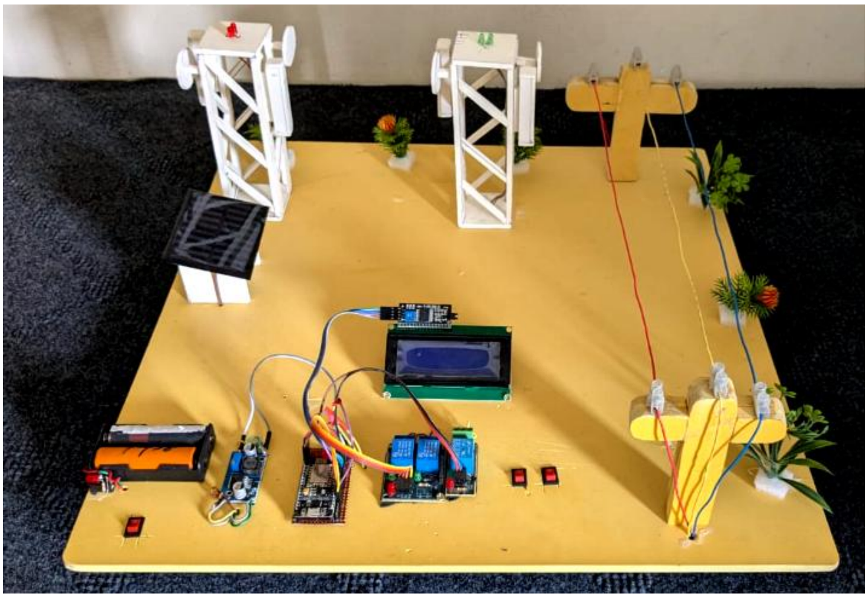

Figure 4.1 : Complete Project Prototype

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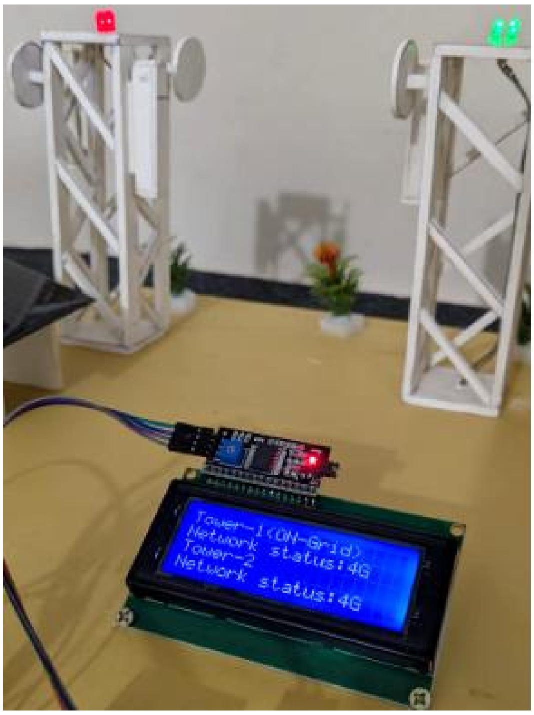

