HYBRID RENEWABLE ENERGY

MOBILE MICRO HYDRO TURBINE

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THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE MASTER'S DEGREE OF POWER SYSTEM ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2018

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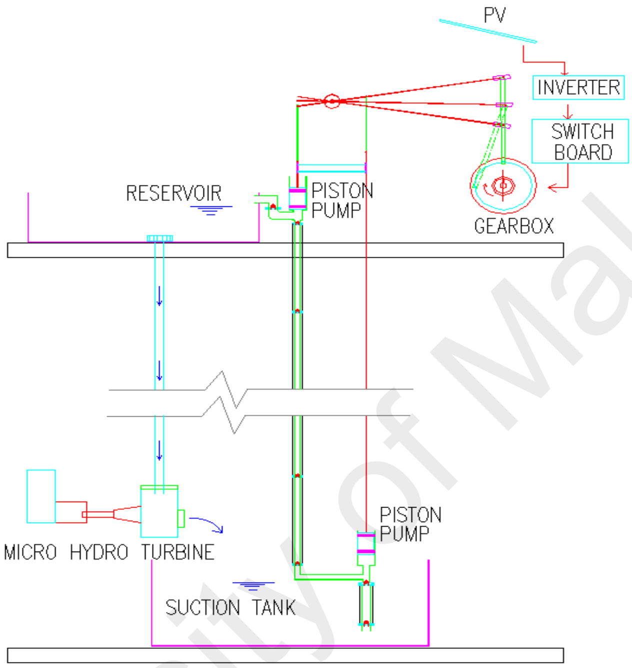

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ORIGINAL LITERARY WORK DECLARATION

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Title of Thesis: Hybrid Renewable Energy - Mobile Micro Hydro Turbine

Field of Study: Renewable Energy

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ABSTRACT

The HRES (Hybrid Renewable Energy System) involves combination of two or more renewable energy sources, or mixed with conventional sources to make a new set of power generation. The combination can be any blend of renewable sources. The renewable energy sources in the nature is always facing an intermittent predicament. To overcome and ameliorate the issues, hybrid combination with storage (aka battery) Semiconducting Magnetic Energy Storage (SMES), water storage as potential for hydro turbine implemented in the invention of HRES. Mobile Micro Hydro Turbine and the energy supply by photo voltaic (PV) make this research project as a HRES by moving the gearbox and lifting water to storage tank through two sets of piston pumps and a long arm connected to gearbox for reducing force. The optimum sizing method for stand-alone HRES, introduces an optimum size of battery bank, using SMES and excessive energy convert to storage water as hydro power generation. This is to maximize the components for power generation and also to incorporate the DPSP (Deficiency of Power Supply Probability) and the LCC (Life-cycle Cost). It also can achieve technical and economical application by the system reliability. The PRA (power reliability analysis) is so important when come into the design process inclusive of satisfy load demand and calculate the cost effective in economic aspect. To apply the cost analysis for HRES, some economic criteria is required. The Net present cost is involved the installation works and the energy levelised cost. The levelised cost is the ratio of the total yearly system cost to the yearly electricity supplied by the system and LCC (life-cycle cost) of the components installed.

ABSTRAK

Sistem tenaga yang boleh diperbaharui secara hibrid (HRES) melibatkan percampuran daripada dua atau lebih punca tenaga yang boleh diperbaharui, ataupun percampuran dengan punca janakuasa konvensional untuk membuat sesuatu janakuasa yang baru. Percampuran boleh dilakukan dengan berlainan jenis punca tenaga yang boleh diperbaharui. Punca tenaga yang boleh diperbaharui daripada alam semulajadi selalunya menghadapi masalah keadaan sekejap-sekejap. Untuk mengatasi dan selesaikan masalah ini, percampuran dengan simpanan kuasa (bateri aka), simpanan tenaga dalam semi konduktor magnet (SMES) dan simpanan air dalam tangki sebagai potensi untuk janakuasa hydro telah diimplikasi dan dijadikan sebagai ciptaan HRES. Mikro janakuasa hydro yang mudah alih dan tenaga daripada cahaya (PV) membuatkan projek penyelidikan ini sebagai HRES. Kaedah ukuran optima untuk persendirian HRES, telah memperkenalkan saiz yang optima untuk bank bateri, penggunaan SMES ataupun penukaran tenaga kepada simpanan air sebagai potensi janakuasa kuasa. Ini adalah untuk memaksimakan penggunaan komponen yang disebut di atas untuk sistem janakuasa dan menggabungkan kebarangkalian dalam masalah kekurangan bekalan kuasa (DPSP-`Deficiency of Power Supply') dan juga kos kitaran hayat (LCC-Life Cycle Cost). Ini juga boleh mencapai tahap teknikal dan ekonomi dalam sistem kebolehpercayaan. Analisi kebolehpercayaan kuasa (PRA-`Power reliability Analysis') adalah penting apabila masuk ke dalam proses rekabentuk termasuk memenuhi permintaan beban kuasa dan kiraan kos yang berkesan dalam aspek ekonomi. Dalam permohonan kos analisis untuk HRES, beberapa kriteria ekonomi adalah diperlukan. Kos semasa bersih (Net present cost) melibatkan kos pemasangan dan kos tenaga yang bertingkat (energy levelised cost). Kos tenaga yang bertingkat adalah nisbah bagi jumlah kos sistem tahunan kepada jumlah bekalan elektrik tahunan oleh sistem dan kos kitaran hayat daripada komponen yang dipasangkan.

ACKNOWLEDGEMENT

First of all, I would like to express my deep gratitude to my supervisor, Assoc. Prof. Ir. Dr. Jeevan Kanesan. I have been amazingly fortunate to have a supervisor who has given me the freedom to explore things on my own, and with his patient guidance whenever my steps are faltered. His kindness and support have helped me to overcome many critical situations throughout my research project. It has been a great pleasure to work under him as one of his research project students.

A special thanks to my brother indoor, Mr. Wong Mun Foo for sharing his ideal to fabricate the piston pumps with one way ball valve and helping me in making the prototype at his workshop.

I also acknowledge the inspiration from others who contributed their good references published in the website, text books, data sheets, etc. which details are mentioned in the reference section.

Lastly, I would like to thank my family, classmate and to those who has helped me in the research project directly or indirectly.

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LIST OF SYMBOLS AND ABBREVIATIONS

HRES	:	Hybrid Renewable Energy System
RE	:	Renewable Energy
SMES	:	Superconducting magnetic energy storage
WP	:	Wind Power
DC	:	Direct Current
AC	:	Alternative Current
ENN	:	The Extension Neural Network
LCC	:	Life-cycle Cost
CHP	:	Combined Heat and Power
PCA	:	Principle Components Analysis
CCA	:	Canonical Correlation analysis
CSP	:	Concentrating solar power
DPSP	:	Deficiency of Power Supply Probability
MPPT	:	Maximum Power Point Tracking
NREL	:	National Renewable Energy Laboratory
HOMER	:	Hybrid Optimization Model for Electric Renewable
NPV	:	Net Present Value
RERL	:	Renewable Energy Research Laboratory
ANN	:	Artificial Neural Network
GA	:	Genetic Algorithm
PSO	:	Particle Swarm Optimization
ACO	:	Ant Colony Optimization
LPSP	:	Loss of Power Supply Probability
LOLP	:	Loss of Power Load Probability

SPL	:	System Performance Level
LOCH	:	Loss of Load Hours
NPC	:	Net Present Cost

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CHAPTER 1: INTRODUCTION

1.1 Background

The demand of electrical energy is increased in the world nowadays and because of that, additional electrical energy need to be generated. More energy is required to meet the demand and during the power generation, the pollution problems happened mainly due to the conventional method of electrical power generation by using fuel and coal technologies. Due to high pollution, people has started to consider how to reduce pollution and therefore, the renewable energy comes as alternative options. Renewable energy from nature which involve solar energy i.e. PV (photo voltaic), follow by wind turbine, dam for hydro power generation, wave of water tide, biomass process, etc. [1]

Apart from the individual RE (renewable energy) source, the power generation by RE can be mixed among the source and come to HRES (Hybrid Renewable Energy System). These combinations of the above RE sources can be designed by mixing two of them, three of them or more. They also can be mixed with those conventional power generation which involve combination of any RE with coal / fuel / gas.

The title of the research project is a method of using PV (Photo voltaic) energy to move a set of gearbox for lifting water from suction tank to reservoir for hydro power generation. The whole set of HRES (Hybrid renewable energy system) can be built at any location and can be relocated easily as `Mobile Micro Hydro Turbine'. This set of HRES is a suitable design for a small workshop or a rural village. This project only involves a simple reservoir as a potential of water for hydro power generation. Water is circulating by lifting water from suction tank through cylinder and pistons to reservoir. The energy to run the gearbox is supplied by PV. This research project is a simple and cheaper in cost, also meet the friendly environmental concept. For a solar farm, the excessive of PV energy can be converted as an energy to move the piston pumps through a gearbox. So, the energy storage can be use after daytime when PV is not in operation.

The research project required a set of prototype for carry out the experiment and take measurements for calculation but due to cost constraint, only a small prototype to be fabricated for this research report. The concept of prototype is to move one pair of pistons with cylinders and fully filled with water. The moving part of pistons to be controlled by a set of gearbox with turning at 30rpm in order to maintain the velocity at 1m/s constantly. The two pairs of pistons to be moving in opposite direction by cross function concept and to lift water at approximate 90.74L/s alternatively in each cycle for feeding water into the reservoir. The reservoir act as a potential for hydro turbine rather than a set of battery where the battery has more maintenance and shorten life span. The energy supply by PV is free from nature and water storage at reservoir for hydro power generation is a conversion of energy from PV to hydro power. The usage of gearbox to lift water through pistons can be controlled by low rpm and small energy is enough for the activity but normal transfer pumps required high rpm for pumping system and more power is consumed.

The fabrication of prototype required a competent mechanic to install the pistons, one way valves, jointing of PVC cylinders, connect a long arm to a moving gearbox, putting a pulling scale for measurement and other related works.

1.2 Problem Statement

The conceptual design of this project is to lift water from suction tank to a 35metre height reservoir but due to limited budget and the space available for prototype, the height of storage tank reduced to 3m only which just can be built inside a workshop. Theoretically, a higher reservoir can generate higher efficiency power compare to a lower head. The data taken would be more accurate if the reservoir is high enough but only two data can be taken for two section of cylinder built for this project. By using a gearbox with very low turning rpm, a weighing scale can be used to measured the load of moving arm but for this experiment, only by hand pulling and measure through a pull scale device which may facing accuracy problems. Therefore, few times of experiment need to be carried out for getting an average results.

1.3. The Objectives

The objectives of this research project are stated below:-

1. To determine the best method for lifting water by piston pumps instead of electrical transfer pump through a set of Mobile Hydro Turbine as shown in figure 1.1.
2. Using gearbox to move piston pumps like a flywheel to move a long arm through energy supply by photo voltaic (PV).
3. The power supply by PV to turn the gearbox is proportional to the turning in rpm. Lower turning required small power and can be designed at any turning speed while electrical transfer pumps required higher rpm to achieve higher static head i.e. about 3000 rpm with a fix power supply by PV.
4. The water lifted from suction tank to reservoir can be kept as a potential for hydro power generation rather than using batteries as a backup renewable energy.
5. Maintenance for piston pumps is simple and cheaper.
6. Battery has shorten life span and water can be recycled easily, evaporation of water is very little and cheap in cost.

