Project B: Solar Generation for Remote Bore Fields

Team 12: Team Power

Author

Jessica Armstrong (21149475)

Design Approach Individual Submission

Project Partners: John-Ross Torre, Jacobs

Demonstrator: Ms Catherine Hatch

Academic Supervisor: Dr Sally Male

Group Meeting Day and Time: Friday 12pm

Word Count: 2,617

Word Limit: 2,500

Version 1.2

Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Date** | **Version** | **Description** | **Author** |
| 30/03/17 | 1.0 | Initial Draft | Jessica Armstrong |
| 04/04/17 | 1.1 | Second Draft including addition of lit review and edits | Jessica Armstrong |
| 05/04/17 | 1.2 | Final edit and review | Jessica Armstrong |

Table of Contents

Table of Figures 3

Table of Tables 3

1. Introduction 4

1.1 Purpose 4

1.2 Scope 4

1.3 Definitions, Acronyms, and Abbreviations 4

1.4 References 4

2. Summary of Contribution 6

3. Literature Review 6

3.1 Wave and Tidal Power 6

3.1.1 Wave Power 6

3.1.2 Tidal Power 6

3.1.3 Advantages and Disadvantages 6

3.2 Diesel Generators 7

3.3 Cooling System 7

4. Proposed Design 7

4.1 Design Details 7

4.2 Design Approach 8

4.3 Meeting the Requirements 8

5. Evidence of Teamwork 9

6. Appendices 10

6.1 Appendix A 10

# Table of Figures

[Figure 1: Tapered Channel 6](#_Toc479163471)

[Figure 2: Hybrid System Configuration 8](#_Toc479163472)

# Table of Tables

Table 1: Advantages and disadvantages of wave and tidal power 6

Table 2: Up-to-date Requirements 10

# Introduction

The project is to design a power generation system for a remote bore field located in Newman, Western Australia. The main project goals (Appendix A) are to provide a continuous power supply in a remote location at the lowest cost to the client. The design approach looks at the justification of the design and how the design meets the requirements. This document deals with the Authors contribution to the project thus far, a brief literature review and the design justification of a hybrid design involving solar power, a battery and a diesel backup generator.

## Purpose

The purpose of the design approach is to outline proposed designs and detail how the team will be modelling and testing them. This is a necessary step in a design project because without the necessary preparation and research, it is difficult to ensure project goals and requirements are met.

## Scope

The scope of a design approach deals with the timeline and dependencies in scheduling, design decisions, elements and justifications, cost estimates, risk management, configuration management, communication and tracking safety issues. The scope of this document covers the authors contribution to the project, a literature review and the design decision, elements and justification of one design option.

## Definitions, Acronyms, and Abbreviations

|  |  |
| --- | --- |
| PV | Photovoltaic |
| DC | Direct Current |
| AC | Alternating Current |
| NPV | Net Present Value |
| PPIR | Professional Performance Index |

## References

[1] J. Twidell and J. Twidell, *Renewable Energy Resources*, 2nd ed. ed. Taylor and Francis, 2014.

[2] E. Mehlum, "TAPCHAN," in *Hydrodynamics of Ocean Wave-Energy Utilization: IUTAM Symposium Lisbon/Portugal 1985*, D. V. Evans and A. F. O. de Falcão, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 1986, pp. 51-55.

[3] L. W. Turner, *Electronics Engineer's Reference Book*. Kent, UNKNOWN: Elsevier Science, 2013.

[4] H. Hotta, Y. Washio, H. Yokozawa, and T. Miyazaki, "R&D on wave power device “Mighty Whale”," *Renewable Energy,* vol. 9, no. 1–4, pp. 1223-1226, 9// 1996.

[5] (2010, 3 April). *Power Generation from Waves*. Available: <https://www.thermalfluidscentral.org/encyclopedia/index.php/Power_Generation_from_Waves>

[6] M. H. Rashid, *Alternative Energy in Power Electronics*. Saint Louis, UNITED STATES: Elsevier Science, 2014.

[7] K. Kusakana and H. J. Vermaak, "Hybrid diesel generator/renewable energy system performance modeling," *Renewable Energy,* vol. 67, pp. 97-102, 7// 2014.