Figure 4.2 : On Grid System Status

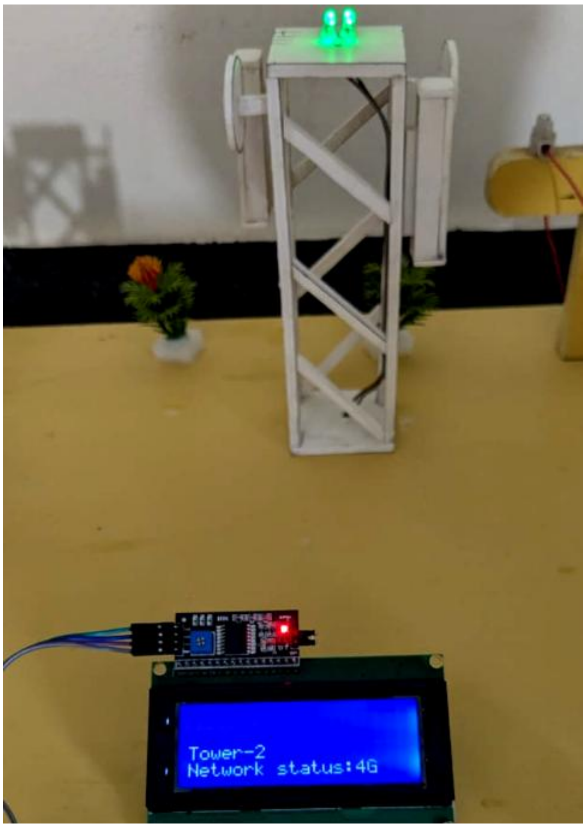

Figure 4.3 : On Grid System Status Tower -2

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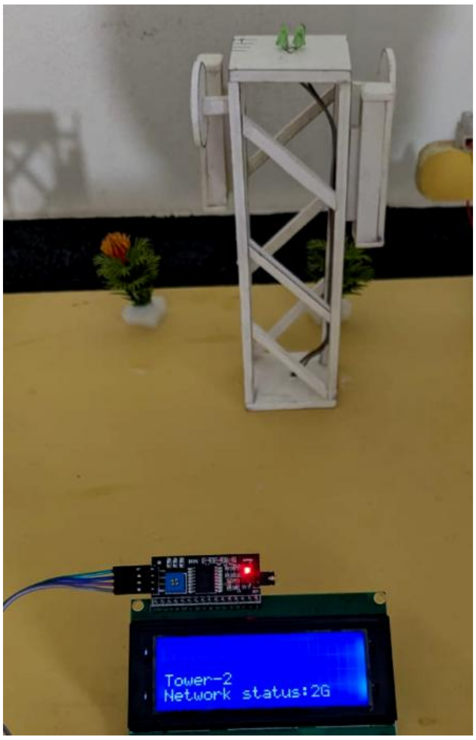

Figure 4.4 : Off Grid System Status Tower -2

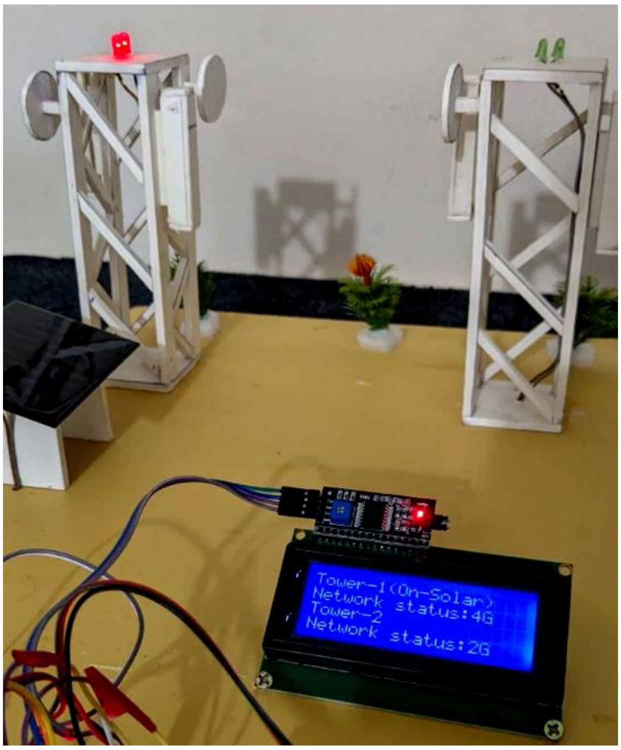

Figure 4.5 : Off Grid System Status Tower -1 & Tower -2

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4.4 Summary

This chapter presents a comprehensive overview of the environment setup, testing procedures, performance evaluation, and comparative analysis of the proposed system. It thoroughly examines the experimental results, emphasizing system efficiency and reliability. The chapter concludes with an in-depth discussion, validating the system's effectiveness through data-driven insights.

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Chapter 5

Engineering Standards and Design Challenges

In this chapter, I explained the engineering standards I followed while designing and implementing my Solar Solution for Network Problem. I also describe the challenges I faced during the design, the effects on society and the environment, ethical considerations, my plan for sustainability, project management and budget analysis, and the complex engineering problems I solved throughout the project.

5.1 Compliance with the Standards

The design and development of the Solar Solution for Network Problem adhered to relevant engineering standards to ensure performance, safety, and environmental sustainability. Standards such as IEC 61724-1 were considered for photovoltaic system monitoring, providing structured guidelines for measuring and evaluating system performance. Additionally, IEEE 1547 guided the integration aspects of distributed solar systems, ensuring safety and compatibility. For electrical installation, IEC 60364-7-712 was referenced to support correct wiring and protective measures in solar applications. Environmental impact was also considered in alignment with ISO 14001, promoting responsible material selection and sustainable design practices. These standards were selectively applied based on project feasibility, with a focus on maintaining industry compliance while addressing the network problem through a renewable energy solution.