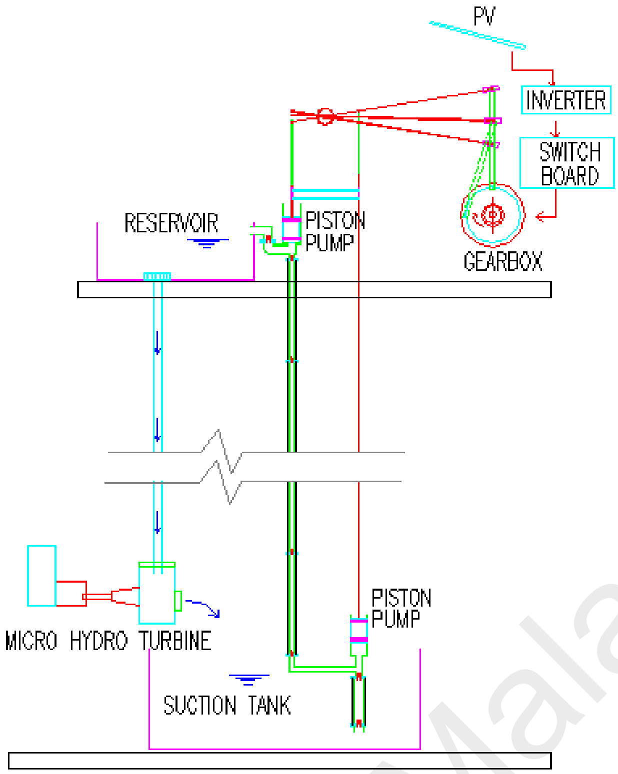


Figure 1.1: Sectional view of a Mobile Micro Hydro Turbine

1.4. Scope

This study will cover on how to lift water by piston pumps with a gearbox to turn at 30rpm to constantly move the long arm by velocity at 1m/s, water flow through cylinders with one way valves and water flowing inside the tube like `hydraulic concept'. Water will start to flow when gearbox activated by solar energy through PV panels and converters. By calculation, water is expected to flow at 14.1 Liter per second (L/s) and feed to the reservoir. Water fall down to micro hydro turbine is to be designed at 14 Liter per second at 35m height. Due to problems encounter, the height is designed at 3m above suction tank. Two results to be taken from 1.7m and 0.9m height for determining the gearbox capacity. The measurement to be carried out at the end of long arm by a pull scale device.

1.5. Research Report Organization

This research report is organized in five chapters. In Chapter 1, the explanation for this project is to provide a general terms, problem statements and elaborated by the scopes of this project.

Chapter 2 describes the fundamental of hybrid renewable energy system (HRES) and the sources of renewable energy (RE). The application of HRES is regarding the connection of power generation connected to grid or stand-alone called off-grid. The power produce required optimal sizing methods, power reliability and system cost analysis. The basic components of mechanical parts involve in this research project i.e. piston pumps, check valves, PVC pipes as cylinders for transfer water to reservoir and gearbox for moving the piston pumps.

In Chapter 3, it describes the methodology on how to develop the systems that can be measured and sizing the power generation by mobile micro hydro turbine with the source supply by photo voltaic (PV) through the inverter and also compare with conventional transfer pump for doing the same activity.

As for Chapter 4, the results that are obtained are discussed as well as both discussions and analysis for this project. The strength and weakness of this project are also discussed in this chapter.

Finally, in Chapter 5, a conclusion is made for this project and recommendations for future works for this project will be the ending for this research report.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this chapter, the application of HRES (hybrid renewable energy system) for the distributed generation, off-grid and on-grid connected including the basic components of RE (Renewable Energy) especially sources from natural i.e. solar energy called photo voltaic, wind power generation and hydro turbine power generation are discussed. The RE also involve the storage energy either use battery, SMES (superconducting magnetic energy storage) or water storage at reservoir for hydro power generation and ancillary resources. Mechanical part in this chapter involves components such as different type of piston pumps, cylinders, valves control and gearbox. The combination of PV and mechanical parts become a new set of HRES for green energy power generation which is micro hydro turbine in this research report.

This research project also cover the application of the energy management which involves system cost analysis, the reliability of the system in providing power supply and LCC (life cycle cost).

2.2 HRES (Hybrid Renewable Energy Systems) Applications

Nowadays, the demand of electrical energy is keep on increased and at the same time, the lack and depletion of raw material e.g. the fossil fuel, is a problem for electrical power generation. The problem of global warming issue and greenhouse effect also encounter by the conventional power generation. Due to these problems, the alternative of power generation by renewable energy is encouraged. The usage of renewable energy can meet the environmental friendly concept. By using the RE (renewable energy) i.e. solar energy by PV (photo voltaic), dam for hydro power generation, WP (wind power), the wave of ocean tidal, other chemical process (biomass) and geothermal, the new application of HRES were developed. The benefits of these developments overcome the problems of carbon emission, reducing the heat generation and reduced the usage of fossil fuel by conventional power generation. [3]

There are some different type of HRES as shown in figure 2.1. [2].

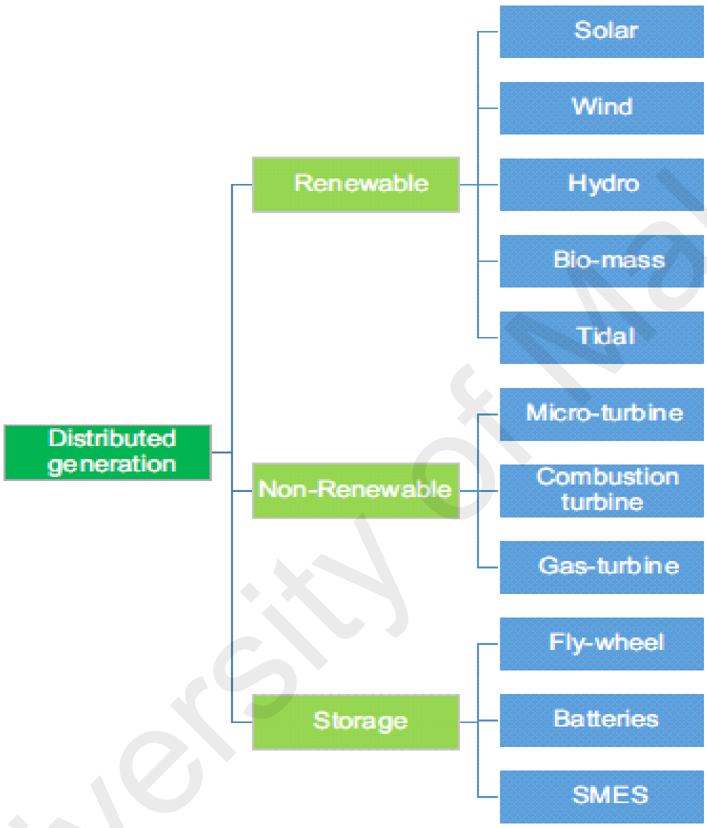


Fig. 2.1: Distributed Generation.[2]

The mixing of HRES, i.e. among the RE by WP (wind power), Hydro Turbine, PV (photo voltaic), Bio Mass, Tidal Wave or among the Non-RE, i.e. Micro turbine, Combustion turbine and Gas-turbine or by storage energy such as Fly-wheel, batteries and SMES or even the blended of anyone of them to form a distributed generation.

The distributed generated by HRES involve the mixing of any one of RE, non-RE or storage or among the group of RE, non-RE and storage. The involvement of these sources required the basic components in the distribution system where AC/DC, DC/AC power electronics converters are adopted. These basic components and loads are required in the performing of power generation and also distribution system. The configuration of the system is shown in fig.2.2. [2]

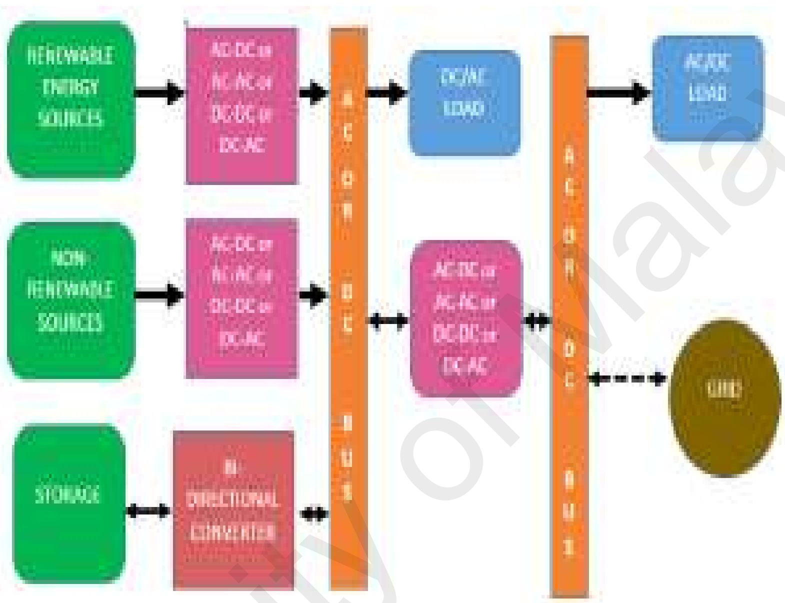


Fig. 2.2: The basic components of Hybrid System [2]

Power electronics involve the Buck boost or Boost / Buck converters which is always apply in the method of DC to DC. The configuration can be set as DC coupled for DC source. For micro grid, the AC matched with high frequency of AC. Furthermore, the HRES can be the combination of any hybrid components. [2]

The problem of intermittent predicament always happened to RE (renewable energy) sources in nature. In order to solve or ameliorate these problems, the combination of RE (renewable energy) sources and non-RE sources (conventional sources) together with storage were implemented in the power generation and distribution systems.

The maintenance is lesser in use of RE (Renewable energy) compare to conventional type of power generation. By using RE, the wastage can be reduced during the process and also control the impact to environment.

The energy management in the design of HRES is mainly to improve the efficiency of the RE and some assessments has been carried out. One of them is utilize the Fluidized bed technology and electrostatic precipitator in Biomass process. In the PV power generation, the Singlet fission technology is applied and for wind turbine, the sound isolation material is applied on it. [2]

The software for calculating the unit sizes and energy storage for combination of HRES in power generation can improve the efficiency, stability and reliability of power supply. [5]

A data proved that the HRES in India, provide by MNRE (Ministry of New and Renewable Energy, in India) shown the usage of RE was increased from 12.5% in year 2013 and the HRES involved mainly by the combination of PV and wind power. The power supply by HRES also involved the control of strategic studies and their relation with grid integration. [9]

In year 2011, a case study in Algeria, showing the HRES by the combination of wind power and PV, supplying 70% of the demand and save the fossil fuel about 69%. [11]

Another development of HRES in Ursira Island, Norway, the combination of PV and hydrogen backup has improved the HRES in power supply system. [5]

The HRES by the combination of PV and wind power is better than a single RE (renewable energy) source and the supply is improved by adding backup batteries. [15. 16, 18, 24] as shown in fig.2.3.

