UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Engineering, Built Environment and Information Technology

ENR 420

RESEARCH PROJECT

ASSIGNMENT 1: RESEARCH PROPOSAL

Name and Surname	Student Number	Signature
Brighton Chikomo	16071558	

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December 24, 2025

ENR 420 Assignment 1: Research Proposal for assignment topic 1

Brighton Chikomo (16071558)

I. Observation

A. Problem statement

The increase in population growth and technology led to high energy demand in rural areas from fossil fuels such as diesel. On the other hand, the concerns about the high cost of diesel and global warming have led to the use of renewable sources of energy such as solar energy. Due to the reason that PV solars cannot provide constant power to the load since the energy from PVs depend on the time on the day, the use of Photovoltaic-Diesel-Battery(PVDB) hybrid power system is important.

B. limitations

The PVDB hybrid system to be considered focuses on energy efficiency as the main key to optimize the power system. This review will assume that the system operation costs will only include the costs incurred after the installation of the system. The operation costs will only be limited fuel, maintenance and replacement cost. The operational costs of PVs and batteries are assumed to be negligible and hence will not be used to determine the total operation cost of the hybrid system. Assume the amount of charge which can be stored in a battery is finite. [1]

II. Research question

How to reduce the operation cost of a photovoltaic-diesel-battery hybrid power specifically for non-fixed loads and practical operation costs for people living in rural areas?

III. Hypothesis

If non-linear operation costs of a hybrid power system are taken into consideration in the development of a PVDB hybrid power system, then a minimum cost solution of a PVDB hybrid power system can be found.

IV. Literature study

A literature review of five relevant articles published by various authors between August 2009 and July 2019 identified various optimization strategies to reduce the operation cost of PVDB hybrid power for people living in rural areas.

Various authors have looked into the use of PVDB for fixed loads and uniform operation costs. The current or proposed solution to reduce the operation cost of the PVDB hybrid system looks into PVDB for more practical loads and operation costs [2].

Nafeh [3] proposed the use of FLC (fuzzy logic controller) and ON-OFF controller to optimize the battery and diesel operation under fixed load conditions. FLC and ON-OFF controller decides the time to switch ON the generator to compensate for load profile changes. This means that the generator is switched ON only if there is a shortage in power supply. This lead to reduced operation time of the diesel generator in the PVDB hybrid system hence reducing the operation cost of the system. The main advantage of the FLC is that it gives a robust system response as it can control complex non-linear systems with parameter variations. The study is relevant as it gives a robust PVDB hybrid system with reduced fuel consumption.

The modelling and optimization of the PVDB hybrid system in Karakoulidis and Mavridis [4] are done using the Hybrid Optimization Model for Electric Renewable (HOMER) programming. HOMER is a disentangled enhancement model that can perform numerous hourly simulations in order to come up with the least-costly hybrid system. The HOMER optimization approach by Karakoulidis and Mavridis [4] is relevant as it calculates the monthly diesel cost of the hybrid system and determines the least-costly solution. The work of Karakoulidis and Mavridis [4] only look at the optimization of the PVDB hybrid system for constant demand.

Kanzuma Kusakana [5] in his paper emphasis more on lowering the operational cost of the diesel generator through the use two control strategies which are continuous and ON-OFF control strategies in the PVDB hybrid power system as the way to achieve the minimum operation cost for the hybrid system. The study is relevant as it gives control strategies that can be used in PVDB hybrid systems to reduce fuel consumption. The weakness of this approach is that it only caters for constant daily demand and fixed load conditions.

Fodhil and Hamidat [6] use Particle Swarm Optimization(PSO) and the e-constraint to reduce the operational cost of the hybrid power system. PSO is simply a meta-heuristic method which is used to optimize different systems. PSO is based on the algorithm that the particle in its present velocity moves in the direction that will give the best possible solution. The study is relevant as it provides the optimization model with a minimum cost solution for the PVDB hybrid system. Although the PSO can provide a minimum cost solution for the hybrid system, it does not take the varying load operation costs into considerations.

Jeyaprabha and Berclin [7]suggested the use of artificial intelligence (AI) to optimize the size and tilting angles of the hybrid power system. They used the meteorological data from different locations to find the solar panel tilting angles which

give more solar energy. This lead to the reduction of the ON time of the diesel generator. The main strength of this hybrid optimization approach is that it can provide more solar energy. This study is relevant in the sense that it points out that it is possible to reduce the PVDB hybrid system operational costs if more solar energy is captured.

From the reviewed previous papers, all authors have looked on an optimization approach for a hybrid system connected to a constant load and with uniform operational cost [2]. This approach is wrong because consumer behaviour patterns vary. This review assesses the more practical optimization approach where varying load conditions and non-uniform operation costs are taken into consideration to optimize the hybrid system.