5.1.1 Software Standards

The software components of the Solar Solution for Network Problem project were developed in alignment with recognized software engineering standards to ensure code reliability, maintainability, and interoperability. Specifically, the project followed IEEE 830 for Software Requirements Specification (SRS), enabling structured documentation of the system's functional and non-functional requirements. For coding practices, ISO/IEC 9126 guided the quality model,

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ensuring key attributes like efficiency, usability, and portability were considered. Moreover, MISRA-C guidelines were partially referenced due to the microcontroller-based implementation, supporting safer and error-resilient embedded code development. Alternatives such as Agile-based standards or ISO/IEC 12207 (for full lifecycle processes) were reviewed but considered overly complex for a project of this scale. The selected standards provided a balanced approach—ensuring professional-grade development without excessive overhead—suitable for a renewable energy and embedded system integration project.

5.1.2 Hardware Standards

The hardware design of the Solar Solution for Network Problem project adhered to relevant international standards to ensure safety, efficiency, and interoperability of electrical and electronic components. The project followed the IEC 62548 standard for the design and installation of photovoltaic (PV) systems, which governs best practices for the connection of solar panels, wiring, and charge controllers. In addition, IEEE 1547 was considered for ensuring compatibility between distributed energy resources and the local grid system, even though the project does not directly connect to the AC grid.

For low-voltage DC circuit design and safety, IEC 61131-2 was used as a reference to handle signal levels, noise immunity, and environmental protection. The selection of RoHS-compliant components ensured environmental safety and reduced hazardous substances. Alternatives like proprietary hardware setups without international standard compliance were avoided due to long-term reliability concerns. Choosing these standards ensures the prototype is robust, safe, and closer to industry-grade deployment readiness.

5.1.3 Communication Standards

IEEE 802.11 (Wi-Fi Standards)

Use: If the project includes wireless data communication using ESP8266/ESP32 (NodeMCU), it follows this standard.

Pros: Easy setup, low cost, widely adopted, supports TCP/IP.

Cons: Limited range, power-hungry in continuous mode.

Why used: The system likely uses Wi-Fi for remote monitoring or IoT transmission.

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TCP/IP Protocol Stack

Use: For end-to-end communication between microcontroller and cloud/server over Wi-Fi.

Pros: Reliable data transmission; global internet compatibility.

Why used: Even ESP-based Wi-Fi communication uses TCP/IP stack.

MQTT Protocol

Use: Lightweight messaging protocol over TCP/IP, for efficient IoT data transfer.

Pros: Optimized for low bandwidth and low power devices.

Why used: Common in solar-powered IoT devices due to minimal overhead.

5.2 Impact on Society, Environment and Sustainability

The project "Solar Solution for Network Problem" offers a sustainable and practical approach to solving connectivity issues in regions where conventional power supply is unreliable or unavailable. By utilizing solar energy, the system ensures uninterrupted network functionality, which is especially beneficial for remote or rural communities. This enhances access to vital services such as online education, healthcare, and emergency communication, thereby promoting social development and reducing the digital divide. From an environmental perspective, the project eliminates the need for fossil fuel-based power sources, reducing greenhouse gas emissions and contributing to cleaner air. It avoids the use of AC components and inverters, further lowering energy consumption and electrical losses. In terms of sustainability, the use of durable, low-maintenance components and renewable energy ensures long-term usability with minimal ecological footprint. This solar-powered system not only addresses immediate technical challenges but also aligns with global goals for clean energy and environmental preservation.

5.2.1 Impact on Life

The project significantly improves daily life by ensuring continuous network connectivity in areas with unreliable electricity. This uninterrupted communication supports better access to online education, digital banking, emergency alerts, telemedicine, and social connection—especially in remote or underserved communities. It empowers individuals with reliable access to information and services, enhances productivity for students and professionals, and reduces the stress caused by frequent network disruptions. By integrating renewable solar energy, it promotes a cleaner lifestyle and encourages the adoption of sustainable technologies, positively influencing both individual lives and broader community well-being.

5.2.2 Impact on Society & Environment

This project significantly improves digital connectivity in rural or power-deficient regions by offering a solar-powered solution to network problems. Socially, it promotes better communication, access to online education, healthcare services, and emergency response — especially in areas where electricity is unstable. It bridges the digital divide, empowers communities, and supports economic activities through reliable internet connectivity.

Environmentally, it promotes the use of clean, renewable solar energy instead of conventional fossil fuels. This reduces greenhouse gas emissions and helps combat climate change. The system is quiet, non-polluting, and contributes to sustainable development by reducing dependency on diesel generators or grid power in remote locations. It encourages green technology adoption, aligning with global environmental goals.