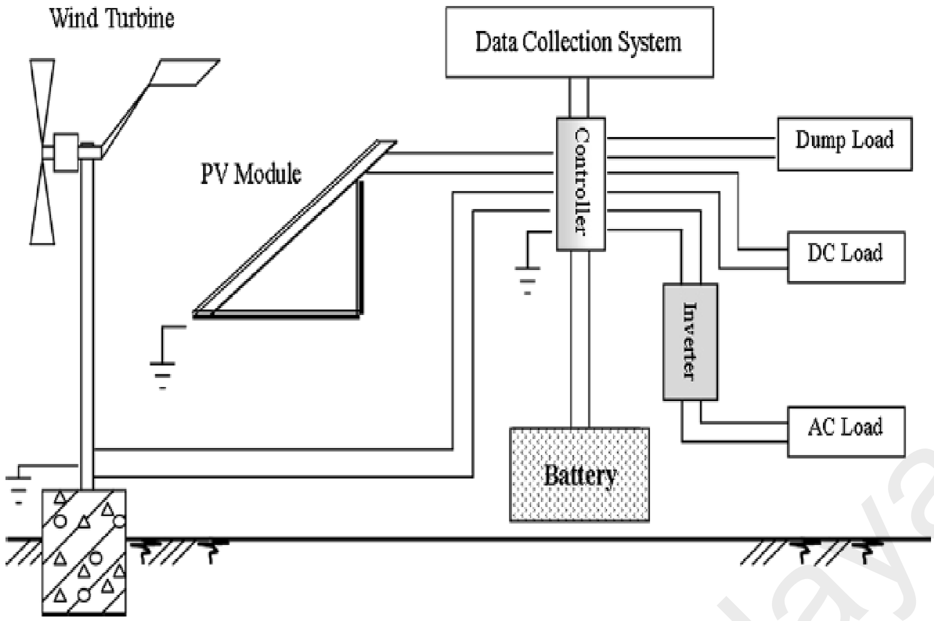


Fig.2.3: Block diagram of PV/wind power/battery [15. 16, 18, 24]

2.3. Off-grid system

The design of HRES (Hybrid Renewable Energy System) is suitable for standalone power supply called Off-grid system. This independent power supply can avoid the high cost and complicated in the installation of grid infrastructure [3]. By the HRES, it is easily to focus and examine the sustainability of electricity generated. HRES also providing a good effects to the isolated communities, for socio-economic and friendly environment. [12]

The optimal power distribution can be achieved by putting the generator close to the demand point together with the backup battery for the design of isolated power. [19]

The HRES with the combination of PV, wind power and deep chargeable battery for a 1.5kW load demand was design for a telecommunication relay station in Dalajia, China. [19]

2.4 On grid connected

A project in Hachinohe city, Japan was built as a micro grid system for the investigation of power supply in terms of the stability and also for integrity for the grid system. [5]

In the connection to the grid system, HRES is acting as a backup source during shortage of power supply. [21] This RE (renewable energy) is operating at maximum performance when it is needed.

In Malaysia, PV as RE (renewable energy) system is the main application of On-Grid connection. It is well organized in the national power grid. [39]. Majority of PV panels are installed at roof top or placed on ground. The PV panels also mounted on side wall or integrated into the building design. This known as BIPV (Building Integrated Photo voltaic). By using the concept of BIPV, these PV panels are replacing awning, wall cladding, window or roof whereby they serve dual purpose. This option can save some costs in construction and gain the return from SEDA [39].

Fig. 2.4 showing a On-Grid connected PV system configuration. [40]

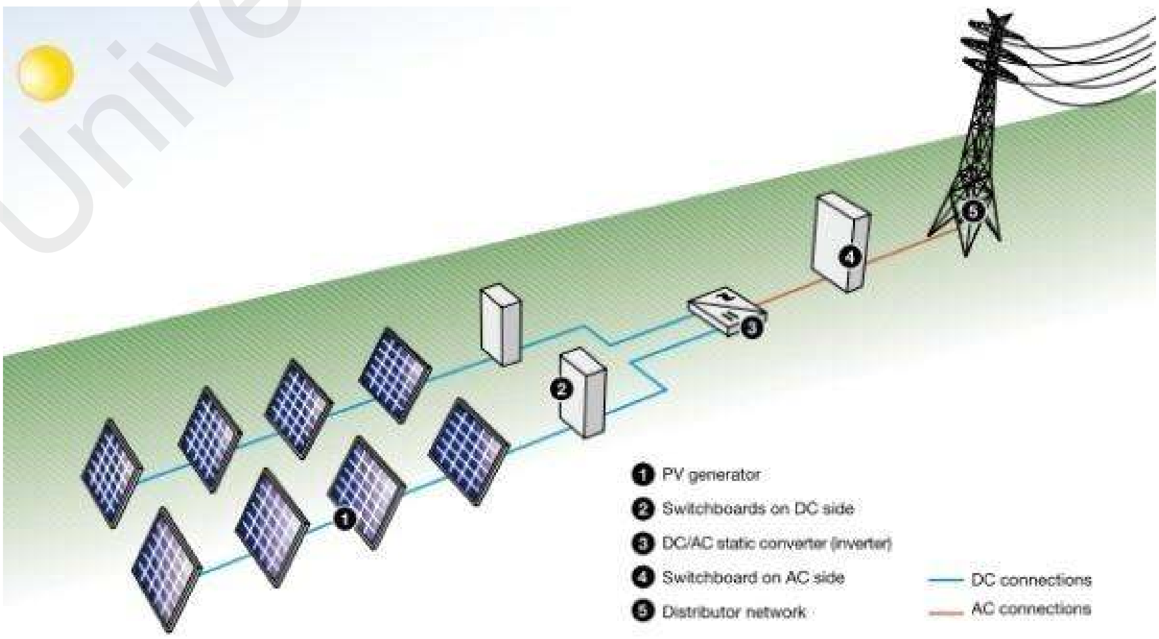


Figure 2.4: On Grid-connected of solar PV system configuration [40]

2.5. RE. (Renewable Energy) Source

Sun light for PV is one of the common RE source available surrounding us. The selection of PV is the most significantly of our option. Their cost is cheap and can be obtained anywhere. Other option of RE (renewable energy) are hydro power generation, wind power, water tide wave, biomass, etc.

2.5.1. Solar Power, PV (Photo voltaic) Energy

There are two types of solar power, I.e. thermal energy to generate heat and PV (Photo voltaic) for electricity generation. This can be divided into passive and active type of solar power. [21]

The material of solar cell which use for mono crystalline and poly crystalline PV panels are mainly from Silicon, Gallium Arsenide, Cadmium Telluride, Copper Indium Gallium di-Selenide and amorphous Silicon. [5]

There are so many crystalline / thin film to form a PV panel and this is an interconnected by a single PV cells. The individual PV panel is easy to take for installation.

Light sensitive semiconductor is use to make PV cells. The use of photons is to dislodge the electrons for driving electric current. Two type of majority PV cells called mono crystalline silicon and poly crystalline silicon which is shown in Fig. 2.5 & fig. 2.6. The new products is thin film panels.

Figure 2.5: Mono Crystalline Silicon PV Cell

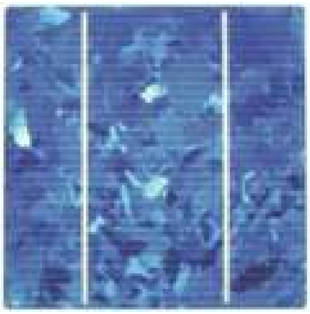


Figure 2.6: Poly Crystalline Silicon PV Cell

The technology of PV cell available today by the name of "family tree" shown in Figure 2.7 provide the products name and the technology is shown in Fig. 2.8.

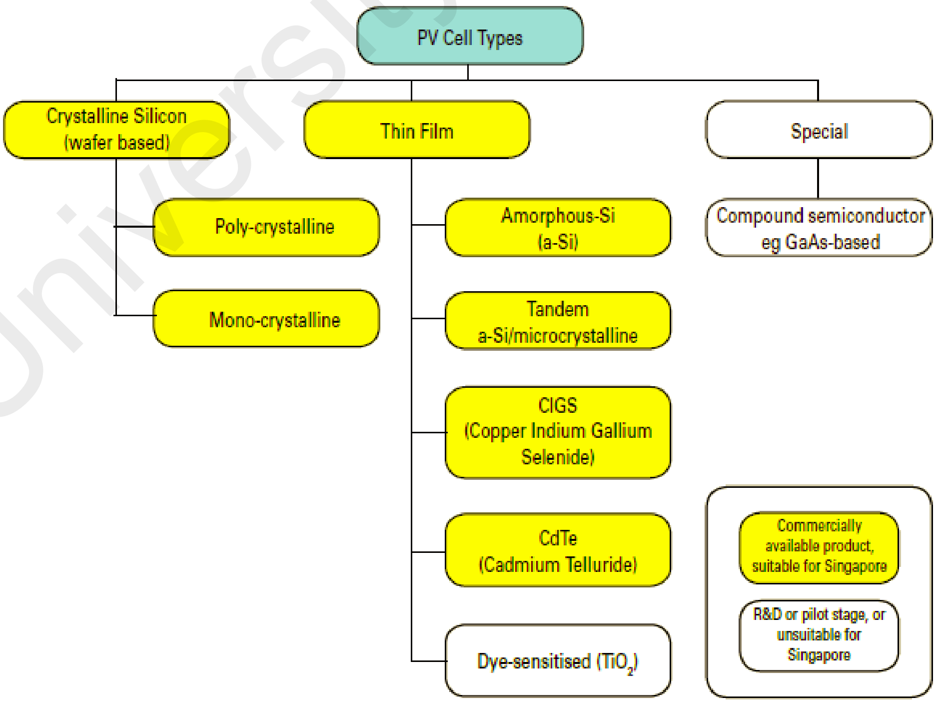
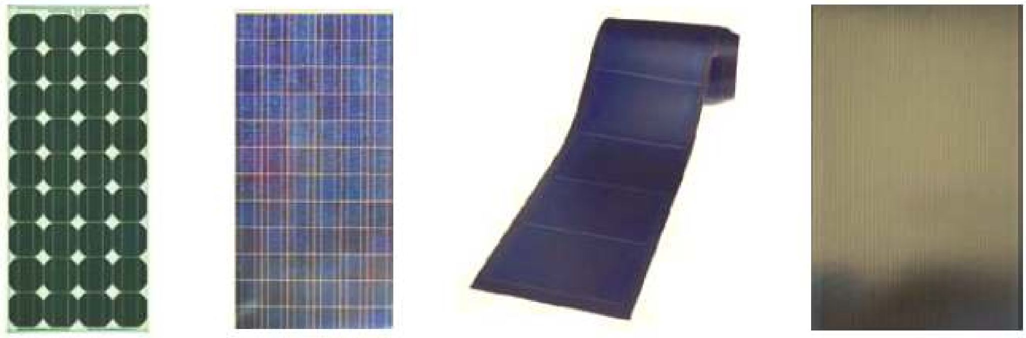


Figure 2.7: PV technology family tree



Mono crystalline Poly crystalline Flexible amorphous CIGS thin film

Figure 2.8: Common PV module technologies

The raw material of crystalline cells for Mono/Poly Crystalline and Thin Film are made from ultra-pure silicon as in semiconductor chips. The silicon wafers with thickness 150-200 um or one fifth of a mini meter is used.

