Master in Industrial Engineering

Research Project

Energy Master Plan: IIT Campus

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HISTORICAL TIMELINE
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Contents

1. Introduction

In response to the urgent need for mitigating climate change and reducing carbon emissions, significant attention has been directed towards enhancing energy efficiency in buildings. Buildings are known to contribute significantly to carbon emissions because of how much energy they use. As a result, creating thorough energy master plans for buildings has become a key tactic in accomplishing sustainability objectives.

Several strategies have been put forth and put into practice to increase building energy efficiency. These include replacing old boilers with newer, more efficient units, updating heating and cooling systems, and implementing energy-saving lighting systems. Although these isolated acts help reduce energy use, there is an increasing awareness of the need for comprehensive strategies that can optimize efficiency gains and produce long-term results.

The creation of building energy master plans has goals beyond energy reduction. It includes the broader goals such as maximizing energy output and consumption while providing affordable, sustainable, safe, and reliable energy to a campus or cluster of buildings.

Installing microgrids on campuses is an innovative strategy that is gaining popularity. Microgrids provide a distributed power distribution system that can improve energy efficiency, increase resiliency, and facilitate the integration of renewable energy sources. Campuses and building complexes can reduce their carbon footprint, decrease their reliance on non-renewable energy sources, and effectively control their energy consumption by implementing microgrids.

In summary, creating energy master plans for buildings is a calculated step toward achieving comprehensive energy efficiency goals. Campuses and building complexes can create resilient, sustainable, and environmentally responsible energy systems by utilizing both active and passive energy management strategies.

2. State of the Art

2.1 Earlier Infrastructure before Microgrid

- Historical Background: Before transitioning to a microgrid, IIT relied on electricity from two main substations provided by ComEd, with a limited capacity of 14 MW despite a potential of 20 MW due to regulatory constraints. The infrastructure dating back to the 1940s and 1950s was inadequate for the growing demands of the campus, leading to frequent power outages and escalating maintenance costs.

- Infrastructure Updates: Recognizing these challenges, IIT began upgrading the North Substation with modern equipment in 2003 to enhance reliability and pave the way for future developments, which eventually led to the microgrid's installation.

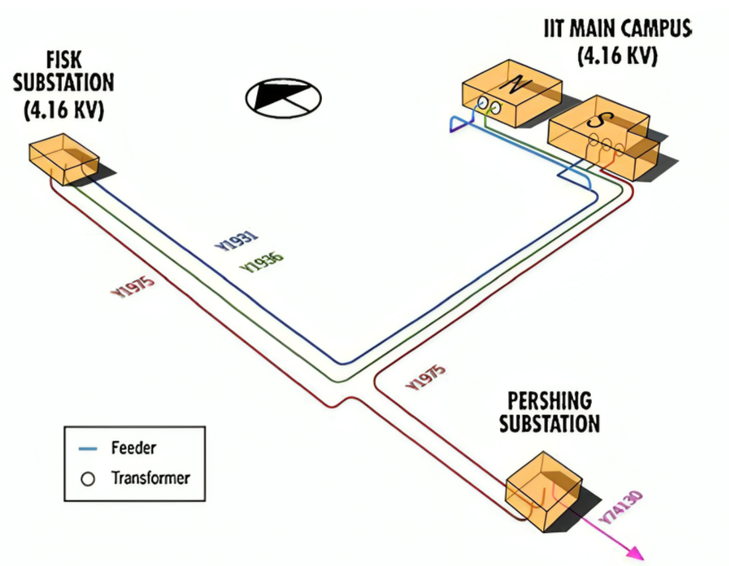

Figure 2.1: North and South Substations

2.2 The Promise of the Microgrid

- Pioneering Initiative: Led by Professor Mohammad Shahidehpour, the microgrid at IIT was developed as one of the nation's first smart microgrids by 2013. This strategic shift aimed to address the issues of reliability, demand management, and sustainability in energy supply.
- Benefits Realized: Since its implementation, the microgrid has not only mitigated the problem of frequent outages but also resulted in substantial financial savings and enhanced the sustainability of the campus's energy supply.

