Specialisation Project (VT)
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Platform for Investment Analysis

Optimization Framework for Energy Asset Management using Linear Programming in Python

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1 Introduction

1.1 Project Context

Brief introduction to energy investment optimization and the need for automated analysis tools.

1.2 Objectives

- Develop a Python-based platform for energy investment analysis
- Implement linear programming optimization for asset management
- Create scenario analysis capabilities
- Provide AI-powered insights for decision support

2 Theoretical Background

2.1 Linear Programming in Energy Systems

Overview of optimization techniques in energy asset management.

2.2 DC Optimal Power Flow

The DC Optimal Power Flow (DC-OPF) is a simplified version of the AC power flow problem, commonly used in power systems analysis and optimization. This linearized model makes the following key assumptions:

- Voltage magnitudes are assumed to be 1.0 per unit (p.u.)
- Line resistances are negligible compared to reactances ($R \ll X$)
- Voltage angle differences between connected buses are small
- Reactive power flows are ignored

2.2.1 Mathematical Formulation

The DC-OPF problem can be formulated as follows:

$$\min_{\mathbf{P_g},\boldsymbol{\theta}} \quad \sum_{i \in \mathcal{G}} c_i(P_{g,i}) \tag{1}$$

subject to:

$$P_{g,i} - P_{d,i} = \sum_{j \in \mathcal{N}_i} B_{ij}(\theta_i - \theta_j) \quad \forall i \in \mathcal{N} \tag{2}$$

$$P_{g,i}^{\min} \leq P_{g,i} \leq P_{g,i}^{\max} \quad \forall i \in \mathcal{G} \tag{3}$$

$$-P_{ij}^{\max} \leq B_{ij}(\theta_i - \theta_j) \leq P_{ij}^{\max} \quad \forall (i,j) \in \mathcal{L} \tag{4}$$

$$\theta_{\text{ref}} = 0 \tag{5}$$

where:

- $\mathcal{N}$ is the set of all buses
- $\mathcal{G}$ is the set of generator buses
- $\mathcal{L}$ is the set of transmission lines
- $\mathcal{N}_i$ is the set of buses connected to bus i
- $P_{g,i}$ is the active power generation at bus i
- $P_{d,i}$ is the active power demand at bus i
- θ_i is the voltage angle at bus i

- B_{ij} is the susceptance of the line connecting buses i and j
- $c_i(P_{g,i})$ is the cost function for generator i
- $P_{g,i}^{\min}, P_{g,i}^{\max}$ are the generation limits
- $P_{ij}^{\max}$ is the transmission line capacity

The objective function (1) minimizes the total generation cost. Constraint (2) ensures power balance at each bus, (3) enforces generator limits, (4) ensures transmission line limits are not violated, and (5) sets the reference bus angle to zero.

2.2.2 Line Flow Calculation

The power flow P_{ij} through a transmission line connecting buses i and j is calculated as:

$$P_{ij} = B_{ij}(\theta_i - \theta_j) \tag{6}$$

This linear relationship between power flow and voltage angles is a key characteristic of the DC power flow approximation.

2.3 Economic Analysis Framework

NPV calculations, investment metrics, and risk assessment methods.

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- AI critique module

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