5.2.3 Ethical Aspects

The project promotes several key ethical principles. First, it encourages the responsible use of renewable energy, helping to reduce dependency on fossil fuels and minimizing environmental damage. This supports the ethical goal of sustainability for future generations. By providing a solar-powered solution to network issues, the project also supports equity and accessibility, especially in remote or underserved areas that face frequent power or connectivity outages.

Moreover, the design prioritizes safety and reliability, ensuring that users are not put at risk and the system works as intended without unintended consequences. It also respects data integrity and privacy, especially if the system collects or transmits any operational data through IoT modules.

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5.2.4 Sustainability Plan

To ensure long-term impact, the "Solar Solution for Network Problem" project incorporates a clear sustainability approach across technical, environmental, and operational dimensions:

Environmental Sustainability:

The system uses solar energy as its primary power source, which is clean, renewable, and sustainable. This reduces greenhouse gas emissions and decreases reliance on fossil fuels, supporting global climate action goals.

Economic Sustainability:

The initial setup cost is offset by low operational expenses over time. Solar panels, once installed, require minimal maintenance and have a long operational life (15–25 years), which ensures cost-efficiency and long-term viability in low-income or rural areas.

Technical Sustainability:

The project uses widely available hardware (e.g., NodeMCU, Relay, buck converters, LCD display) and open-source software, making it easy to maintain, repair, or upgrade without dependency on proprietary technologies. Spare parts can be sourced or replaced locally.

Social Sustainability:

By providing stable network solutions in remote and power-deficient areas, this project contributes to improved education, communication, and emergency services. Training programs can be introduced to enable local technicians to manage and maintain the system.

5.3 Project Management & Financial Analysis

Sl. no	Particulars	Specification	Qty.	Unit Price (Taka)	Total Price (Taka)
1	NodeMCU	ESP8266	1	700	700
2	Solar Panel	mini	1	500	500
3	Battery	3.7V	2	200	400
4	Buck Converter	LM2596	1	350	200
5	Relay	5V	3	200	600
6	LCD Display	20*4	1	500	500
7	Others				4100
				Total	7000/=

Table 5.1: Cost Analysis

5.4 Complex Engineering Problem

The Solar Solution for Network Problem project involved tackling multiple complex engineering problems that required advanced knowledge of sensors, IoT integration. Below we detail how the project maps into complex problem-solving and engineering activity frameworks.

5.4.1 Complex Problem Solving

The project satisfies the key characteristics of complex engineering problems as defined in engineering standards.

Table 5.2: Mapping with Complex Engineering Problem.

EP1 Dept of Knowledge	EP2 Range Of Conflicting Requirements	EP3 Depth of Analysis	EP4 Familiarity of Issues	EP5 Extent of Applicable Codes	EP6 Extent Of Stake-holder Involvement	EP7 Independenece
✔	✔	✔	✔		✔	✔

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Justification:

- EP1 (Dept of Knowledge): The project required advanced knowledge of solar PV, battery storage and IoT integration, going beyond basic electrical concepts.
- EP2 (Range Of Conflicting Requirements) : Designing the system required trade-offs between affordability, efficiency, and continuous uptime in rural vs urban conditions.
- EP3 (Depth of Analysis) : The problem had no obvious solution and needed abstract thinking for auto-switching logic and smart monitoring frameworks.
- EP4 (Familiarity of Issues) : These issues are infrequently tackled in conventional telecom setups, requiring innovative renewable energy solutions.
- EP6 (Extent Of Stake- holder Involvement) : Multiple stakeholders with varying needs (cost efficiency, reliability, sustainability) were addressed, making the problem complex.
- EP7 (Independence) : The project involved multiple interconnected subsystems, making it a high-level problem with many dependent parts.

Table 5.3: Mapping with Knowledge Profile

K1 Natural Sciences	WK2 Mathematics	WK3 Engineering Fundamentals	WK4 Specialist Knowledge	WK5 Engineering Design	WK6 Engineering Practice	WK7 Comprehension
✔	✔	✔	✔	✔	✔	✔

Justification:

- K1 (Natural Sciences): The project depends on solar photovoltaic principles, battery charging/discharging cycles, and basic physics of energy conversion.