2.3 Reliability

- High-Reliability Distribution System (HRDS): The microgrid incorporates a loop feeder structure with smart switches that can automatically isolate faults, maintaining power supply to all connected buildings.
- On-Site Generation: Integration of on-site generation and storage capabilities ensures that the campus remains powered even in island mode, effectively making IIT independent from external power interruptions.

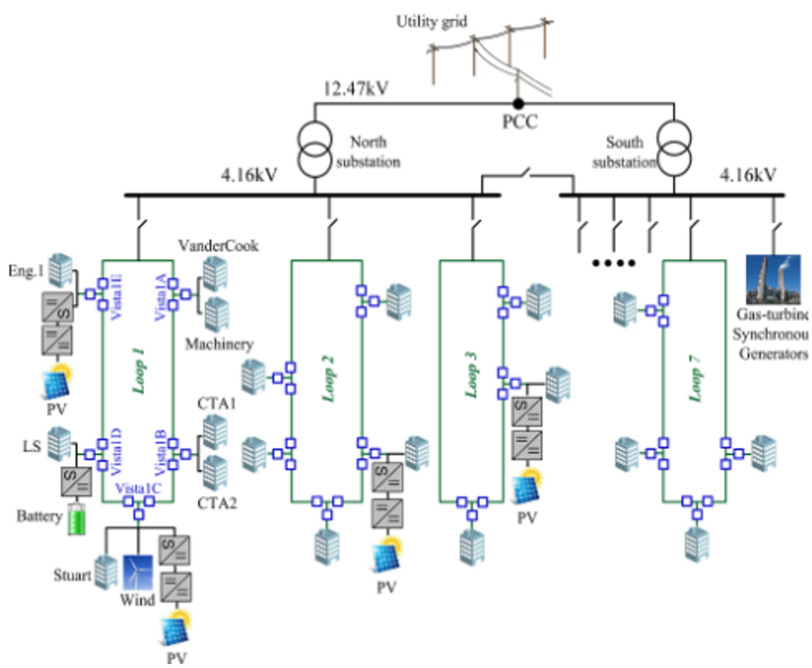

Figure 2.2: Loop Distribution Diagram

2.4 Efficiency

- Advanced Control Systems: Enhanced monitoring and control over electrical loads through a hierarchical control system, including real-time performance monitoring with phasor measurement units (PMUs), optimize energy usage and improve overall efficiency.
- Demand Management: Intelligent building controllers and smart feeders with real-time monitoring systems respond to electricity usage dynamically, helping to manage peak loads efficiently.

2.5 Existing Facilities and Technologies

- On-Site Generation: Facilities include combustion microturbines and an 8 MW gas-fired power plant, providing reliable on-site power generation.
- Renewable Energy Sources: An 8 kW wind turbine and approximately 160 kW of solar panels, with plans to expand solar capacity to about 1.3 MW.
- Energy Storage: A 500 kWh ZBB storage unit supports demand management and adds economic value by storing excess energy.
- Electric Vehicle Charging Stations: Multiple solar-powered charging stations promote the adoption of electric vehicles and integrate with the microgrid's renewable energy resources.

Figure 2.3: Renewable & Sustainable Facilities

3. Motivation

The main objective of this research project is to create a thorough Energy Master Plan to evaluate the energy generation and consumption of the Illinois Institute of Technology (IIT) campus. This means examining the various buildings on campus, analyzing the current microgrid, and the active and passive components of energy management. In order for this research project to successfully achieve its goals, a strategic plan with several critical phases will be followed as shown in Figure 3.1:

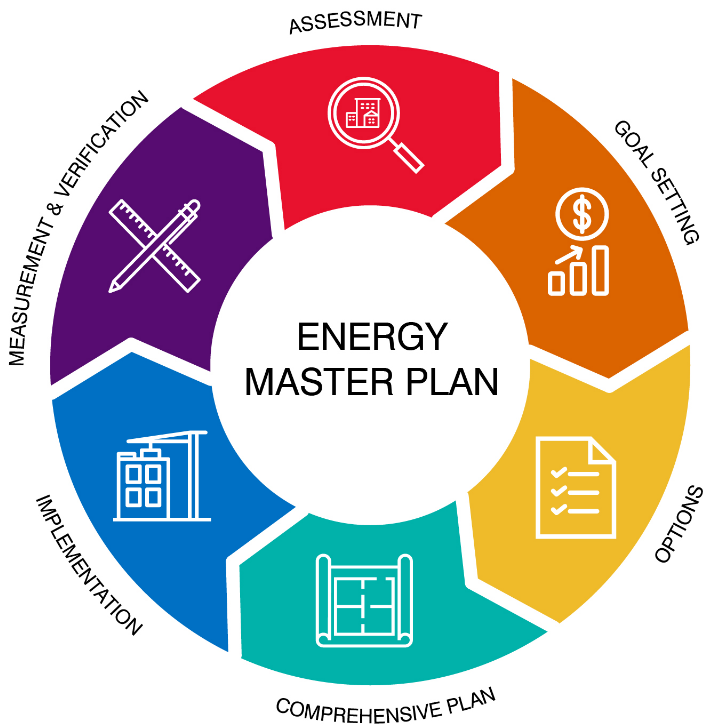

Figure 3.1: Energy Master Plan Strategy Steps

1. Assessment of Conditions and Needs: The first step entails a comprehensive evaluation of the energy circumstances and requirements that exist at the Illinois Institute of Technology (IIT) campus. Data on patterns of energy usage, the capacity of the infrastructure, and current energy management techniques will all be gathered for this study.

2. Goal Setting: To guide the creation of the Energy Master Plan, specific, quantifiable goals will be established in response to the assessment results. These include minimizing environmental impact, optimizing energy production and consumption within the campus or building cluster, reducing energy consumption, increasing renewable energy integration, and improving resiliency.

3. Options for Improvement: This phase explores various alternatives and tactics to increase energy efficiency and sustainability. This includes assessing the feasibility and effectiveness of integrating renewable energy technologies, implementing energy-efficient building designs and systems, fine-tuning microgrid operations, and incorporating smart energy management solutions to maximize energy output and consumption.

4. Comprehensive Plan: Based on the identified goals and selected improvement options, a comprehensive energy master plan is developed. This strategy, which will include both short-term and long-term efforts, will provide specific recommendations and solutions tailored to the unique needs and characteristics of the IIT campus. It will also include investment plans that define the return on investment (ROI) and quantify the amount of money needed to implement the proposed solutions.

5. Implementation: After the energy master plan is developed, the next phase would be to implement the proposed tactics and initiatives. Implementing energy management protocols, installing renewable energy generation systems, upgrading microgrid infrastructure, and retrofitting buildings with energy-efficient technologies are some examples of actions that can be taken to optimize energy generation and consumption while maintaining cost effectiveness.

6. Measurement and Verification: Rigorous measurement and verification methods would be used to evaluate the performance and effectiveness of the solutions adopted, both during and after the implementation process. This includes monitoring operational efficiency, environmental impact, renewable energy production, energy consumption, and refinement of the energy master plan. It also regularly evaluates the return on investment of the measures implemented.

However, it's important to note that due to the scope and nature of this research, the final two steps of Implementation (5) and Measurement and Verification (6) will not be feasible. While these steps are necessary for the full implementation and evaluation of an energy master plan, their implementation will not occur within the confines of this research project. Instead, the focus will be on developing a robust plan that lays the groundwork for future implementation efforts.

By following this strategic plan, the research project hopes to maximize both energy production and consumption while providing practical suggestions and assisting the IIT campus in transitioning to a more resilient, efficient, and sustainable energy infrastructure.

4. Objectives

The primary objective of this research project is to develop a comprehensive energy master plan for the Illinois Institute of Technology (IIT) campus. The plan is designed to optimize energy usage across campus facilities, with a focus on improving efficiency, sustainability, and the integration of renewable energy systems. The approach is structured as follows:

1. Building-Specific Simulation: Detailed simulations of individual buildings will be conducted, examining both active and passive elements of energy use. This includes the analysis of building envelopes and Energy Use Intensity (EUI) to identify potential energy conservation and efficiency opportunities.

