Software Requirements Specification for Minimization Analysis

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May 5, 2023

Contents

Revision History

Date	Version	Notes
February 8th	1.0	Initial Release
May 5, 2023	2.0	Second Release

1 Reference Material

This section records information for easy reference.

1.1 Table of Units

Throughout this document SI (Système International d'Unités) is employed as the unit system. In addition to the basic units, several derived units are used as described below. For each unit, the symbol is given followed by a description of the unit and the SI name.

symbol	unit	SI
m	length	metre
kWh	energy	kilowatt
m^3	volume	cubic meter
s	time	second
°C	temperature	centigrade
HM/s	computational power	hashrate
W	power	watt ($W = J\,s^{-1}$)

Additionally, currency for the total cost, is labelled by unit "CAD" which define Canadian dollars.

1.2 Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The choice of symbols was made to be consistent with existing documentation for electricity distribution systems. The symbols are listed in alphabetical order.

symbol	unit	description
L_{total}	W	total power demanded by the given combination plan
R_{total}	W	total electricity supply by the renewable energy
P_{total}	W	total electricity supply by the distributed energy

1.3 Abbreviations and Acronyms

symbol	description
C_{total}	total cost
C_r	renewable cost
C_p	grid electricity cost
d_i	Distance between data center and power station
A_i	Computational power for data center
IM	Instance Model
LC	Likely Change
PS	Physical System Description
R	Requirement
SRS	Software Requirements Specification

2 Introduction

Data centers use about 1%-4% of the electricity in the world[1]. Using energy more efficiently is one of the fastest, most cost-effective ways to save money, reduce greenhouse gas emissions, create jobs, and meet growing energy demand. This project aims to minimize the total energy cost for a set of data centers by determining the optimal power consumption from renewable energy sources and the power grid.To get started, please provide a CSV file containing information about the data centers, such as their distances to renewable energy sources and their maximum power consumption. You will also be asked to input any restrictions on the Grid Power and Renewable Power limits. The program will then process the input data, set up an optimization problem, and solve it using a linear programming approach. The resulting optimal power consumption for each data center will be displayed, along with the total cost of the energy. A plot illustrating the relationship between the distances to data centers and their optimal power consumption will also be provided for further analysis.

2.1 Purpose of Document

The purpose of this document is to provide a analytical model of allocate the computing power to each data center with minimize the cost to program users (Section 4.2.1). This document should clearly communicate all necessary background information and detailed system context is described in Section 3.

2.2 Scope of Requirements

The domain of this problem is restricted to given renewable energy pricing and factory electricity loss proportionate to transmission. In particular, different areas will have varying electricity pricing and distinct types of renewable resources. However, we can set constant renewable pricing and minimize the total cost to determine the optimal computing distribution plan for each data center. The domain focuses on one specific type of input data: the distance between the data center and the power station. In this program, specifically, we will identify the optimal cases of combination under static pricing. Therefore, it has been decided to use distances as input. Subsequently, since this project is limited to any renewable energy with a given price, any transmission power loss of renewable energy is considered out of scope. Essentially, while this program is intended to eventually be used within the context of specific physical data, it is developed and constructed for application to another area in North America as well.

2.3 Characteristics of Intended Reader

This document assumes the intended reader has familiarity with basic optimization analysis, power system analysis, and electricity distribution analysis. Courses which contribute to background knowledge may be titled Linear Systems (undergrad), Electric Machines and

Power Systems (undergrad), Electric Power Transmission, Distribution and Utilization (undergrad). Data constrain and model limitation will be discussed in this document. However, our exposition will only cover the concepts needed for our purposes. For proofs and for a complete exposition of all background materials. Furthermore, this document will explain as entry as possible aiming to appliable for more readers.

2.4 Organization of Document

This document is built on the template recommendations in cas 741 github that seeks to standardize communication tools for software development. The suggested order for reading this SRS document is: Goal Statement, Instance Models, Requirements, Introduction, and Specific System Description.