[8] Central Maine Diesel. (2017, 30 March). *Perkins Diesel Generator 100 kW*. Available: <http://www.centralmainediesel.com/order/09152.asp?page=9152>

[9] Blue Diamond. (2017, 30 March). *Blue Diamond Machinery*. Available: <http://www.bluedm.com.au/138-kva-diesel-generator-3-phase-415v-cummins/>

[10] Australian Institute of Petroleum. (2016). *Pump Prices (Retail)*. Available: <http://www.aip.com.au/pricing/retail.htm>

[11] *Steel tanks for flammable and combustible liquids*, 2006.

[12] T. Zhang *et al.*, "Investigation on the promotion of temperature uniformity for the designed battery pack with liquid flow in cooling process," *Applied Thermal Engineering,* vol. 116, pp. 655-662, 4// 2017.

[13] K. H. Sueker, *Power Electronics Design : A Practitioner's Guide*. Amsterdam: Newnes, 2005.

[14] Z. Salameh, *Renewable Energy System Design*. Saint Louis, UNITED STATES: Elsevier Science, 2014.

[15] S. Yilmaz, H. R. Ozcalik, M. Aksu, and C. Karapınar, "Dynamic Simulation of a PV-Diesel-Battery Hybrid Plant for Off Grid Electricity Supply," *Energy Procedia,* vol. 75, pp. 381-387, 2015/08/01 2015.

[16] H. E. LLC. (2015). *HOMER Energy*. Available: <http://www.homerenergy.com/HOMER_pro.html>

[17] T. Lambert, P. Gilman, P. Lilienthal, T. Lambert, P. Gilman, and P. Lilienthal, *Micropower System Modeling with Homer*. John Wiley & Sons, Inc., 2006, pp. 379-418.

[18] Australian Government Bureau of Meteorology. (2017). *Climate statistics for Australian Locations*. Available: <http://www.bom.gov.au/climate/averages/tables/cw_007151.shtml>

# Summary of Contribution

Jessica’s responsibility in the project thus far has included being minute taker during group meetings, chairing group meetings and to maintain the PPIR and risk register for the group. Her contribution to the design approach is the literature review for wave and tidal power, diesel generators, and cooling systems. Also, the design justification of one of the team’s chosen hybrid solutions, solar, batter and diesel combination.

# Literature Review

## Wave and Tidal Power

### Wave Power

Wave Power is generated from the large energy changes in deep sea waves. The amount of energy produced in a deep sea wave is proportional to the amplitude of the wave squared and the period of the wave, for example a wave with a 2 metre amplitude and a period of 10 seconds has energy fluxes between 50 and 70 kW/min [1].

Wave power can be generated with on-shore or off-shore devices. Some on-shore devices include the Tapchan and oscillating water columns and the whale is an off-shore device. The Tapchan uses a tapered channel as seen in Figure 1, where wave energy is converted into potential energy. It is an entirely passive system with no moving parts, and the energy conversion is very similar to that of a hydroelectric power plant[2]. Another on-shore system is the use of an oscillating water column, this uses the rising and falling action of the wave to push air in a piston like action to turn a turbine to convert energy into a usable form. This occurs naturally in the form of blow holes[3]. The whale is a floating device with turbines for converting wave energy efficiently [4].

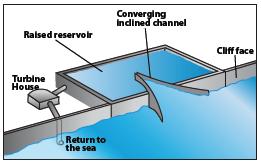


Figure : Tapered Channel[5]

### Tidal Power

Ocean tides are caused by the gravitational pull of the sun and the moon on the earth. Tidal energy can be captured by tidal stream or tidal current turbines. Barrages could also be used to capture potential energy created by the changing height of tides. This has a low efficiency, of a predicted 3.7TW of available power, 0.8TW is usable due to fluctuations in tide[6].

### Advantages and Disadvantages

Table 1: Advantages and disadvantages of wave and tidal power

|  |  |  |
| --- | --- | --- |
|  | Advantages | Disadvantages |
| Wave Power | * Large power fluctuations * Predictability of wave conditions from weather and wind * Renewable power source * Some devices can store energy for use during peak time (Tapchan) | * Inefficient, approximately 20% can be successfully converted to electric power[6]. * Best power is available in hard to reach areas (dangerous oceans) making maintenance and power transmission difficult and expensive * Risk of extreme weather that the structure would have to withstand. * Wave frequencies are very low compared to the requirements of electrical generator. |
| Tidal Power | * Renewable power source * Predictability of ocean tides | * Inefficient * Disrupt marine life * Expensive |

The use of both wave and tidal power in this project would be inappropriate. Transmitting power from the coast to the required site over 350 km would incur power losses and be very expensive.