2. Campus-Wide Simulation: Expanding beyond individual buildings, a comprehensive simulation of the entire campus will be performed. This step will assess energy savings, greenhouse gas (GHG) emissions, and financial viability, aiming for a sustainable and economically feasible energy strategy for the campus.

3. Interconnection and Renewable Integration: In this phase, a thorough assessment of campus interconnection systems, including steam distribution, chilled water infrastructure, and communication networks, will be conducted. Exploration of renewable energy integration will enhance energy autonomy and resilience. The existing smart grid will undergo comprehensive analysis, with a focus on evolving technologies. A new proposal will be formulated, rooted in foundational concepts but incorporating contemporary techniques and state-of-the-art technologies. Updated strategic planning will ensure alignment with the latest advancements in the field, aiming to establish a new benchmark for energy management and sustainability at IIT.

This sequential and multi-scaled approach aims to chart a course towards a more sustainable and energy-efficient future for the IIT campus.

5. Work Methodology

The project commenced with thorough research and analysis of relevant reports pertaining to the topic. Task scheduling and progress tracking were facilitated through a Gantt chart, ensuring efficient navigation through the design and testing phases. Additionally, a Project Timeline table was utilized to provide a comprehensive overview of milestones and deadlines throughout the project lifecycle.

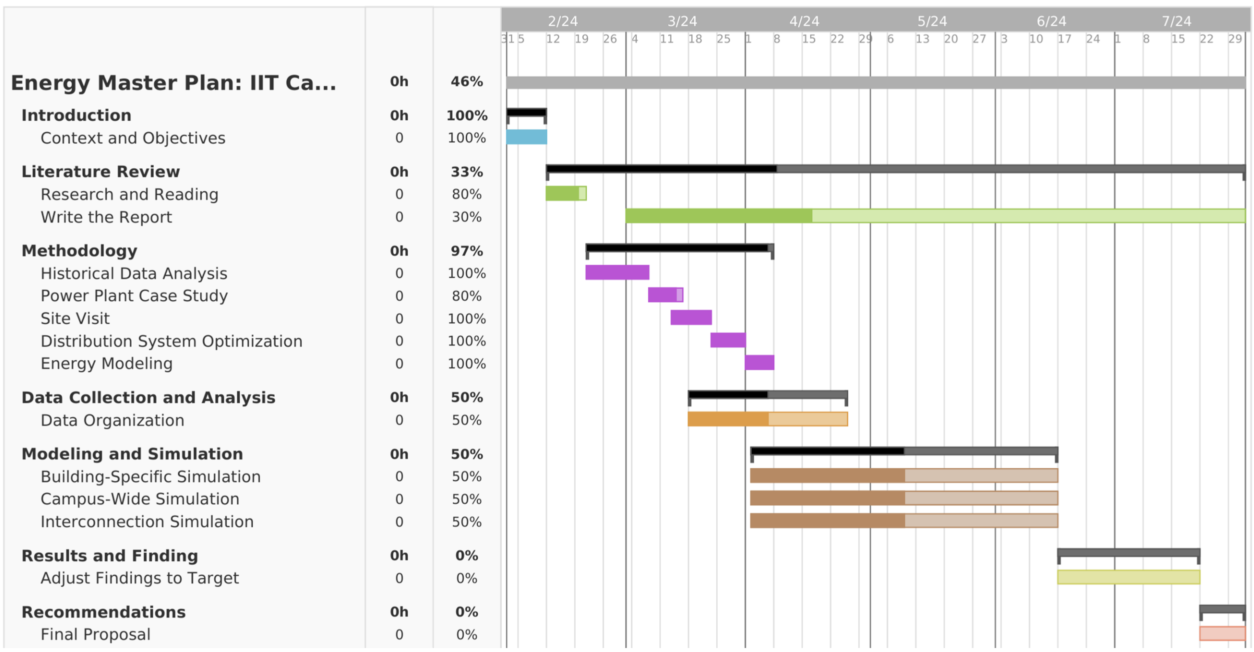

Figure 5.1: Gantt Chart

Research Activity	Duration	Start Date	Finish Date	Notes
I. Introduction - Context and objectives	2 h	Project Start	Project Start	Define scope, goals, and research questions
II. Literature Review	20 h	Project Start + 2h	Project Start + 22h	Identify existing research, gaps, and relevant sources
III. Methodology	20 h	Project Start + 24h	Project Start + 44h	Develop research methods and define tools (software, data sources)
- Historical data analysis	15 h	Project Start + 46h	Project Start + 61h	Compile and analyze energy consumption data
- Power plant case studies	10 h	Project Start + 63h	Project Start + 73h	Research existing campus power plant solutions
- Interviews & Site Visits	20 h	Project Start + 75h	Project Start + 95h	Conduct interviews & visit Galvin Center for insights
- Distribution System Optimization	15 h	Project Start + 97h	Project Start + 112h	Evaluate potential improvements
- Energy Modeling Software Training	10 h	Project Start + 114h	Project Start + 124h	Learn and practice using dedicated software
IV. Data Collection & Analysis	30 h	Project Start + 126h	Project Start + 156h	Organize and analyze collected data from various sources
V. Modeling & Simulation	30 h	Project Start + 158h	Project Start + 188h	Develop and run simulations for different efficiency scenarios
VI. Results & Findings	20 h	Project Start + 190h	Project Start + 210h	Analyze simulations, interpret results, and identify key trends
