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Portable Energy Unit for Natural Disaster Situation

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ABSTRACT

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Keywords: Renewable Energy; Portable Unit; Remote Application

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Abstract

The portable renewable energy power unit was designed from a need. The need was for first response teams in remote natural disaster situations to have a reliable source of energy to power a small vaccine refrigerator or water purification system and a basic satellite communication system. It is important that such a need is explored as a practical solution has the potential to save the lives of people in remote areas, who would otherwise suffer from a lack of humanitarian aid. Currently diesel generators are the primary source of electricity generation for disaster responders and in most situations work very well and provide a sufficient amount of electricity to meet the power needs. However, in remote areas road infrastructure is often damaged. In this type of situation getting a constant supply of diesel to the area is an expensive or impractical operation. This is where the portable renewable energy power unit bridges the gap and allows a more practical solution to be implemented. The specific aim of the work was to design a compact, stand-alone, product that can be easily transported by people across uneven terrain. It can generate power from wind, solar and hydro energy sources. A complete Solid works model and FEA analysis, on required components, was completed. The scope of the work encompasses both the electrical and mechanical design of the system.

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1. Introduction

Energy storage and power generation are some of the largest influences that have driven both the industrial and agricultural sectors in the developed world to what it is today [1]. In addition, a large majority of the world today is powered by finite, unsustainable resources such as fossil fuels [2]. With growing economies and growing populations of people, renewable energy generation, such as solar, wind, and hydro generation is quickly growing as a means of producing electricity for people. Natural Disasters, such as tsunamis, earthquakes and cyclones etc. are uncontrollable events that affect people's lives with little or no warning. Such events can wipe out homes and destroy power infrastructure, potentially leaving large amounts of people without power, water and sanitary items [3]. Over 50% of New Zealand's aid for natural disasters goes to the Pacific area. This includes island nations such as the Cook Islands, Fiji, Niue, Samoa, Solomon Islands, Tokelau, Tonga, Vanuatu and

others [4]. The pacific region is one of the most prone regions in the world for natural disasters to occur. 3.4 million people in the pacific islands have been directly affected by natural disasters and there has been 1700 reported deaths since 1950 (excluding Papua New Guinea) [5]. Furthermore, New Zealand is within this prone pacific region and experiences natural disasters, which creates demand in cities, towns and remote communities for disaster relief. There are about 100 formal disaster relief organizations worldwide. When a disaster strikes an area, 95% of the work that these organizations do is to address critical needs such as water, food and medical attention. Once these needs are addressed, shelter is the next priority [3]. In order to meet these initial needs for people, in areas that have lost power, having access to a reliable power resource is essential to provide the aid that is needed [6]. Transporting a power generator into a disaster zone has its issues, as often there is restricted access as road infrastructure can be damaged. Moreover, diesel power generators have the continued

issue of the transport of diesel into the area; they are also very heavy, make a lot of noise and contribute negatively to preventing greenhouse gas emissions into the atmosphere. Analyzing the trends, this presents a need for a mobile power generation unit, powered by abundant renewable resources such as solar, wind and hydro in order to provide reliable power to aid disaster relief applications. A disadvantage of an individual renewable energy source in the form of solar radiation or wind is its unreliability. There is not always direct sunshine and likewise, there is not always wind. Also, certain areas are not within close proximity of a flowing river. Furthermore, different environments provide different weather patterns. However, integrating renewable energy sources effectively into one system ensures the reliability of being able to produce power [6]. In addition, energy storage, such as batteries, will enhance the adaptability and reliability of a renewable energy system by being able to cover the fluctuations in the load of the applications being used [7]. As lowering greenhouse gas emissions is a sub-focus for mobile, off-grid, green power systems, it is important that the greenhouse emissions and sustainability of the energy storage systems are considered also as they could be in place for long periods of time [5],[7].

There are few mobile, hybrid renewable energy systems for disaster relief on the market. Most of the systems currently on the market are singular systems usually consisting of solar generation and the hybrid systems that do exist have very inefficient methods of optimizing wind power capture. Adding energy generation sources has the potential to improve reliability of producing power in any environment. Furthermore, current systems usually need to be towed on a trailer. This makes it difficult to access areas where road infrastructure is damaged and makes it difficult for such systems because of size

and weight to be transported into remote areas by air.