The thickness of 0.3 to 2 micro meter semiconductor material is depositing layer onto the stainless steel or glass substrates and due to the layer is thin, cost is lower. The efficiency of various PV module technologies is summarized and tabulated in table 2.1 to show their difference in performance.

Table 2.1: Conversion efficiencies of various PV module technologies [41]

Technology	Module Efficiency
Mono-crystalline Silicon	12.5-15%
Poly-crystalline Silicon	11-14%
Copper Indium Gallium Selenide (CIGS)	10-13%
Cadmium Telluride (CdTe)	9-12%
Amorphous Silicon (a-Si)	5-7%

For comparison, a thin film amorphous silicon PV array 5 to 7% and a crystalline silicon PV array double of it. The nominal capacity is test under Standard Test Conditions (STC) rating.

For maintenance wise, PV (photo voltaic) system required to do Preventive Maintenance works by every six months.

Table 2.2 showing that those components or equipment need to do the corresponding remedial actions and to carry out the preventive maintenance works.

Table 2.2: Preventive Maintenance For PV Components

S/No.	Components/ Equipments	Descriptions	Remedy/Action
1.	Photovoltaic Modules	1. Dust/debris on surface. 2. Ensure no physical damage on surface. 3. Check for loose wire connection. 4. Check for wiring conditions.	1. Wipe clean. Do not use any solvents other than water! 2. Recommend replacement. 3. Retighten connection. 4. Replace wiring when necessary.
2.	Inverter	1. Check functionality. 2. Check for loose wiring connection. 3. Check for abnormal operating temperature.	1. Recommend replacement. 2. Retighten connection. 3. Recommended replacement.
3.	Lightning / Surge Voltage Protection	1. Check for loose wiring connection. 2. Check for all wiring conditions. 3. Check fuses, blocking diodes, circuit breakers, surge arrestors. 4. Check functionality.	1. Retighten connection. 2. Replace wiring when necessary. 3. Replace when necessary. Ensure to use dc-rated components on the dc side! 4. Replace when necessary.
4.	Cabling / Junction Box	1. Visually check for wear and tear. 2. Check for loose connections.	1. Replace when necessary. 2. Retighten connection.

The data collected in year 2014, showing that PV system provided 1.5GW in USA, follow up by 2.GW in generated in Span and additional of 2GW generated in other countries. [20]

2.5.2 Wind Power

Some area in the world has a certain wind speed for Wind power generation. The output power can be generated smoothly by integrate battery to the large wind farms.

To improve the power generated by wind turbine, using ENN (The Extension Neural Network), the pitch angle of wind turbine can be adjusted and well controlled. [10]

In year 2013, the wind power contributed 22% of the energy demand or 23GW generated in Span. [20]

2.5.3. Hydro Power

The higher efficiency in power generation is using Hydro turbine which required a very high construction cost for building a dam. Normally, to build a small scale dam for Micro Hydro Turbine will reduce the construction but limited to power generation for 5kW to 100kW. Sometime, a very small scale of dam only can generate less than 5kW called `Pico Hydro Turbine'. The larger scale of dam compare to micro is `Mini Hydro Turbine' which can generate power at the range of 100kW to 2MW. Of course, the large dam for hydro turbine can generate more than 2MW. The hydro turbine is suitable to install at water fall, river with higher flow or build a dam at the maintain area. Generally, the power generated at not more than 100kW is refer to small capacity of water flow. [21].

For example, in year 2013, in Udayapur, Nipal, a project by using a micro hydro turbine can produce 17.89kW through the water flow between 432 and 570 L/s in the river and the HRES is hydro power combine with PV and battery. Battery is the backup energy for the power supply system. Again in Nipal, the hydro power generated by small hydro turbine provided 4.54MW in power supply and total power by hydro turbine to the grid was 472.99MW. [25]

In year 2010, the hydro power generated 721TWh or 17% of the energy demand recorded in China, mainly for their local usage. [21]

2.5.4 Storage Energy

Generally, the storage energy keep in the battery bank was supplied by the excessive energy produced by RE (renewable energy). The extra energy can be converted to other method of storage, e.g. SMES (Semiconducting Magnetic Energy Storage). The storage energy system still facing some limitation. For example, the backup energy or the storage energy can be used to main BUS or connect directly to the load during shortage of RE to the system. Furthermore, the storage energy can be used for stabilizing the power supply system.

When PV facing low radiation of solar or sun light, the performance of PV also reduced and therefore, the storage energy is import for backup purpose. The low efficiency of PV can affect the losses in power electronics and affected the power generation. The total power generated will be reduced and cause the payback time longer.

The technology of storage energy through invention and development, can improve the LCC (life cycle cost). By using this system, the load fluctuation can be reduced by backup energy.

Another method of storage energy, using hydrogen which produced by electrolyze as RE (renewable energy) and stored in a high pressure tank was done In National Wind Technology Central. [5]

A method of using hydrogen as energy carrier and medium storage through electrolyze and advance fuel technology was carried out in Newfoundland, Canada. [4]

There are few types or components for energy storage. Most popular are using PHS (Pumped hydro storage), CAES (compressed air energy storage), create flywheels, using hydrogen fuel cell, adding big capacitor, apply SMES (Superconducting magnetic energy storage), batteries, etc. through the excessive energy by RE. These storage energy are critical in continuity supply to the load.

The usage of PB-acid batteries is common and depend on the functionality of charging characteristics. The operating temperature, the output and loads are important features to the components which need to be considered. [23]

The float life and life cycle of battery will affected its lifespan. The maximum time of battery is the float life and charging cycles (charge and discharge) is battery's life cycle. [24]

2.5.5. Ancillary Resources

A type of using biomass as RE is the Fluidized bed system. This process is involve the circulating and bubbling of fluidized bed, and a higher complete carbon conversion produced as shown in fig. 2.9 [5]

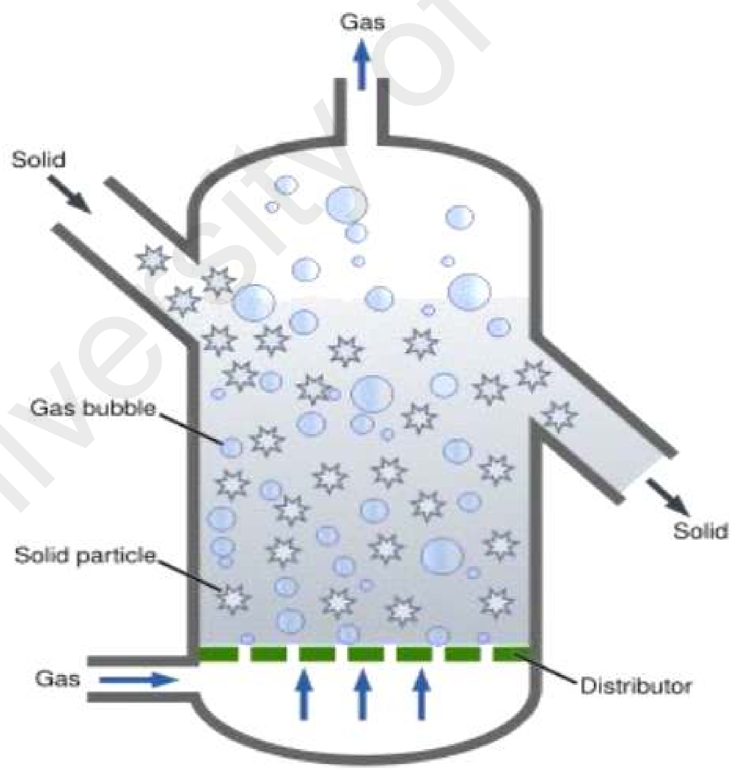


Fig.2.9: Basic Fluidized bed

The discharge wire and collecting plate will generate high voltage by using electrostatic precipitators in the system as shown in fig. 2.10. [5]

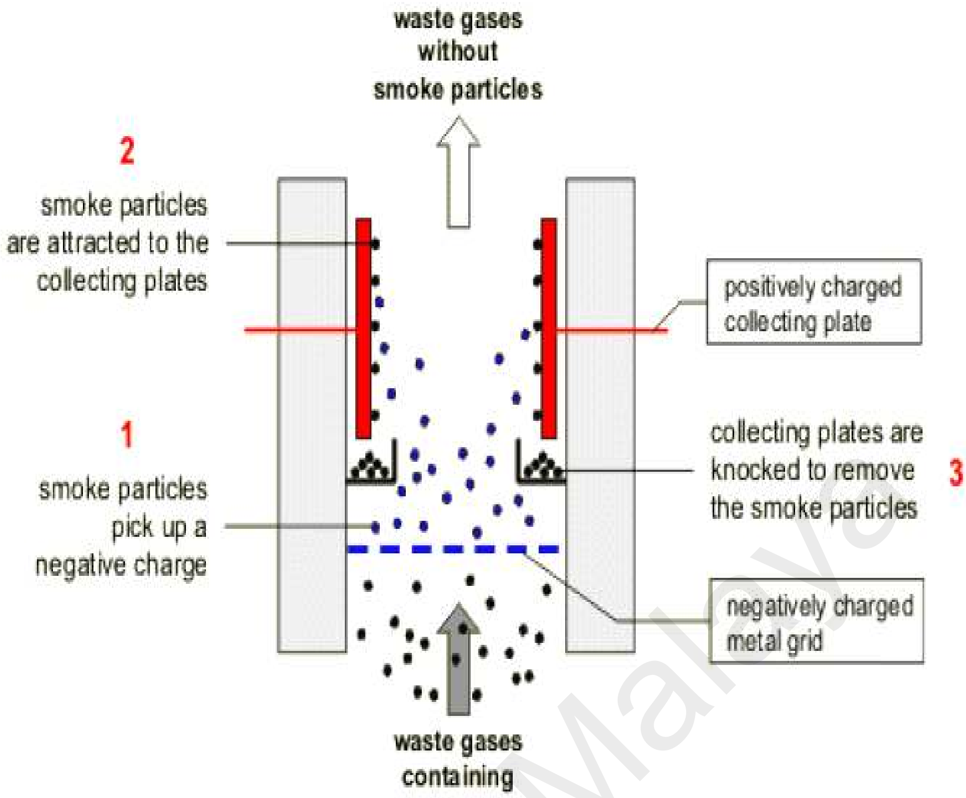


Fig.2.10: System showing the working of Electrostatic Precipitator [5]

The process of combustion induce the energy directly from biomass and through the indirect process of conversion to bio fuel by different methods of chemical, thermal and biochemical which also can produce energy. [21]

2.6 Lifting water

Few methods can be used for lifting water from ground level to storage tank for hydro power generation. Commonly, we use electrical pumps i.e. transfer pumps, booster pumps, submersible pumps, etc. and conventional method is using mechanical hand pumps or piston pumps.