3 General System Description

This section provides general information about the system. It identifies the interfaces between the system and its environment, describes the user characteristics and lists the system constraints.

3.1 System Context

The following figure depicts a system context view of the computing relocation model.

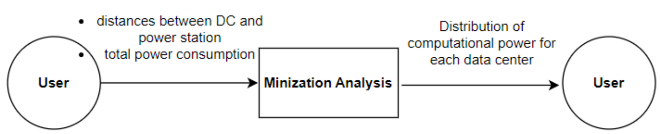

Figure 1: System Context

- User Responsibilities:
  - keep the unit even, keep every input with SI standard
  - Provide the distances between the power station and data centers and keep input under constraint.
  - Change system setting with their unique situations included total power consumption, renewable power rate and grid power rate.
- Minimization AnalysisMinimization Analysis Responsibilities:

- Keep positive input and less than max limit
- Detect if the output is capable for a data center to carry
- Detect data type mismatch, such as relocate data under same unit

3.2 User Characteristics

The front user should keep the unit with SI standard. The end user should have basic knowledge of undergraduate math and physics.

3.3 System Constraints

- Grid Power Consumption Constraint: The grid power consumption for each data center should be within the user-defined maximum grid power consumption restriction.
- Renewable Energy Constraint: The renewable energy consumption for each data center should not exceed the user-defined renewable energy limit.
- Total Power Consumption Constraint: The sum of renewable energy and grid energy consumption for all data centers should be equal to the user-defined total power consumption.
- Maximum Power Consumption per Data Center Constraint: The sum of renewable and grid energy consumption for each data center should not exceed the user-defined maximum power consumption per data center.
- Power Loss Constraint: The power loss due to transmission lines (TL) should be accounted for when calculating the actual grid energy consumption for each data center.

4 Specific System Description

This section first presents the problem description, which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification, which presents the assumptions, theories, definitions and finally the instance models.

4.1 Problem Description

Minimization AnalysisThis model is intended to estimate the minimum cost with different computing distributions of data centers with different distances from electricity power station

4.1.1 Terminology and Definitions

The minimization problem involves finding the lowest possible value of an objective function while taking into account the constraints imposed on the problem. The ideal value is the minimum value of the objective function, which lies within the feasible region defined by the problem's restrictions. To better understand the problem, one can construct a graph representing the feasible region, which visually displays the viable combinations of variables. By examining this feasible region, it is possible to determine the optimized distribution of computing resources that adheres to the given constraints.

4.1.2 Physical System Description

Physics system will regarding to real world. HVDC transmission losses are quoted as less than 3% per 1,000 km[(2)], a formula was designed to calculate the total power lose along the transmission line. With various of distance as input, the system operation like a net flowing. Each data center will consuming electricity from both renewable resources and grid power station. In the model, only transmission along electricity grid will assume have power lose, renewable resource stations are assuming very close to the data centers the supplied.

The physical system of Minimization Analysis, as shown in Figure2, includes the following elements:

- Data centers are not uniformed in the area.
- Renewable resources stations are very close to the data centers they supplied.

4.1.3 Goal Statements

GS1: Develop a program that optimizes the power consumption and associated costs for a given set of data centers, taking into consideration their distances, rates of renewable and grid energy, and power consumption limits.

GS2: Ensure that the program is user-friendly by prompting the user to input a CSV file containing relevant data, along with any specific grid power restrictions and renewable power limits.

GS3: Design the program to be robust and flexible, able to handle cases where specific information is not provided by the user, by assigning default values when necessary.

GS4: Provide clear, informative results that display the optimal power consumption for each data center, detailing the amounts of renewable and grid energy used, as well as the total cost, allowing users to make informed decisions regarding their data centers' energy consumption.