2. Current System

From literature review, it was found that there are two different types of hybrid systems in terms of the choice of energy generation that is currently being developed. The first system is wind/solar hybrid systems and the second is wind/solar and diesel hybrid systems. The wind, solar, diesel generation hybrids still have the issue of needing access to diesel supply and still emit greenhouse gasses, however, these issues are reduced due to the backup of the solar and wind resources. A third concept that arose within the literature was described as “an ad-hoc self-organized micro-grid based on moveable and renewable energy sources and fully distributed co-ordination between intelligent power routing nodes” [7]. The purpose of this concept is for remote communities and natural disaster victims to be able to rapidly establish a small grid of electricity sharing with little infrastructural development. There is need of further research to be done in this area as no working prototype of the proposed system was discovered.

A wind, solar hybrid trailer system called Mobile Elemental Power Plant (MEPP), designed for disaster relief in remote areas is presented [8] and shown in Figure 1.



Figure 1 CAD model of the MEPP

This system consists of two 240 watt solar panels and a 600 watt wind turbine that is fixed to a telescoping mast system that can raise the turbine to a height of 10 meters to gain access of less turbulent, faster flowing air [9]. The whole system is mounted on a trailer for mobility of the system with a vehicle. One issue with having the mobility of the system constrained to a vehicle is that if road infrastructure was destroyed by a disaster it would be difficult to get the system into the area of need. However, more research needs to be done to integrate micro-hydro generation into the system to increase the power reliability and flexibility. Furthermore, a smaller, more mobile version of the MEPP is required to increase system agility and reduce the cost.

3. Energy Storage Technologies

One issue related to renewable energy is its variability in its supply of electricity generation. Batteries can be integrated into a system to generate a more constant supply of power to users [4]. Chemical, kinetic or potential energy are all forms in which the electricity produced by the renewable resources can be stored in. The following is a list of storage appliances that can be used to store electricity [9].

- Batteries
- Flow batteries
- Fuel cells
- Fly wheels
- Superconducting magnetic energy storage (SMES)
- Super capacitors
- Compressed air energy storage
- Pumped hydro

Compressed air energy storage and pumped hydro are not sufficient for a movable micro-generation due to their size and weight. They are also very costly, therefore more appropriate for large scale energy systems. Super capacitors and SMES have high-power characteristics and their efficiencies are very good compared to other energy storage systems. They can also be drained and recharge numerous times without the capacity of energy storage

being lost [10]. SMES and super capacitors are still being developed before they become readily available to purchase on the market at a viable price, therefore they are not reviewed further in this article. According to [4], flywheels, fuel cells and flow batteries are seen to be more suitable for small renewable energy systems. Flywheel energy storage has high-power and short-cycle characteristics. Energy is lost through friction in the system. Hydrogen/fuel cell technology is environmentally friendly as it uses air and hydrogen to store electricity however, it is not readily available at a viable price to be used for further research. Flow batteries have high-power, low self-discharge but low efficiency characteristics[4].

4. Renewable Energy System Design

In this work a modular renewable energy system is presented as a solution to fulfill energy needs in a remote area struck by natural disaster. In this system wind turbine, hydro turbine, solar panels and power storage unit are housed in their own separate units. This arrangement provides several benefits to the first response team going into remote areas

- A modular setup provides maximum adaptability when packing the system into confined spaces, such as a helicopter or truck, as it can be configured in many different ways to fit in with other supplies and resources.
- The modular design makes human transportation of the system easier as the weight of carrying each wheeled unit can be split between each team member. If the system was integrated as one large unit, the logistics of carrying the unit becomes a lot more difficult as multiple people would have to handle the unit at one time.
- The product is also a lot more adaptable as a modular system in terms of the weather conditions for each circumstance. It is not always necessary that all modules are taken where aid is needed. For example if the weather forecast for an

affected remote area predicts a lot of sunshine but little wind and the area is not near a stream or river then it is practical to take only the solar and power storage unit as a power generating resource. In contrast, if the weather predicts rain, with little wind, but the affected area is near a constant flowing stream or river then it may be practical to just take the hydro and power storage unit. As demonstrated this provides a large amount of system adaptability and ensures no unnecessary weight and space is added to the aid supplies.



Figure 2. Solid works model for wind turbine unit, solar module unit, hydro turbine unit and storage unit.