## Diesel Generators

Diesel generators are diesel engines coupled to a generator, converting mechanical energy into electrical energy. Generators can generate electricity at the rated power, and any unused power can be used to charge battery storage. The use of diesel generators in hybrid power systems is common place where there is a lack of reliable power supply [7]. The project requires 90 kW of power to supply three 30 kW bore pumps plus some extra power for telemetry. While the generator will be used primarily as a backup system, it will need to be able to supply sufficient power to allow the bore pumps to continue running at full load. To cost the backup system, the price of the generator, the fuel and fuel delivery must be considered.

The cost of a diesel generator that meets the power requirements is approximately $20,000 to $28,000 [8, 9]. Such a generator consumes up to 25 L/hour when running at full load. This incurs a significant cost in using the fuel, in 2016 the average retail price of diesel was 121.6 c/L [10]. Diesel fuel can be transported by pipeline or by vehicle, this project is better suited to the use of a vehicle. Furthermore, the storage of diesel fuel on site must be considered. Any storage tanks must comply with AS 1692 (Tanks for flammable and Combustible liquids) [11].

## Cooling System

For the power system to operate in Newman’s harsh weather conditions it will require its own cooling mechanism. Elements such as photovoltaic cells will not require cooling however, elements such as battery banks will. Battery banks are more efficient at an optimal temperature range. There has been investigation to air cooling and liquid cooling in battery packs. It has been found that liquid cooling has a higher heat transfer due to its higher heat capacity than air cooling [12]. Air cooling requires forced air flow, this could be from fans, or a ventilation system, or a combination of both. Water or liquid cooling requires a secondary heat exchanger, cool liquid is streamed around the system and then recycled. Since the liquid is being used to cool electronics, low conductivity water or a glycol solution is used [13]. The simplest method to protect equipment from the environment is to remove it from direct sunlight.

# Proposed Design

## Design Details

The design option to investigate is the use of a photovoltaic (PV) system, with a power storage system and a diesel backup system. The configuration of the proposed system can be seen in Figure 2. This system relies mainly on solar power for generation, while storing unused power in a battery for when sunlight is unavailable at night or on cloudy days. To ensure supply is continuous, there is also a diesel backup generator for use when the battery storage is depleted, or there is a failure in the PV or battery system. This system also demands the use of an inverter since PV only produces DC (direct current) and the load requires AC (alternating current) [14].

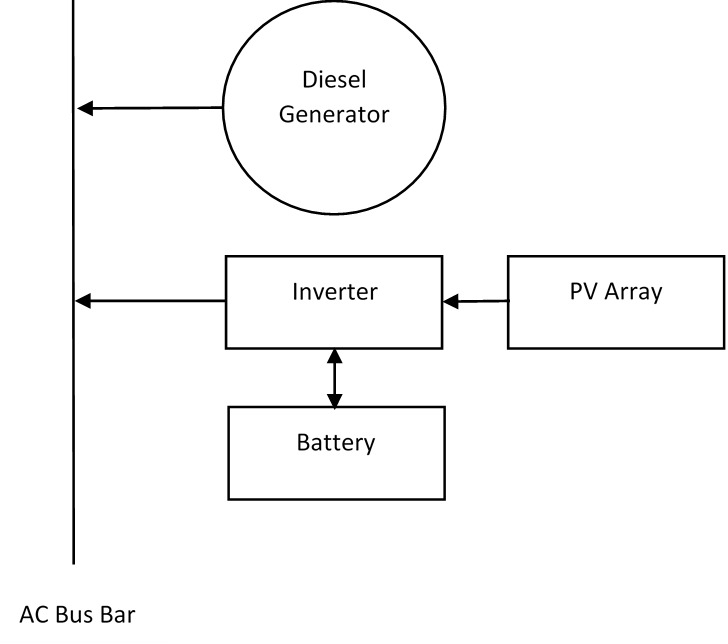


Figure : Hybrid System Configuration

PV, battery and diesel systems have had success in similar previous projects where the location meant that the power supply was best suited off grid. This has been used to supply power to homes in Kahramanmaras, Turkey where the temperatures are extreme like those in Newman. It was found that in summer, the system could rely only on the PV and battery but required the generator in the winter months but was always able to meet the power requirements [15]. While this system does not meet the same power requirements as the project, it is relevant due to its success in a harsh climate.