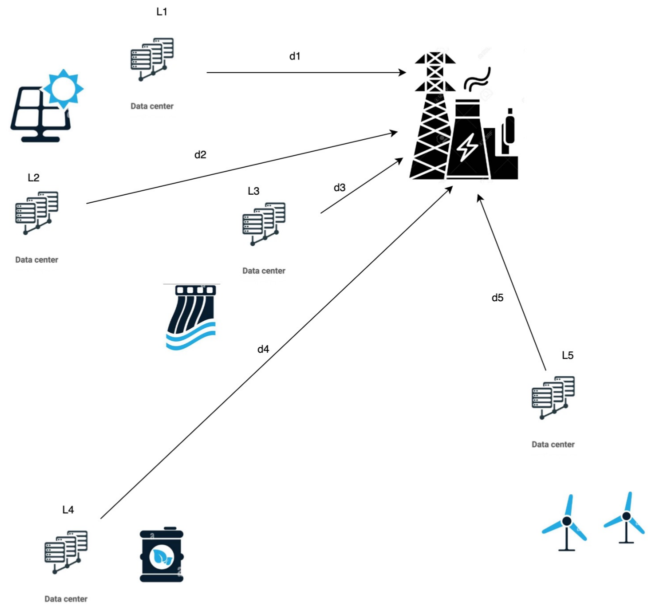

Figure 2: System Context

4.2 Solution Characteristics Specification

This section characterizes the attributes of an acceptable solution. Both analysts and stakeholders should agree on these attributes so that the solution can be accepted when the project is complete.

4.2.1 Assumptions

This section simplifies the original problem and helps in developing the theoretical model by filling in the missing information for the physical system. The numbers given in the square brackets refer to the theoretical model [T], general definition [GD], data definition [DD], instance model [IM], or likely change [LC], in which the respective assumption is used.

A1: We know that distances as input should be positive and a reasonable number.

A2: The software will estimate the distribution of load from a given total load.

A3: The objective of setting power loss with a constant coefficient is to eliminate the impact of power loss in substations.

A4: Depends on the pricing with C_r and C_p, the L_i will be distributed with either descending or ascending order of di

4.2.2 Theoretical Models

Applying the terminology and definitions from 4.1.1, this section records theorems required to identify a minimum optimal solution.

Consider the total cost for all data centers this is the sum of the total grid power supply cost plus the total renewable supply cost. The computing power distribution will as the same proportion as their electricity consumption[(3)].

RefName: **T1**

Label: Minimize the cost

Equation: $C_{\text{total}}{=}\sum_{i=1}^{n}\mathrm{C}_r i \,*\, R_i{+}C_p i \,*\, P_i$

Description: The above equation gives the value of the total cost for given Cr and Cp with power consumption as Ri and Pi respectively. When solving a minimizing problem, some constrain of variables must apply to find the feasible region.

Notes: None.

Source: https://www.superprof.co.uk/resources/academic/maths/linear-algebra/linear-programming/steps-to-solve-a-linear-programming-problem.html

Ref. By: GD2

Preconditions for T1: None

Derivation for T1: Not Applicable

RefName: T2

Label: Calculate for P_i

Equation: P_i=$P_{\text{i-theoretical}}$ *(1-(0.03 d_i / 1000))

Description: The above equation gives the value of power lose with transmission distance varied. The Pi is the actual consumption of energy, Pi-theoretical is the consumption without transmission lose. HVDC transmission losses are quoted as less than 3% per 1,000 km

Notes: None.

Source: See Reference

Ref. By: GD1

Preconditions for T2: None

Derivation for T2: Not Applicable

RefName: **T3**

Label: The power consumption for each data center

Equation: $L_{\text{total}}=\sum_{i=1}^{n} \mathrm{L}_i = R_i + P_i$

Description: The power consumption for each data center will come up with renewable supply and grid power supply.

Notes: None.