2.6.1 Variable Type of Lifting Water

Mechanical hand pumps is a common pumps applied in the world for many years. It has been practiced for rural poor people to obtain clean water through the cheapest and cost-effective way. The usage of hand pumps is mainly for those area facing access problem to obtain water, facing limitation of finance, investment, operation and maintenance for water source. The requirement of hand pumps is simply to be capable to obtain water from the deep well up to 100m. These characteristics make hand pump so important in the application of obtaining water in rural area. [42] In fact, there are several types of hand pump. For example, the shallow well hand pump as shown in fig. 2.11. The suction is created by the cylinder and piston when handle is moving down for lifting water.

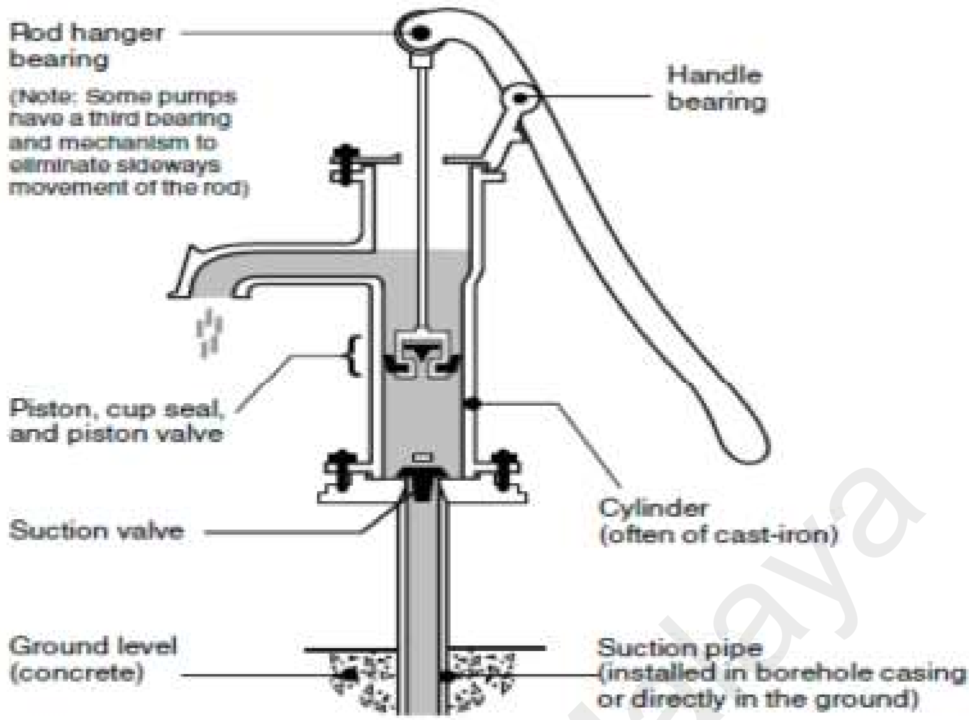


Figure 2.11: Shallow Well Hand Pump

The application of this hand pump is limited to 7m by a maximum suction lift with condition that water must be fully filled in the rising main and make it as `Priming' the pump. The usage of clean water is important for this application. This pump is widely used globally and cheap in cost including easy to maintain. [43] The advantages and disadvantages of shallow well hand pump is shown in table 2.3.

Table 2.3: Advantages and Disadvantages of Shallow Well Hand Pump [43]

Advantages	Disadvantages
Relatively simple maintenance (main pump components positioned above ground) Large piston diameter gives fast water delivery (24-36 litres/min at 7 m depth)	Limited to wells of less than 7 metres in depth Pump priming may cause water contamination. Most designs have maximum usage of around 50 people/day

Another hand pump for lifting water called `Tara hand pump'. The detail of Tara hand pump is shown in figure 2.12.

The operation of Tara hand pump is depending on the operator with their strength to lift the piston. The Tara model is designed by a plastic pipe. When the pipe fully filled with air, it will act as a pump rod. The buoyancy of water will upstroke the operation of lifting water. If a very small diameter of cylinder is applied as rising main, it can pump up a small quantity of water from a deep well. Generally, this product is cheaper in cost compare to high lift hand pumps [44]. The Tara hand pump has the advantages and disadvantages as tabulated in table 2.4.

Table 2.4: Advantages and Disadvantages For Tara Hand Pump [43]

Advantages	Disadvantages
Relatively cheap, and easy to manufacture. Maintenance facilitated by easy access to piston which can be pulled up through the rising main.	Limited to depths of up to 12 m. Most designs have a maximum usage of around 50 people/day.

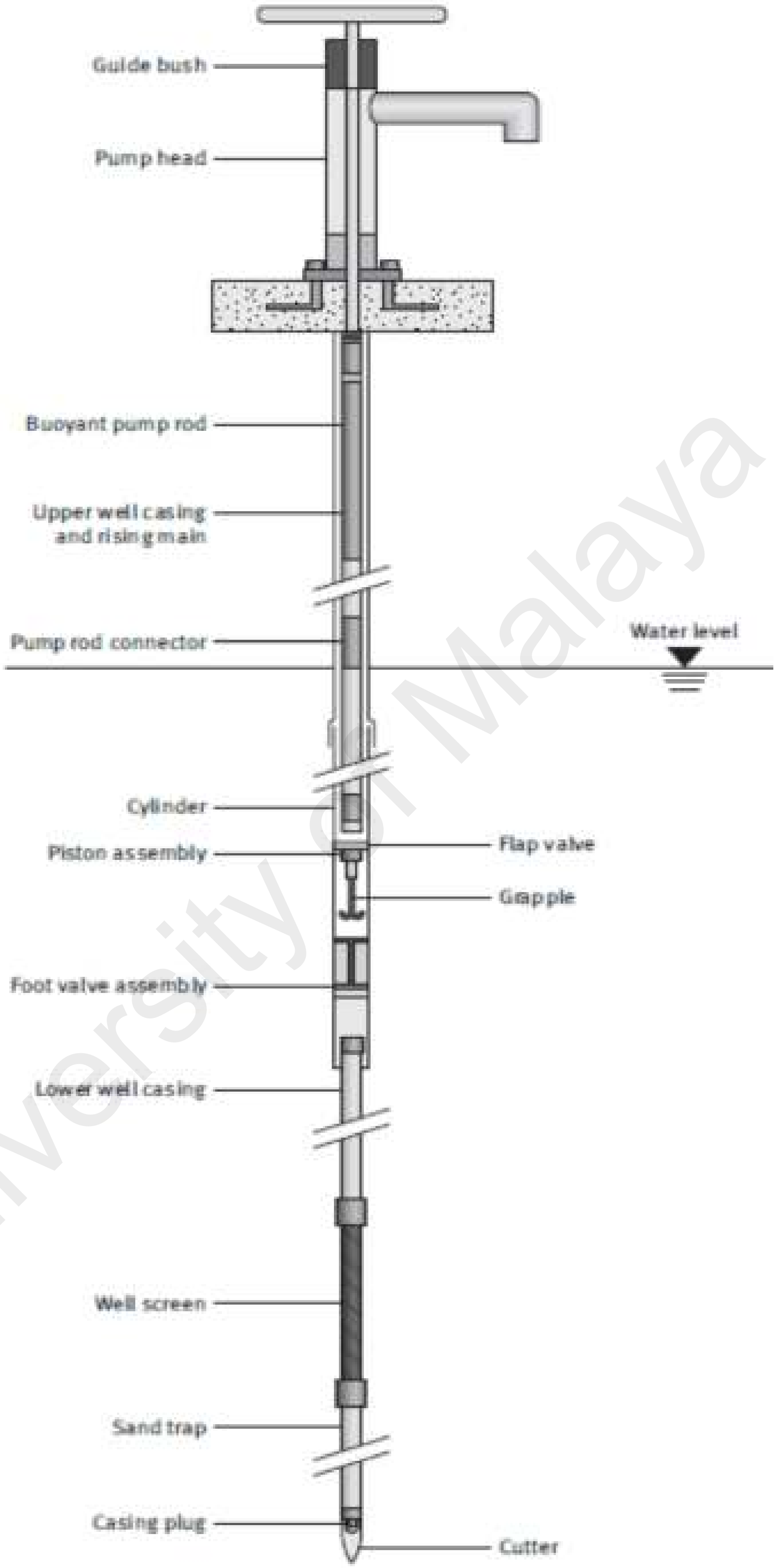


Figure 2.12: Tara Hand Pump

The more popular pumps is `High lift Afridev hand pump' as shown in Figure 2.13. The design of this hand pump is the piston pump having as open top, easy to remove the piston, pump rods and foot valve during maintenance. This hand pump is suitable for deep well less than 45m. [44]

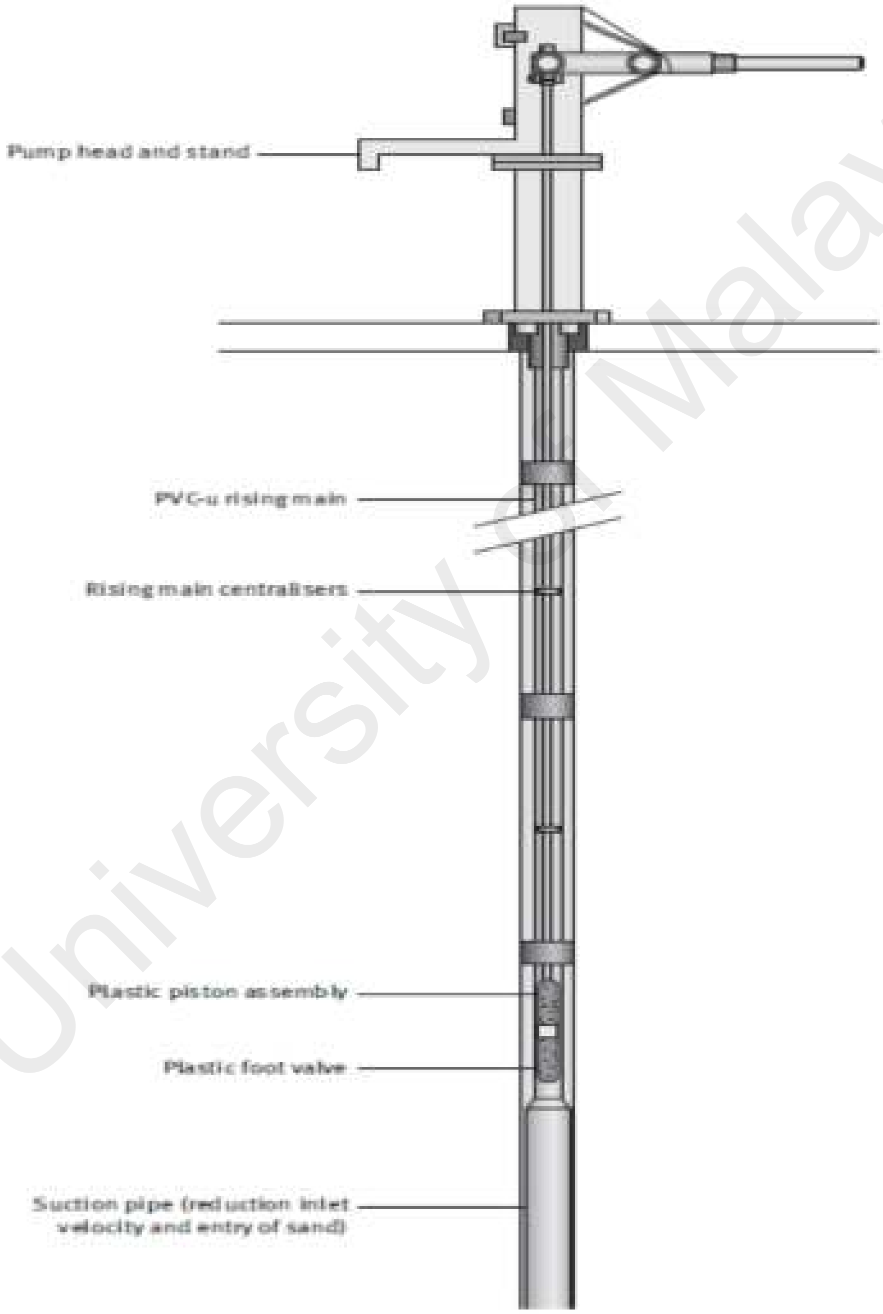


Figure 2.13: High Lift Afridev Hand Pump [44]

The special design of High Lift Afridev Hand Pump make it the second popular in the world and just behind India Mark II [45] which is the most popular. The advantages and disadvantages of high Afridev hand pump is tabulated in Table 2.5.