## Design Approach

To design the optimal solution, simulations will be run to calculate the most efficient configuration of the design. To do this, the team will be using HOMER [16]. HOMER allows simulations to be run based on the geographic location, using any combination of equipment. The software can size the equipment and calculate lifetime costs using the net present value (NPV) analysis. The team will be able to optimise and cost the design using data inputs relevant to the project [17].

## Meeting the Requirements

The main requirements (appendix 1) that this option is required to meet are 1, 2, 3, 7, 8, and 9. This means that the system should operate continuously providing sufficient power in Newman. It should also be maintainable, last the required 10 years, and minimise environmental impact. The economy and safety (requirements 4 and 5) of the solution will be compared to other options by means of a risk register and cost benefits analysis carried out by other team members.

The inclusion of a backup generator and battery allows the system the best chance to run without disruption hence meeting the main requirement for the project. This also helps to meet requirement 3 since any poor weather conditions due to the systems location that stop the PV system from generating power is counteracted by including a battery and generator. By sizing the system correctly and selecting appropriate equipment, it will meet the power requirements for all three pumps and telemetry meeting requirement 2. This also helps to meet requirements 7 and 8, equipment that has been used successfully before has the best chance to last the full 10-year lifetime. Equipment used widely in industry is also well documented simplifying maintenance and staff may be familiar with it. The use of a PV array is particularly appropriate in meeting requirements 3 and 9. Due to the remote location (Newman) there is enough land for large PV arrays and the climate has a low number of cloudy days [18]. Solar power is a renewable energy source with no emissions therefore minimising harm to the environment. This system meets some requirements better than others; however it is important to meet requirements of a higher priority first. For example, the system will be costly, but it will also provide a continuous power supply without disruptions.

# Evidence of Teamwork

Jessica has contributed to the team significantly over the past six weeks. This is evident from her prompt sharing of minutes during her time as minute taker and her inclusion of actions that the team was required to complete to a deadline. Jessica has also chaired meetings, actively listening to group members and initiating group discussions. The key to successfully chairing a team is not to talk the most, but to encourage all members to contribute equally. An example of doing this was in team meetings Jessica engaged the team in a discussion about risks even though it had been assigned to an individual member of the group, encouraging all members to make contributions to team decisions. By making decisions about risks as a group, the team is less likely to miss any important safety issues associated with the project. Jessica also took the initiative to create and share the team professional performance index (PPIR). Additionally, she started the risk register and shared it to a Google Drive where all team members could make contributions.

# Appendices

## Appendix A

Table 2: Up-to-Date Requirements

|  |  |  |  |
| --- | --- | --- | --- |
| Priority | Requirement | Description | Classification |
| 1 | 24/7 | The power generation system is required to operate for 24 hours a day, 7 days a week, 365 days a year. | EXP, SPO |
| 2 | 90 kW++ | The power generation system must produce 90kW of power to supply the main pumps, plus additional power to supply other essential systems. | EXP, SPO |
| 3 | Newman | The power generation system must operate in Newman. This includes tolerating the harsh conditions. | EXP, SPO |
| 4 | Safety | The system must run safely. Any safety equipment that requires power must also be supplied. | EXP, SPO, UNS |
| 5 | Economy | Maximise the economy of the proposed solution. | EXP, SPO |
| 6 | Telemetry | The system requires telemetry and communications equipment, and these will also require power. | EXP, SPO |
| 7 | Maintainable | The system must be maintainable. | EXP, UNS |
| 8 | 10-year life | The system must last for at least ten years | EXP, SPO |
| 9 | Environment | The proposed solution should minimise harm to the environment. | EXP, EXC |
| 10 | Time | The proposed solution should take a minimum amount of time to construct. | EXP, EXC |