Source: See Reference

Ref. By: GD1

Preconditions for T3: None

Derivation for T3: Not Applicable

4.2.3 General Definitions

General Definitions (GDs) are a refinement of one or more TMs, and/or of other GDs. The GDs are less abstract than the TMs. Generally the reduction in abstraction is possible through invoking referencing Assumptions. This section collects the laws and equations that will be used in building the instance models.

Number	GD1
Label	**Power losses along transmission line**
SI Units	kWh
Equation	Loss= 0.03 * d_i/1000
Description	Transmission and distribution (T&D) loss are amounts that are not paid for by users.
Source	https://www.electricalindia.in/losses-in-distribution-transmission-lines/#:~:text=Transmission%20and%20distribution%20(T%26D,))%20%2F%20Energy%20Input%20kwh%20x100.
Ref. By	T2

Detailed derivation of calculating power transmission losses

It is fact that the unit of electric energy generated by the power station does not match the units distributed to the consumers. Some percentage of the units is lost in the distribution network. This difference in the generated & distributed units is known as transmission and distribution losses. Distribution Sector is considered the weakest link in the entire power sector. Transmission losses are approximately 17% while distribution losses are approximately 50%. In this model, we assume all of the data centers pass through the same number of sectors, so only transmission line losses are calculated.

4.2.4 Data Definitions

The Data Definitions are definitions of symbols and equations that are given for the problem. They are not derived; they are simply used by other models. For instance, if a problem depends on density, there may be a data definition for the equation defining density. The DDs are given information that you can use in your other modules.

All Data Definitions should be used (referenced) by at least one other model.

This section collects and defines all the data needed to build the instance models. The dimension of each quantity is also given. Modify the examples below for your problem, and add additional definitions as appropriate.

Number	DD1
Label	**Level of load (computing power) for each data center**
Symbol	L_p
SI Units	MW
Equation	None
Description	In each data center, the load represents its computational power. This means that a higher load indicates a greater capacity to process and handle complex tasks and large amounts of data. As the load increases, the data center can effectively manage more simultaneous operations, ensuring efficient performance and meeting the demanding needs of today's data-driven world.
Sources	https://bitflyer.com/en-eu/s/glossary/hashrate
Ref. By	IM??

4.2.5 Instance Models

The motivation for this section is to reduce the problem defined in "Physical System Description" (Section 4.1.2) to one expressed in mathematical terms. The IMs are built by refining the TMs and/or GDs. This section should remain abstract. The SRS should specify the requirements without considering the implementation.

This section transforms the problem defined in Section 4.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 4.2.4 to replace the abstract symbols in the models identified in Sections 4.2.3.

The goals reference your goals are solved by reference your instance models. other details, with cross-references where appropriate. Modify the examples below for your problem and add additional models as appropriate.

4.2.6 Input Data Constraints

Table 1 shows the data constraints on the input output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable. The column for software constraints restricts the range of inputs to reasonable values. The software constraints will be helpful in the design stage for picking suitable algorithms. The constraints are conservative, to give the user of the model the flexibility to experiment with unusual situations. The column of typical values is intended to provide a feel for a common scenario. The uncertainty column provides an estimate of the confidence with which the physical quantities can be measured. This information would be part of the input if one were performing an uncertainty quantification exercise.

The specification parameters in Table 1 are listed in Table 2.

Table 1: Input Variables

Var	**Physical Constraints**	**Software Constraints**	**Typical Value**	**Uncertainty**
di	$di > 0$	$0 \leq di \leq \mathrm{d_{max}}$	1000 m	10%
L_{total}	$L_{\mathrm{total}} > 0$	$0 \leq \mathrm{L_{total}} \leq \mathrm{L_{max}}$	10 MWh	10%

(*) the system able to convert MWh to KWh

Table 2: Specification Parameter Values

Var	**Value**
C_r	$0 < \mathrm{C_{ri}} < \mathrm{L_{max}}$
C_p	$0 < \mathrm{C_{pi}} < \mathrm{L_{max}}$

4.2.7 Properties of a Correct Solution

A correct solution must exhibit fill in the details. These properties are in addition to the stated requirements. There is no need to repeat the requirements here. These additional properties may not exist for every problem. Examples include conservation laws (like conservation of energy or mass) and known constraints on outputs, which are usually summarized in tabular form. A sample table is shown in Table 3

Table 3: Output Variables

Var	**Physical Constraints**
A_i	Under data center computational power capable size

5 Requirements

The requirements refine the goal statement. They will make heavy use of references to the instance models.