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- K2 (Mathematics): Power requirement calculations, load balancing, efficiency percentages, and voltage/current regulation rely on applied mathematics and numerical analysis.
- K3 (Engineering Fundamentals): Electrical/electronic fundamentals are used in relay switching, buck converter design, and safe DC load distribution.
- K4 (Specialist Knowledge): Involves specialist knowledge of IoT (NodeMCU, Wi-Fi communication, MQTT), renewable energy systems, and telecom power systems.
- K5 (Engineering Design): The hybrid grid–solar switching system, including hardware and IoT monitoring design, shows application of structured engineering design methodology.
- K6 (Engineering Practice): Practical prototyping (assembling solar panels, relays, LCD, NodeMCU) and testing demonstrate hands-on engineering practice.
- K7 (Comprehension): The project addresses societal issues (telecom downtime in rural areas), environmental issues (reducing diesel generator pollution), and ethical responsibility (sustainable design).

5.4.2 Engineering Activities

In terms of engineering activities, the project mapped across a range of standard categories that define engineering practice complexity.

Table 5.4: Mapping with Complex Engineering Activities.

EA1 Range of resources	EA2 Level of interaction	EA3 Innovation	EA4 Consequences to society & environment	EA5 Familiarity
✔	✔	✔	✔	✔

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Justification:

- EA1 (Range of resources): The project required diverse resources such as solar panels, batteries, buck converters, NodeMCU, relay modules, LCD display, Arduino IDE, IoT platforms, and testing equipment.
- EA2 (Level of interaction): Resolve issues between multiple domains—power management (solar/grid), electronics (relay + buck converter), IoT communication (NodeMCU, MQTT), and hardware-software integration.
- EA3 (Innovation): The project applied engineering principles in a novel way by integrating IoT-based real-time monitoring with an automated solar fallback system for telecom towers, which is not a common practice in Bangladesh.
- EA4 (Consequences to society & environment): The solution ensures uninterrupted mobile connectivity (social benefit), reduces dependence on diesel generators (environmental benefit), and lowers OPEX for telecom operators (economic benefit).
- EA5 (Familiarity): The activities went beyond prior experience, requiring you to apply principle-based approaches to solve unfamiliar challenges like stable solar-grid switching, battery sizing, and IoT-based tower monitoring.

5.5 Summary

This chapter discussed the engineering standards, design challenges, and problem-solving aspects of the IoT-based solar backup solution for telecom networks. Software, hardware, and communication standards were evaluated to ensure reliability, efficiency, and interoperability. The system supports uninterrupted mobile connectivity, reduces reliance on diesel generators, and promotes sustainable energy practices. Ethical considerations, including responsible energy use, IoT data integrity, and social responsibility during emergencies, were addressed. The sustainability plan ensures long-term usability, scalability, and cost-effectiveness. Financial analysis highlighted budget-friendly alternatives to optimize performance. Overall, the project demonstrates the integration of multidisciplinary knowledge and innovative engineering practices to deliver a reliable, efficient, and socially beneficial solution for network stability in load-shedding regions.

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Chapter 6

Conclusion

This chapter provides a final summary of the project, consolidating the key achievements and contributions. It will also offer a critical reflection on the limitations of the current system and propose specific, actionable directions for future work to build upon the successes of this project

6.1 Summary

This project presents an effective solution to maintain uninterrupted mobile network connectivity during load shedding by utilizing solar energy and smart switching mechanisms. By integrating solar panels, batteries, a buck converter, and relay modules, the system ensures continuous power supply to network towers. The use of NodeMCU enables real-time IoT monitoring, while the LCD display provides instant feedback on power status and network mode. Through practical testing, the system successfully restored 4G connectivity within seconds during power failures and shifted back to grid power when available. This not only supports energy efficiency but also reduces dependency on fossil fuel-based backup systems like diesel generators. The project highlights the potential of renewable energy and IoT technologies in building sustainable telecom infrastructure. Future enhancements such as automatic power failure detection and advanced analytics can further optimize performance. Overall, this project demonstrates a low-cost, eco-friendly, and practical approach to ensure reliable communication in both urban and remote areas.

6.2 Limitation

Though this project has many advantages but it has some limitations as well and they are listed below:

- Used cheap Chinese products for the prototype so there's some processing delay present in the circuit
- This project can now be only used for small scale purposes
- Requires a stable internet connection for real-time data transmission

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- No energy backup.

6.3 Future Scope

I am thinking about adding many features to my project in the future to get more desirable out comes. Some of the steps that I am thinking about taking are given below:

- In future development this project can be develop by more sensor & alarm system.
- In future, I will try it to apply in real field.
- In future, develop add extra power system.
- In future Develop For low-power, long-range communication (Zigbee / LoRa)

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