Power System Optimization for Port Electrification System

[Specific Port Name]

Technical Report

ME 401: Engineering Systems and Applications

Submitted by:

[Name]

[email@u.boisestate.edu]

Boise State University

Department of Mechanical and Biomedical Engineering

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This report presents the thermodynamic analysis and optimization of a power generation system as part of a broader port electrification project addressing decarbonization challenges.

EXECUTIVE SUMMARY

[Your executive summary here.
”Concise but complete” is the goal.]

1. INTRODUCTION

1.1 Project Context and Motivation

[Describe the engineering challenge: port electrification requirements, energy demand characteristics, role of thermal power generation in renewable energy systems, and connection to sustainability goals.]

1.2 Technical Objectives

- Optimize Rankine cycle thermal efficiency for port-specific operating conditions
- **What did we set out to do, try to come up with a handful of items **

2. METHODOLOGY

2.1 Computational Architecture

[Describe the computational approach: how the project is decomposed into functions, the workflow from inputs to outputs, and how different modules interact. Include a brief explanation of your verification strategy.]

The thermal efficiency of the Rankine cycle is defined as:

$$\eta_{th} = \frac{W_{net}}{Q_{in}} = \frac{W_{turbine} - W_{pump}}{Q_{boiler}} \tag{1}$$

where W_{net} is the net work output and Q_{in} is the heat input to the cycle.

2.2 Thermodynamic Analysis Framework

The Rankine cycle consists of four main processes:

1. **1-2 (Pump):** Isentropic compression of liquid
2. **2-3 (Boiler):** Constant pressure heat addition
3. **3-4 (Turbine):** Isentropic expansion through turbine
4. **4-1 (Condenser):** Constant pressure heat rejection

The first law of thermodynamics for each component yields:

$$\text{Pump work:} \quad W_{pump} = \dot{m}(h_2 - h_1) \tag{2}$$

$$\text{Heat input:} \tag{3}$$

$$\text{Turbine work:} \tag{4}$$

$$\text{Heat rejection:} \tag{5}$$

2.3 Optimization Approach

[Describe the role of optimization in engineering and how it can help guide design processes and decisions.]

[Insert your T-s diagram here]
Generate using matplotlib and save as .png or.jpg
Uncomment the includegraphics line above

Figure 1: Temperature-entropy diagram for optimized Rankine cycle operating with [working fluid]. State points labeled 1-4 correspond to pump inlet, boiler inlet, turbine inlet, and condenser inlet respectively.

3. RESULTS AND DISCUSSION

3.1 Optimized Cycle Parameters

Table 1: Optimized Rankine cycle operating conditions and performance metrics

Parameter	**Value**	**Units**
Working Fluid	[e.g., Water]	–
Boiler Pressure	[value]	bar
Boiler Temperature	[value]	°C
Condenser Pressure	[value]	bar
Mass Flow Rate	[value]	kg/s
Thermal Efficiency	[value]	$\%$
Net Power Output	[value]	kW
Heat Input Required	[value]	kW

3.2 Verification and Validation

[Present evidence that your computational results are physically valid. Include energy balance checks, comparison to theoretical limits (Carnot efficiency), and any hand calculations you used for verification.]

The energy balance for the overall cycle is verified:

$$Q_{in} - Q_{out} = W_{net} \quad \Rightarrow \quad \text{[your values show this holds within X\%]} \tag{6}$$

3.3 Sensitivity Analysis and Trade-offs

[Discuss how cycle performance varies with key parameters. Identify some trade-offs? How might practical considerations (cost, materials, environmental impact) affect your recommendations?]

[Insert sensitivity analysis plot]
e.g., efficiency vs. boiler pressure

Figure 2: Thermal efficiency as a function of boiler operating pressure, demonstrating diminishing returns beyond [X] bar and practical constraint considerations.

4. INTEGRATION WITH PORT ENERGY SYSTEM

[Discuss how your optimized thermal power system integrates with the port's overall energy infrastructure. Reference the Python data analysis work. When does thermal generation supplement renewables? What role does it play (is it meeting peak demand or providing baseload power)?]

Potential discussion points:

- Hourly dispatch strategy based on renewable availability
- Capacity factor and annual energy production estimates
- Fuel requirements and associated emissions/costs
- Comparison to alternative dispatchable sources (batteries, grid connection)

5. AI-ASSISTED ENGINEERING: PROCESS AND REFLECTION

5.1 Computational Development Strategy

[Describe your approach to using AI tools in developing the validation code. How did you balance AI assistance with your own understanding? Provide specific examples of effective prompting strategies or situations where verification caught AI errors.]

5.2 Lessons Learned in AI-Augmented Engineering

[Reflect critically on the role of AI in your engineering process. What worked well? What didn't? How did this experience shape your understanding of AI as an engineering tool versus a solution machine? What practices will you carry forward?]

Key reflection areas (address those most relevant to your experience):

- Iterative refinement vs. one-shot code generation
- Verification as essential practice with AI-generated code
- Understanding AI's limitations in domain-specific knowledge
- Building mental models while leveraging AI capabilities
- Ethical considerations in AI-assisted academic work

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Key Findings

[Summarize your main technical results in 3-5 bullet points. Be specific and quantitative.]

6.2 Engineering Recommendations

[Provide actionable recommendations for the port electrification system based on your analysis. Include caveats about assumptions, limitations, and areas requiring further investigation.]

6.3 Future Work

[What would you do next if this were a real consulting project? More detailed economic analysis? Consider alternative cycle configurations? Validate with pilot-scale testing? This shows you understand engineering as an iterative process.]