This section provides the functional requirements, the business tasks that the software is expected to complete, and the nonfunctional requirements, the qualities that the software is expected to exhibit.

5.1 Functional Requirements

R1: The system shall allow the user to input a CSV file containing information on data centers and their power consumption, renewable energy rate, and grid energy rate.

R2: The system shall extract and display the number of data centers, their distances, the rate of renewable energy, the rate of grid energy, the total power consumption, and the maximum power consumption per data center from the CSV file.

R3: User should keep input validate data type and reasonable value.

R4: The system shall solve the optimization problem using linear programming to calculate the optimal power consumption for each data center.

R5: The system shall display the optimal power consumption for each data center, including the amount of renewable energy and grid energy used.

R6: The system shall calculate the total cost of the optimal power consumption.

R7: The system shall plot a graph of the optimal power consumption for each data center against their distances, with the y-axis representing the total power consumption.

5.2 Nonfunctional Requirements

NFR1: **Accuracy** The computed solutions must meet the accuracy level required for engineering applications.

NFR2: **Usability** The program should not have a user interface, but the output should be easy to read and copy.

NFR3: **Maintainability** The time complexity of the program must be O(n) to ensure maintainability.

NFR4: **Portability** The program must be easily integrable with other software programs.

6 Likely Changes

LC1: It is likely that the program will need to include additional options for renewable energy supply.

LC2: The program may be modified to perform process analysis under minimum CO2 emissions in addition to operating the analysis under minimum cost.

LC3: It is probable that the program will need to be made more flexible to accommodate a wider range of operating systems.

7 Unlikely Changes

ULC 1 :The basic design concept of allocate computing instead of power station will unlikely to change.

8 Traceability Matrices and Graphs

The purpose of the traceability matrices is to provide easy references on what has to be additionally modified if a certain component is changed. Every time a component is changed, the items in the column of that component that are marked with an "X" may have to be modified as well. Table 4 shows the dependencies of theoretical models, general definitions, data definitions, and instance models with each other. Table 5 shows the dependencies of theoretical models, general definitions, data definitions, instance models, and likely changes on the assumptions.

	T1	T2	T3	GD1	DD1	IM1
T1		x	x			
T2					x	
T3					x	
GD1		x				
DD1			x			
IM1			x			

Table 4: Traceability Matrix Showing the Connections Between Items of Different Sections

	A1	A2	A3	A4	A5
T1					
T2	x		x		
T3				x	x
GD1		x			
DD1		x			
IM1					

Table 5: Traceability Matrix Showing the Connections Between Assumptions

9 Values of Auxiliary Constants

Grid Power restrictions:

$$\text{Grid\_Power\_restrictions} \tag{1}$$

Renewable limits:

$$\text{Renewable\_limits} \tag{2}$$

Rate of renewable energy :

$$\text{rate\_renewable} \tag{3}$$

Rate of grid energy :

$$\text{rate\_grid} \tag{4}$$

Maximum power consumption per data center:

$$\text{max\_power\_consumption} \tag{5}$$

References

[1] Michel Rivier, Ignacio J Pérez-Arriaga, and Luis Olmos. Electricity transmission. *Regulation of the power sector*, pages 251–340, 2013.

[2] Juan Rosellón. Different approaches towards electricity transmission expansion. *Review of network economics*, 2(3), 2003.

[3] Richard P Sedano and Matthew H Brown. Electricity transmission: a primer. *National Council on Electricity Policy, June, Washington, DC*, 2004.