Table 2.5: Advantages and Disadvantages for High Lift Afridev Hand Pump [44]

Advantages	Disadvantages
Suitable for a wide range of well depths including application in wells over 100 metres deep. Design can be strong enough to cope with intensive use.	Accessing the piston and foot valve during maintenance in traditional piston pumps is relatively difficult and may require specialist lifting equipment. Newer piston pumps where cylinder can be removed separately from large diameter rising main can be relatively expensive.

The design of India Mark II pump is so robust, heavy duty and it can cater for 300 people in the community. This hand pump can be used for lifting water up to 50 meters. Furthermore, this pump also defined by Indian Standards and RWSN specifications as a public domain pump. It is reliable and can last for a year without failure even is not corrosion proof type. [46].

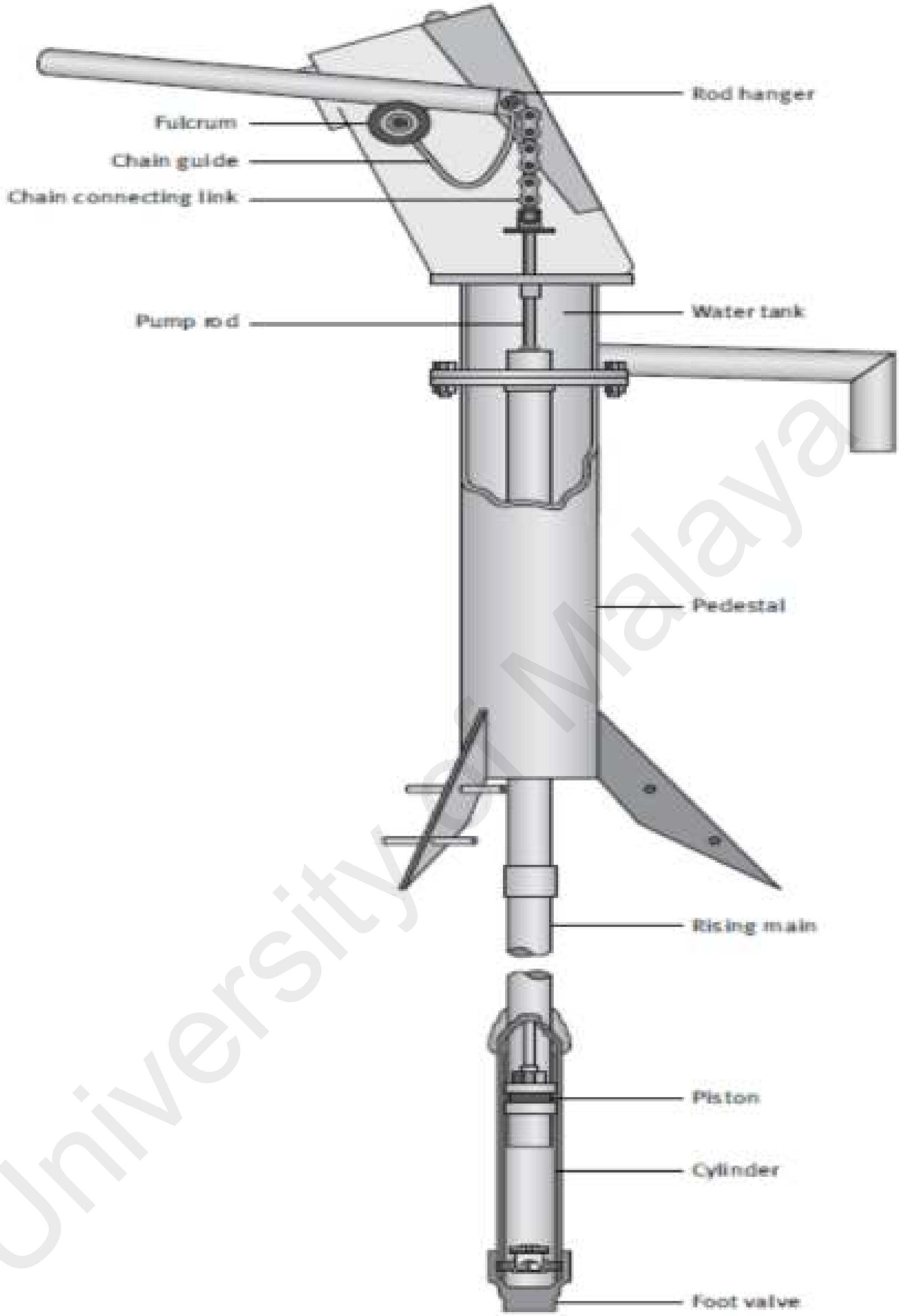


Figure 2.14: India MK II Hand Pump [46]

A diaphragm pump shown in figure 2.15 is another type of hand pump for lifting water.

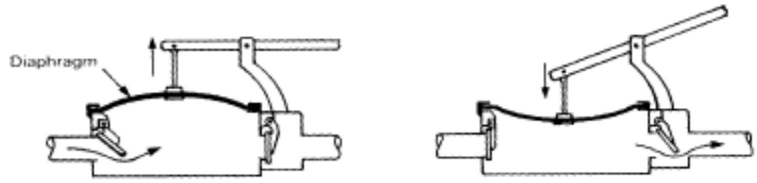


Figure 2.15: Diaphragm Pump

The design of a diaphragm pump is a flexible diaphragm located inside a cylindrical pump body. This pump should put at the bottom of the well and it is operated by the expansion and contraction of the flexible diaphragm to form one wall of a closed chamber. A secondary piston pump is using to expand and contract the diaphragm to move by a foot pedal or hand lever [47].

Table 2.6: Advantages And Disadvantages For Diaphragm Pump [47]

Advantages	Disadvantages
Suitable for deep well applications up to 70 metres in depth. Several pumps can be installed in the same well or borehole. Maintenance facilitated by easy access to main wearing parts in the upper cylinder.	Relatively expensive to manufacture. Replacement diaphragms expensive and required at short intervals. Not suitable for water with sediment or sand particles which damage the pump.

The rope pump shown in figure 2.16, is design as a rotary pump for lifting water up to 35 meters. By the depth as mentioned, the average lifting volume is st 10 liters per minute. The rope pump is always operate at 10m depth with cater water at 40 liters per min. It is suitable for small scale of community and household.

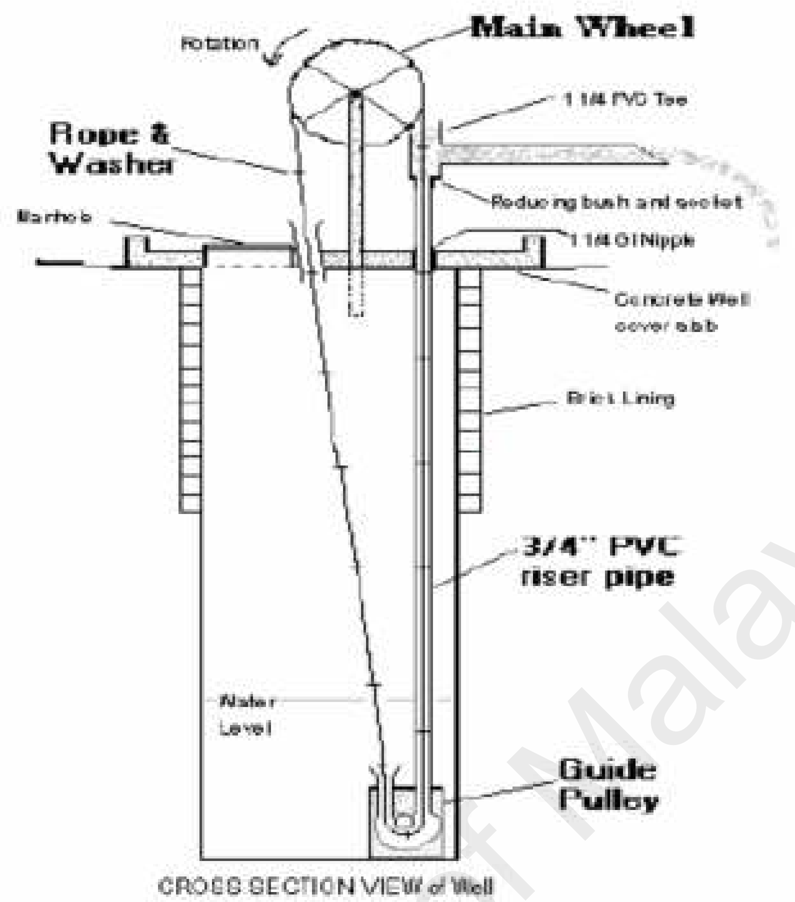


Figure 2.16: Rope Pump [48]

The design of this pump is using hand to turn the wheel in anti-clock wise as indicated in Figure 2.16. It will feed the rope and washers going down into the well, guide by the pulley and to the discharge point by riser pipe. The washers are in the exact fit with the riser pipe and force water up towards to the surface [48]. Table 2.7 shown the advantages and disadvantages of rope pump.