V. Research plan

The research work is going to be divided into two subsections, namely methodology and resources

A. Methodology

1) Model with variables: This section gives a brief explanation of the models and variables to be used in order to complete the proposed research work.

$$\begin{aligned} P_{pv} &= \eta_{pv} A_c I_{pv} \\ where: \ P_{pv} &= \text{PV generator energy output} \\ \eta_{pv} &= \text{PV generator efficiency} \\ I_{pv} &= \text{Solar radiation} \\ A_c &= \text{Size of the PV array} \end{aligned} \tag{1}$$

The following model and parameters are used to model the battery bank

$$\begin{aligned} Bc(t) &= Bc(0) + \eta_c \sum_{\tau=1}^{t} P_3(\tau) - \eta_D \sum_{\tau=1}^{t} P_4(\tau) \\ where: \ Bc(t) &= \text{battery state of charge(SOC)} \\ Bc(0) &= \text{initial battery SOC} \\ \eta_c \sum_{\tau=1}^{t} P_3(\tau) &= \text{power into the battery at time t} \\ \eta_D \sum_{\tau=1}^{t} P_4(\tau) &= \text{power from the battery at time t} \end{aligned} \tag{2}$$

The following model and parameters are used to model the diesel generator. The diesel generator is to be operated in the following power range [2]

$$\begin{aligned} P_1^{min} \leq P_1(t) \geq P_1^{max} \\ where: \ P_1^{min} &= \text{minimum generator operation power} \\ P_1^{max} &= \text{maximum generator operation power} \end{aligned} \tag{3}$$

2) Data collection method: Raw data is going to be gathered practically from the implemented hardware. The gathered raw data is going to be simulated using different software packages so as to fully interpret its meaning. Graphs are going to be plotted from raw data so as to visualize and understand the meaning of the gathered raw data.

3) Data analysis method: Quantitative data analysis methods are going to be used to interpret the collected data. This is because it has the ability to accurately interpret data based on hard facts. Hypothesis test, also known as the "T-test" is going to be used to compare the data collected against hypotheses and assumptions that have made about the operation of the PVDB hybrid system in section III and I-B of this paper. The hypothesis testing will allow the comparison of two variables so as to find the correlation and make decisions on whether the proposed PVDB hybrid system will have low operation costs. Regression analysis is going to be applied to measure the relationship between dependent variables. In the PVDB hybrid system that will be fuel for the diesel generator and power output from the generator. This analysis will reveal zones in operations that can be optimized by featuring patterns and connections between components.

B. Resources

This section gives a list of resources to be used to carry out a proposed hybrid system optimization approach.

1) Time: Figure 1 shows a Gantt chart of how time is going to be managed to accomplish the proposed solution

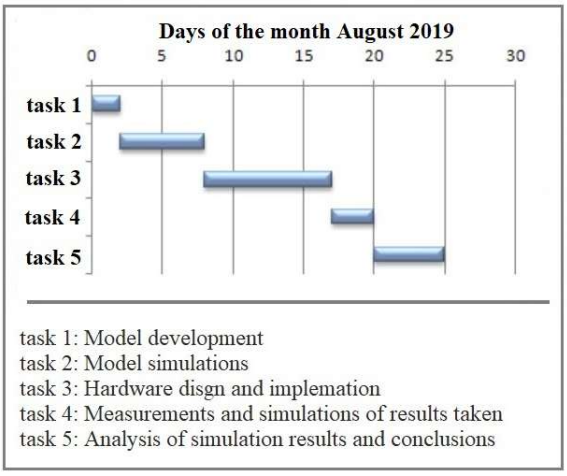

Fig. 1. Gantt chart: time management plan to accomplish the proposed solution

2) Other resources:

- ModelSim software: to simulate the developed model
- Development board (FPGA): to develop a model
- MATLAB: to program the mathematical model
- Microsoft Excel: to plot graphs from raw data

VI. Conclusion

In conclusion, the proposed minimum cost solution of PVDB hybrid system for remote consumers is going to focus more on the practical optimization approach where varying load conditions and non-uniform operational costs are taken into consideration to optimize the hybrid system. Model development, simulations and physical hardware design and implementation are going to be carried out to verify the feasibility of the proposed solution. The proposed solution can be deemed the best optimization approach since it caters for a more practical daily operational cost.