VII. Recommendations	20 h	Project Start + 212h	Project Start + 232h	Suggest optimal energy solutions and implementation strategies
VIII. Conclusion & Implications	10 h	Project Start + 234h	Project Start + 244h	Summarize findings, discuss project limitations, and suggest future research
Report Writing & Presentation	40 h	Project Start + 246h	Project Start + 286h	Draft, finalize, and present research report and findings
Advisor Meetings & Feedback	10 h	Throughout Project	Throughout Project	Schedule regular meetings for guidance and progress updates

Figure 5.2: Project Timeline Table

6. Resources

Effective energy analysis and planning projects rely on diverse software tools. In our study of the Illinois Institute of Technology (IIT) campus, various software platforms were utilized. This section examines their contributions to crafting the energy master plan for the IIT campus.

1. RETScreen: played a pivotal role in conducting energy analyses for the Illinois Institute of Technology (IIT) campus. RETScreen, an energy management software tool, was utilized for campus-wide simulations. It enabled the evaluation of energy consumption, cost savings, and GHG emission reductions across the entire campus. By leveraging its comprehensive database and analytical capabilities, RETScreen facilitated the identification of effective energy conservation measures and renewable energy opportunities on a macro scale.

2. OpenStudio: as an energy modeling software suite, OpenStudio seamlessly integrated with building information modeling to support detailed analyses of individual buildings within the IIT campus. Specifically, OpenStudio enabled the examination of active and passive building elements, building envelope properties, and energy use intensity (EUI) calculations. This detailed analysis provided critical insights for targeted energy optimization strategies for the campus buildings.

3. AutoCAD: a leading CAD software played a significant role in visualizing and planning structural synergies for IIT campus facilities. Its precise drafting tools crafted accurate layouts of campus infrastructure, such as steam distribution, chilled water systems, and communication networks. AutoCAD facilitated visualization of current structures and aided in designing proposed modifications and additions to the campus's smart grid and interconnected systems.

4. Microsoft Office Applications: to document and report findings, Microsoft Office applications were used. PowerPoint visualized data and presented concepts and results. Word compiled written reports and documentation. Excel manipulated and examined energy data, while Project managed scheduling, progress monitoring, and resource allocation.

Together, RETScreen, OpenStudio, AutoCAD, and the Microsoft Office suite formed a comprehensive toolset for energy analysis, planning, documentation, and project management, ensuring accuracy and efficiency in developing the energy master plan for the IIT campus.

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