Table 2.6: Advantages and Disadvantages For Rope Pump

Advantages	Disadvantages
Relatively cheap, and easy to manufacture (for wells down to 35 m rope pumps are five times cheaper than piston lift pumps.) Maintenance uses local skills and materials	Operation limited to depths of up to 35 m. Initial water delivery is relatively slow at greater depths. Water contamination possible because well is not totally sealed. Frequent simple maintenance required

The ranges of mechanical hand pumps or lifting pumps are grouped in the categories as listed below:-

- Low lift pumps for 0-15 meters depth
- Suction pumps for 0-7 meters depth
- Direct action pumps for 0-15 meters depth
- Intermediate lift pumps for 0-25 meters depth
- High lift pumps for 0-45 meters depth or more

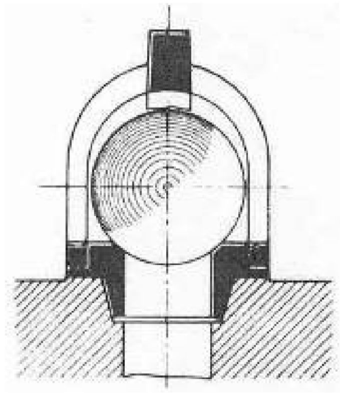
Alternatively, electrical transfer pump is used for pumping water from low level to reservoir where water is to be stored during low demand periods and released for hydro power generation during high demand periods.

Figure 2.17: Transfer Pump

Transfer pump also sometimes known as utility pumps. The transfer pump is performing by one simple direction i.e. it move water from one place to another.

2.6.2 Valves

To prevent the back flow of water, a check valve is required to place in the cylinder for the constant flow of water toward the storage tank. A design of simple ball valve acting as check valve to control the water flow in a one way director shown in figure 2.18.



2.18: Ball Valve as one way valve

2.6.3 Gearbox

Generally, the gearbox design is based on the following formula for turning the lifting arm:-

$$Torque = radius\ (m)\ x\ Force\ (N)$$

$$Formula\ of\ Gearbox\ Power = \frac{Torque\ x\ rpm}{9550}$$

2.19: Gearbox with motor

2.7 Energy Management

The energy management of HRES can be categorized in few complements as stated below: - [1]

1. To calculate the assessment of resources i.e. the available of wind power, total of water flow for hydro power, the array of solar power for PV, the available of biomass and biogas through meteorological data.
2. To survey the assessment of demand for load forecasting, check with local people for load required including the compound / street lighting, quantity of house involved, unit of small industry, commercial buildings and other electrical loads.
3. To check the constraint and the barrier of load demand by calculating the annual electricity consumption, the NPC (net present cost), reliability of energy resources, the factors of employment issue of environment.
4. To consider the combination of RE, non-RE and storage energy or mix among the sources in order to fulfill the demand of HRES as listed below:-

    a). Mixing with PV, Wind Power and Diesel Generator

    b). Mixing with PV, Wind power and Fuel Cell

    c). Mixing with Wind power and Battery

    d). Mixing with Wind power, biomass and Diesel Generator

    e). Mixing with Wind power, PV, biomass and Fuel Cell and so on.

5. After the process of selecting the combination, an optimization solution to be performed with some suitable and relevant techniques, follow by the load

requirement and evaluation of the rest for power reliability and LCC (life-cycle cost) accordingly.

A HRES project was developed in Western Ghats, India, involved the combination of wind power, micro hydro power, PV, diesel generator and batteries. The development of HRES is to study the optimal performance by the system, to minimize the total LCC (life cycle cost) and comply with the power reliability when come to operation. [6]

By using the software and technical methods, the stability and cost effective can be achieved for the various energy management strategies. The flow chart showing the summary of study for the standalone, grid connected and smart grid system as shown in Fig.2.20 [7]

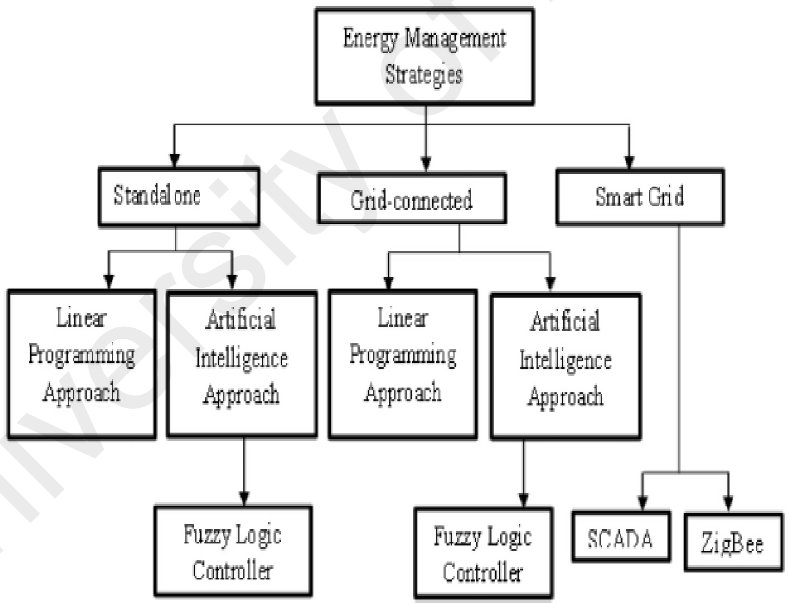


Fig.2.20: Scope of Energy Management Strategies review

Nowadays, the RE (renewable energy) policy become a vital in the central driver of the world and there is a wide range of state wise, meet the local based demand policies and other matter which related to the marketing and commercial aspects. [8]

A project for maximize the utility efficiency, selection of CHP (combined heat and power) plant with high coupled for generating heat and power can be achieved by the energy management subject to the demand conditions. [17]

A energy management project was done in Andalusia, Spain, a pattern study for balancing the pattern from PCA (Principal Components Analysis), CCA (Canonical Correlation analysis) for wind power energy and CSP (concentrating solar power), eventually, these pattern studies can reduce the power fluctuation and this bring more benefits for winter season. [20]

The energy management system which involve the power inverters playing an important parts. They were assuming to have high efficiency as 85 percent for rectifiers and 90 percent for inverters. [21]

2.7.1. Optimal Sizing Methods

The individual HRES involves sizing of battery bank and selecting the components for power generation in order to meet the optimal sizing methods. The optimal sizing method also incorporated the DPSP (Deficiency of Power Supply Probability) and LCC (Life-cycle Cost) in order to achieve the technical and economical application by system reliability.

A case study for a residential area regarding the energy management was carried out in Bouzareah, Algeria. At any different locations and regions, the wind speed, temperature and solar radiation are not stable by the climate conditions. This reasons will causing instability and shortcoming of resources for power generation. In order to achieve the economical utilization, the efficiency of power generation need to be increased. The combination of RE resources by PV, wind power and matching with battery banks is a method to optimize the design of the system.

By using the dynamic programming, multiple objective graphic construction technique, linear programming probabilistic approach and iterative technique, the optimization method to fully utilize the PV/Wind/Battery components can be achieved and the cost can be lower down accordingly.

When HRES is unable to meet the load demand, the DPSP and LCC concept has to be adopted and DPSP technique is one of the criteria for that. There are three parameters in simulation can be adopted for sizing up the PV capacity, calculating the power of wind flow and the requirement of battery capacity in order to lower down the LCC.

Firstly, using MPPT (Maximum Power Point Tracking), by this method, the charger technology for batteries shown in fig 2.21, can extract a maximum power from PV and Wind power sources.

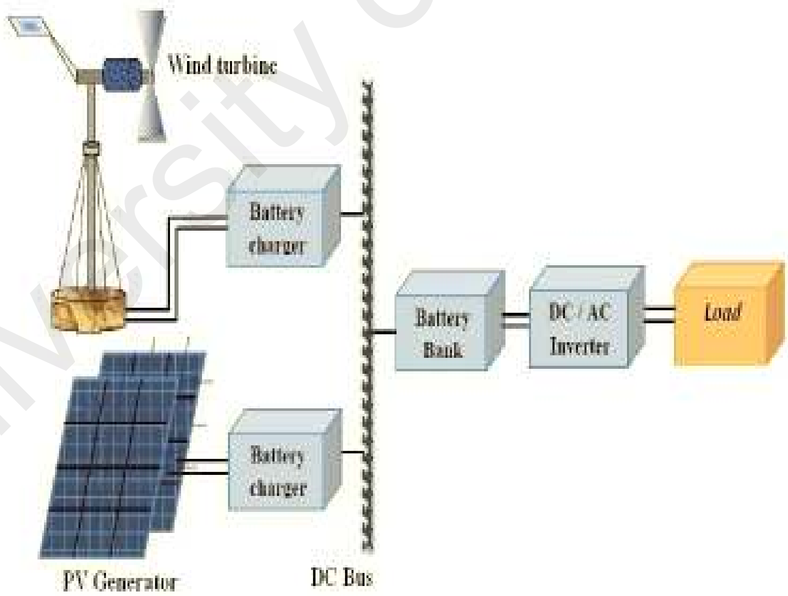


Fig.2.21: Block diagram of hybrid PV/Wind system

Secondly, the tilted plane modules of solar panel can be adjusted and can monitor the temperature, maximum of solar radiation which can be absorbed and increase the PV generator [1, 6]. Another method is to adjust the height of wind turbine which can also produce higher wind power generation. For the storage energy requirement, the capacity of battery bank can be calculated and selected. The total storage energy can be determined for duration of how many days when shortage of RE sources. The deep charge technology for battery charging and discharging, correction of temperature factor, rating of the battery and its lifespan are the main factors to be considered. For the DOD (depth of discharge), the criteria adopted is 50 percent of the total capacity so the lifetime of the batteries can be longer.

The optimal sizing criteria adopted for a HRES is depending on the DPSP technique for the reliability issue, LCC for economic issue, initial capital cost for components and installation cost and finally the present value through the lifetime including the cost for replacement, operation and maintenance.

NREL has performed a case study that RE (Renewable energy) will lead to 80% of electricity generation in the world by year 2050.

There are many ways to carry out the optimization of performance for the system by using software tools. The software can do the simulation and evaluation for the performance. Others methods including probability approach, iterative techniques, graphical construction method, artificial intelligence method, etc.

Apart from the methods mentioned before, there are some other optimal sizing methods can be adopted for HRES:-

1. Using HOMER - this is the Hybrid Optimization Model for Electric Renewable which was provided by the NREL (National Renewable Energy Laboratory). This method isusing hourly simulation and environmental data for NPV (Net Present Value).

2. Using HOGA - this is a simulation software for hybrid system. The Electrical Engineering Department, University of Zaragoza, Spain developed this simulation for one hour interval calculations.

3. Using HYBRID2- this is also a simulation software for hybrid system and more advance by calculating 10 minutes to one hour interval. This software was developed by RERL (Renewable Energy Research Laboratory), University of Massachusetts.

4. Using HYBRIDS - this is a software by Solaris Homes.

5. Using PROBABILITY APPROACH - this was designed to count the effect of solar radiation and wind speed variation. [1, 34, 35]

6. Using GRAPHICAL CONSTRUCTION METHODS - this was designed by Borowy and Salameh. They took the data hourly for 30 years. [1, 32]

7. Other methods, i.e.Markvart [1, 33] who carried out the data for solar and wind power energy value by monthly-average. Iterative technique is another method.

The HSWSO (Hybrid Solar-Wind system optimization), is a model used to utilize the iterative and optimization technique [1, 36], follow by LPSP for system cost and Levelized cost for power reliability. Kellogg et.al [1, 37] using iterative procedure to choose the size of PV panel and wind turbine. Kalogirou [1, 38] adopted ANN (artificial Neural Network) and GA (Genetic Algorithm) which is a best method to find global solution of complex problems.