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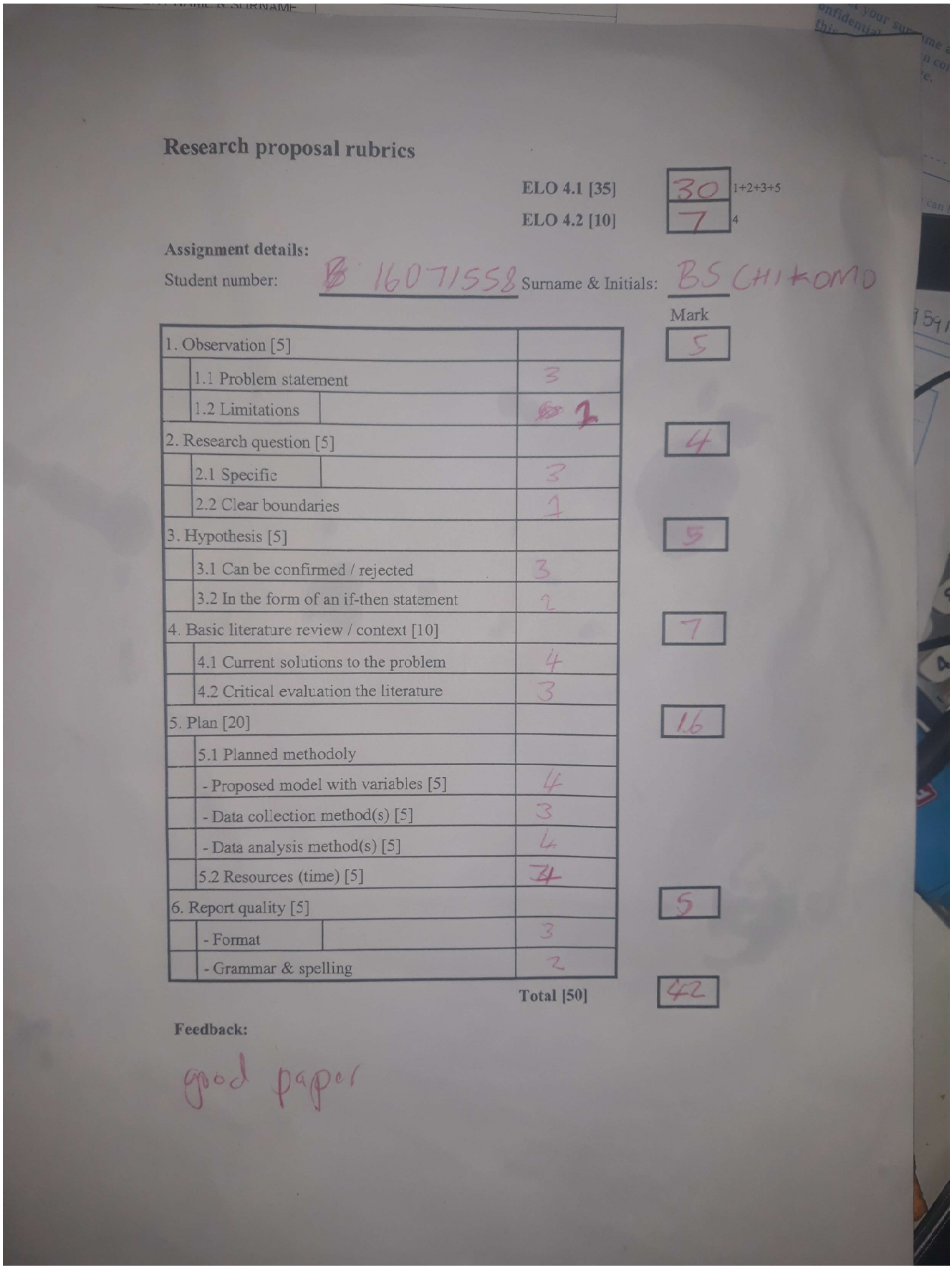

Research proposal rubrics

ELO 4.1 [35]	30	1+2+3+5
ELO 4.2 [10]	7	4

Assignment details:

Student number: B 16071558 Surname & Initials: BS CHITOMO

		Mark
1. Observation [5]		5
1.1 Problem statement	3	
1.2 Limitations	~~2~~ 1	
2. Research question [5]		4
2.1 Specific	3	
2.2 Clear boundaries	1	
3. Hypothesis [5]		5
3.1 Can be confirmed / rejected	3	
3.2 In the form of an if-then statement	2	
4. Basic literature review / context [10]		7
4.1 Current solutions to the problem	4	
4.2 Critical evaluation the literature	3	
5. Plan [20]		16
5.1 Planned methodoly		
- Proposed model with variables [5]	4	
- Data collection method(s) [5]	3	
- Data analysis method(s) [5]	4	
5.2 Resources (time) [5]	4	
6. Report quality [5]		5
- Format	3	
- Grammar & spelling	2	
	Total [50]	42

Feedback:

good paper

Fig. 2. Marking attach for this paper"ALL THE BEST!!"