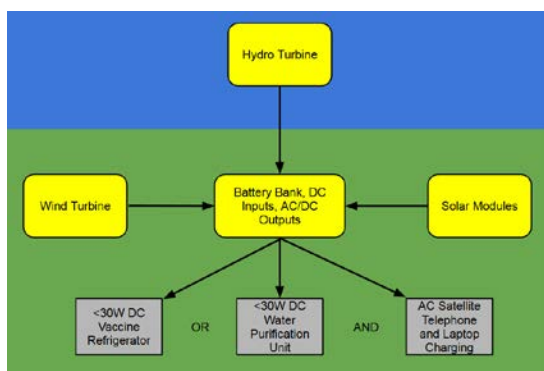


Figure 3 Flow diagram of the interaction of each module and the supply direction of electricity from each power source, to the selected appliances

5. Storage Unit

The storage unit is designed to supply electricity to first responders to power their vital equipment. Furthermore, the unit provides power redundancy when

electricity cannot be produced from the renewable power sources. The power generation sources run 12V DC into the power unit through sockets in the side of the unit. The inputs then run into an Ampair 300W regulator which regulates the current into the battery. There are two regulators as each regulator can only handle a maximum of two inputs. The battery is a 13.2V, 100Ah Lithium Ion Phosphate deep cycle battery, to provide up to 3 hours of redundancy for the system each day. From the battery there are two outputs, one AC and one DC. The AC output runs through a 200W pure sine wave inverter and the DC output runs directly to a DC socket. In addition a 6W cooling fan can be turned on, to cool the battery when necessary and all of the external components have rubber caps to seal them off from water or dust.

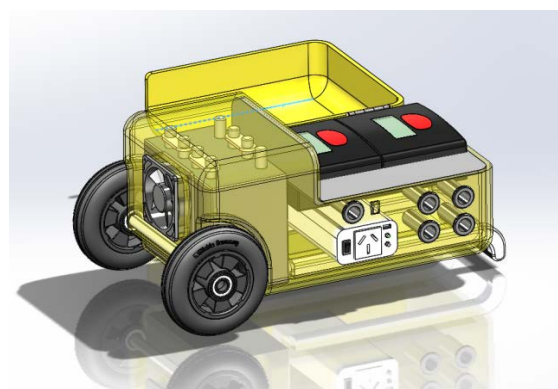


Figure 4 Storage unit design.

6. Solar Module

The solar array module is designed to capture the solar energy using photovoltaics and convert that energy into electricity, to be sent to the power storage unit. Three 55W solar panels as shown in Figure 5, are connected in parallel to create a 12V, 165W solar array. A retractable 12-gauge cable that extends up to 6 meters enables the connection between the solar array and the power storage unit. The unit also has the capability to connect with an additional module to increase the power output in an area that receives a small amount of day light hours. An added solar array connects in parallel with the existing array in order to keep the 12V output to the power storage

unit. The solar arrays angle can be adjusted in order to face perpendicular to the sun at all times of the day, ultimately increasing the arrays power output capacity. The panels fold away into a tough high density polyethylene case which protects the panels during transportation, storage and adverse weather conditions. The soft rubber caster wheels and retractable handle allow ease of human transportation across rough surfaces such as gravel, grass or dirt roads.

Monocrystalline, Polycrystalline and thin film solar panels were considered for the solar array module. The most important factor for choosing the type of solar panel to use was the energy efficiency, as this system requires a high power output from a small, lightweight unit. While slightly more expensive, monocrystalline solar panels have the highest efficiency rates and were therefore chosen to be used on this design [9].



Figure 5 Front side of the solar array module, three 55W solar panels connected in parallel

7. Wind Turbine Model

The wind module is designed to convert wind energy into electrical energy using a 300W horizontal axis Ampair wind turbine. The turbine is elevated into the air, to a maximum of 6 meters in order to get into faster, more laminar flowing air. The 12m long 12 gauge power cord runs from the wind turbine, down the inside of the telescopic tube and out the bottom of the mast holder. The cord has an excess of 6 meters to run to the power storage unit. While the turbine system is a large structure when set up, it can be packed up into a compact casing for transportation and storage. The handle and soft rubber wheels

allow the case to be transported easily by a person across semi-rough terrain. Working and transportation setup of turbine is shown in Figure 6 and figure 7 respectively.



Figure 6 left) turbine out of its case before elevation. Right) wind turbine at its maximum 6m elevation.

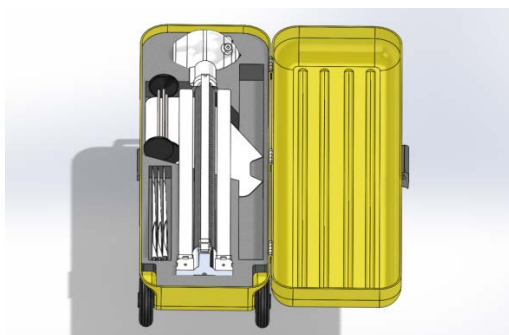


Figure 7 Wind turbine disassembled and packed into its case.

The wind turbine module went through a range of design changes before arriving at the final design. Initially, like the other module designs, the stand for the turbine mast was integrated into the case. In this instance it was more practical to have the mast and stand separate from the case, due to the cases shape and size. A range of stand variations were investigated in the concept development stage, the final design was chosen due to its simplicity in the number of parts it uses which helps with reducing the weight of the product.

In order to have the turbine reach a setup height of 6 meters the mast material needs to be stiff, strong and lightweight. The two options that were considered for the mast material were aluminum and carbon fiber. As the wind turbine is supported near the top of the mast by guy wires the mast only

needs to support a downward force of 1000N (wind turbine), therefore, it can be assumed the strength of both the aluminum and carbon fiber (using 2mm wall thickness) tube is of sufficient strength to support the wind turbine. Although slightly more expensive the carbon fiber tubing is 25% lighter than the aluminum and also has a greater stiffness and strength. Therefore carbon fiber tubing was chosen for the product and the weight benefits outweigh the slight increase in price from extruded aluminum.

8. Hydro Turbine Unit

The hydro turbine is designed to be placed into a stream or river and convert the energy from the moving water into electricity from the use of a turbine. As shown in Figure 8 the hydro turbine is housed inside the plastic casing in its transport state, with the soft rubber caster wheels on the underside of the unit allowing the module to be pulled across semi rough terrain by its retractable pull handle. When the module is setup for electricity generation, the heavy duty latches are undone and the base of the module is flipped 180 degrees. The hydro turbine is then on the outside of the module and the wheels are housed inside the watertight unit. The unit is used as buoyancy for the hydro turbine when it is put into a river or stream, in order to prevent the turbine hitting the riverbed. A 4-meter carbon fiber telescopic pole used to hold the module out from the riverbank. The pole is held perpendicular to the water flow in tension by a spectra line. Both the pole and the guy line are fixed by 400mm stainless steel pegs and also have the option to be tied to a fixed object when pegging is not practical. The carbon fiber pole is also housed within the casing when the unit is in its transport state. The 10-meter-long 12-gauge power cord runs from the turbine, into the tube and out through the peg. The cord then has an excess of 6 meters to run into the power storage unit. Figure 9 shows hydro turbine setup in generation mode.

Whereas Figure 9 shows the placement of hydro turbine in flowing water.

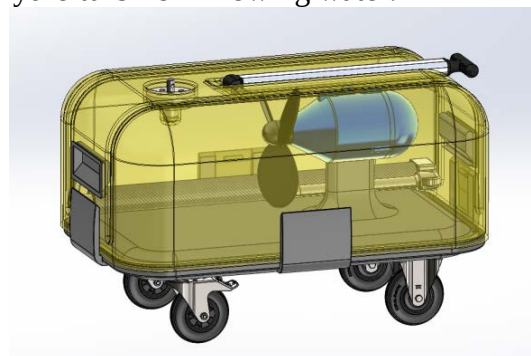


Figure 8 Hydro turbine unit in its transportation setup.

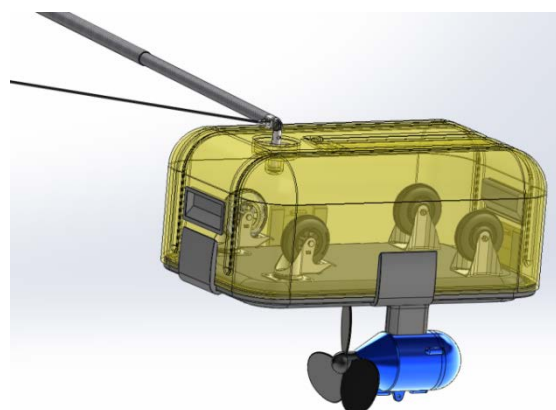


Figure 9 Hydro turbine setup for electricity generation



Figure 10 Function of the hydro turbine in a flowing river

9. Conclusions

The portable power generation system is a practical design that fulfils the need for first response teams in remote natural disaster areas, to have a reliable source of energy, to power a small vaccine refrigerator or water purification system and a basic satellite communication system. The system design

uses innovative features and materials in order to achieve a product that meets the design specifications of the application.

The system fills a niche in the market for a self-sustaining power unit that can be successfully transported by foot or by air into affected remote disaster locations. Because the system is the only product of its kind, there is a reasonable opportunity for the adoption, by non-profit aid organizations who are involved in disaster relief, as natural disasters are always going to exist and are increasing with global warming. With the increase in renewable energy technologies, the long term success of such a product is promising.

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