8. Other application of tools, i.e. using PSO (Particle Swarm Optimization), ACO (Ant Colony Optimization), Fuzzy Logic, etc. for HRES. These tools involved

the record of average output per month, constant load, the excessive energy generated and the storage capacity of batteries required and adopted [3].

9. PV 4 parameter is adopted for mono crystalline and poly crystalline solar cell and PV 5 parameter model is suitable for amorphous solar cell. These parameters is to determine the I-V characteristic [3].

To select the seal lead acid battery, a good method is using the constant current charging curve as a model for reference. [3] The NREL (Renewable Energy Laboratory) using Homer software as a sizing and optimization tools to study the models of energy components and to evaluate the based cost of technology and resources available. [4]

The application of sizing curve is based on the demand pattern and the power conversion with their efficiency so that the minimum capacity of battery can meet the load pattern. [19] The genetic algorithms by computational simplicity is able to attain the optimization of sizes compare to conventional gradient techniques and dynamic programming. [22]

2.7.2. Power Reliability

The design of power reliability is important for HRES (hybrid renewable energy system). It must satisfy in all aspects especially must meet the load requirements and cost effective [1]. There are various methods for calculating the losses and to meet the optimization and the reliability of the system.

1. Using LPSP (The loss of power supply probability) - This is to monitor the shortage of power supply to load required. [1, 26, 27]

2. Using LOLP (loss of load probability) - This is to measure the over demand supply in a specific time period. [1, 28]

3. Using SPL (system performance level) - This is to define the unsatisfied load demand.[1, 29]

4. Using LOCH (The loss of load hours). [1, 29]

To achieve the stability and reliability of HRES, inverters must be used to convert the generated electricity into AC or DC depends on the power flow direction. A generator set act as automatic backup [12] with a rechargeable battery through bidirectional inverter [11] is required. The battery will be used when power failure or shortage of power supply. Fig. 2.22 shown the power reliability for this hybrid system. [11]

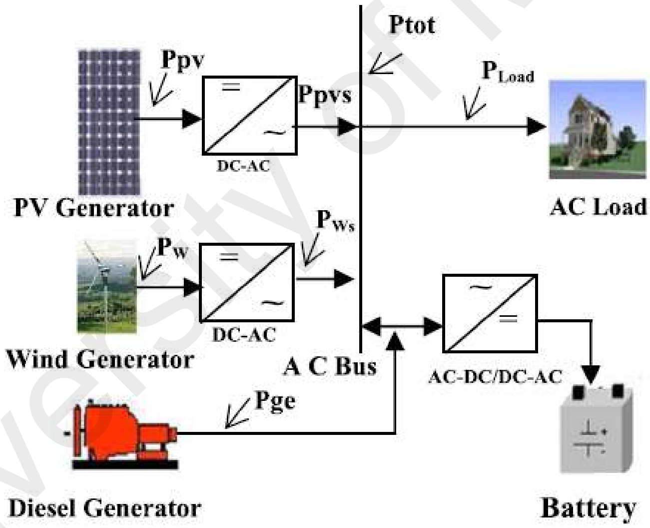


Fig.2.22: Schematic Block for hybrid system

By doing the simulation for power reliability, there are three parameters involved, i.e. the capacity of PV, capacitor bank and rated wind power. Apart from that, the PV module's orientation and the wind turbine's height has to be considered for generate an optimal power with lowest levelised cost. [23]

A set of reliable power system must meet the criteria of `sufficient power to feed the load demand' with a small loss in the power supply probability. [24]

2.7.3. System Cost Analysis

The economic criteria for `system cost analysis' for HRES involving the NPC (Net present cost) and installation cost for the system. The levelized cost for energy [1, 30] is the ratio of total yearly cost of the system to the yearly electricity supplied by the system, and LCC (life-cycle cost) [1, 31] of the components installed [4] also consider as part of the analysis.

To design the optimization of unit sizing, the determination of sizes for HRES is important and that can be performed by minimize the system cost but maintain the reliability. In case of over designed, it will increase the system cost and under designed will cause failure.

HRES by the combination of wind turbine, PV module, diesel generator, fuel cell, electrolizer, batteries and converter modules is a new trend and this will become an economic solution for power generation and distribution. By this HRES, the system can meet the load demand especially the fuel technology will be become cheaper in future and we can emphasis on the hybrid wind power-fuel cell technology system. [4]

In order to achieve the optimal operation, the initial cost and operation cost must be interlinked. Both costs were depending on the sizing of related components and therefore can meet the best performance as per fig. 2.23 [25]

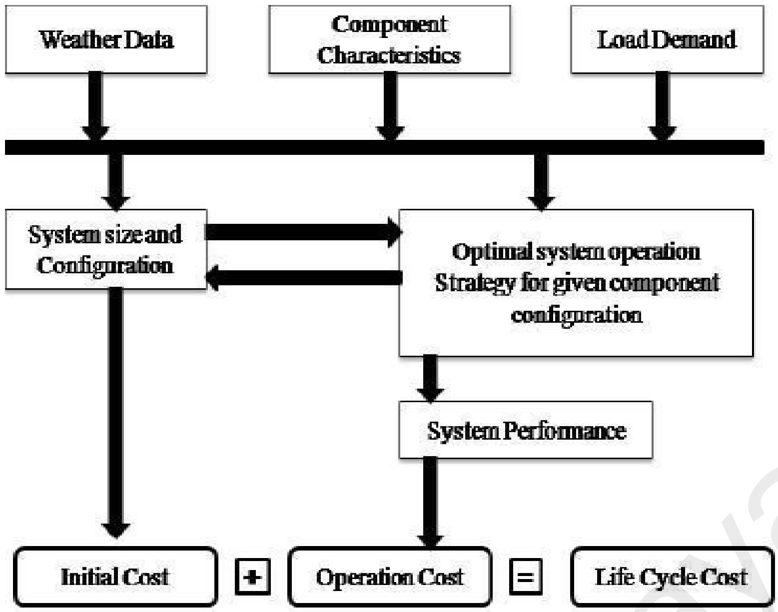


Fig.2.23: Interdependence between the system sizing and operation

The system cost analysis involved the annualized capital cost for the components of wind turbine and towers, PV panels, devices, cables, accessories, installation, etc. The maintenance cost and annual replacement cost has taken into account [24] accordingly.

2.8 Advantages of Hybrid System

A project developed in Newfoundland, found that the hybrid system of a small wind turbine with fuel cell has formed a potential resources versus solar power (PV), and this is the most effective in cost and low emission. [4]

The HRES can be connected directly to load when shortage of conventional source and this system can prevent global carbonization problems. [8]

Another advantage is through the strategic operation of hybrid system, the method is focused on reducing the fossil fuel consumption. The optimal usage of RE (renewable energy) also can reduce the capacity of battery and cut down the running of generator set. Therefore, cost in operation and maintenance reduce accordingly and therefore, meet the greenhouse emission concepts. [11]

2.9 Disadvantages of Hybrid System

The Disadvantages of hybrid system is the RE always facing weather problems, i.e. the intermittent of wind blow, solar radiation, etc.. The HRES also in difficulty of generate large electricity. [3] The hybrid system of PV module and Wind power with hydrogen storage will not meet the cost competitive versus conventional type of power generation. [4]

2.10 Problems and Solution

The non-constant power supply by PV/wind power can be resolved by using some backup batteries. [3]

The numerical method required a long period to obtain data for solar radiation and suggested the alternative method which is analytical method for PV array area and design the storage capacity. [3]

The intermittent and variability are main features by nature RE (resources energy) and that can be overcome by backup source and storage energy. [7]

The combination of PV (photo voltaic) and micro hydro turbine through concept of lifting water from suction tank to storage tank for forming a hydro power generation is ideal to solve problems and is a good solution compare to others HRES.

2.11 Discussion

The RE (renewable energy) is on demand and the research is keep on moving towards the excellent finding in terms of technology and better solution. Thus, to achieve the high efficiency of renewable energy generated, design low loss converters and to meet the power stability, reliability and cost effective through investment and research is needed.

HRES (Hybrid renewable energy system) no doubt is better than individual one. The combination of few renewable energy sources can improved the power generation. Adding storage energy, i.e. batteries and pumped/lifting water storage in reservoir for hydro power generation is helping to improve the power supply system.

Most common used of hybrid system is PV/Wind Power and batteries. The sun light array and wind blow is natural source even the supply were not constant. The intermittent of the sources can be improved by adding batteries and other backup energy (diesel generator set, hydrogen, flywheel, etc.).

The energy management is important in the system through optimal sizing and cost analysis. There were some other methods used in this exercise, i.e. using HOMER, HOGA, HYBRID2, HYBRIDS, PROBABILITY APPROACH, GRAPHICAL CONSTRUCTION METHODS, HSWSO, LPSP and Levelized cost.

The application of tools involved PSO (Particle Swarm Optimization), ACO (Ant Colony Optimization), Fuzzy Logic, etc. for solving the technical problems and increase the optimization of sizing the components for HRES.

2.12 Summary

The HRES can generate electrical energy and overcome the shortage of fossil fuel generation. With the high efficiency of converters, the performance of the system can be improved.

The energy management by software and technical methods also improved the power generation and distribution system. The optimization design will meet the actual load demand without wastage the excessive energy by applying storage energy technology.

With scientific calculations, the system will reduce the quantity of batteries required and reduce the maintenance cost accordingly.

Other HRES e.g. Mobile Micro Hydro Turbine with Photo voltaic is adopted for this research project and can be considered for future development.

CHAPTER 3: METHODOLOGY

3.1 Introduction

Following the Literature review and that has been discussed in chapter 2, there are so many type of renewable energy (RE) sources and the combination of two or three RE sources can form a set of hybrid renewable energy system (HRES) which is ideal and by the HRES, more friendly environmental of green energy can be produced and achieve a better performance of power supply.

The selection of HRES by mobile micro hydro turbine and PV can achieve a new kind of hydro power generation through the lifting water from suction tank to reservoir. From the reservoir, propose water feeding rate should be slightly higher than water falling down to micro hydro turbine for power generation. The design of lifting water from suction tank to reservoir is through two set of piston pumps. The piston pumps is moving by a long arm with velocity at 1m/s. The control of moving arm by the gearbox is based on the 30 rpm turning and the radius is 0.5m to meet the calculation for proportional 1:5. The piston moving at 0.2m and the water flow inside PVC pipe (cylinder) to be determined at maximum 3m/s in order to comply with the plumbing and flow velocity guideline.

For experimental purpose, a prototype is fabricated in a workshop. The maximum height is limited at not more than 7m. Therefore, the experiment just can be done within 6m height only with maximum three sections of PVC pipes (each section is approximate 1.7m length) and the result is to be discussed later.

3.2 Flowchart and prototype

The Electricity supply from photo voltaic (PV) panels to switch board through inverters and convert direct current (DC) to alternative current (AC) for moving the gearbox. The gearbox will move the piston pumps for lifting water from suction tank to reservoir. The reservoir is a potential water supply to micro hydro turbine for hydro power generation. Few alternator will be synchronized and connect power supply to a main switch board. The output power can be supported directly from main switch board by either solar power or hydro power.

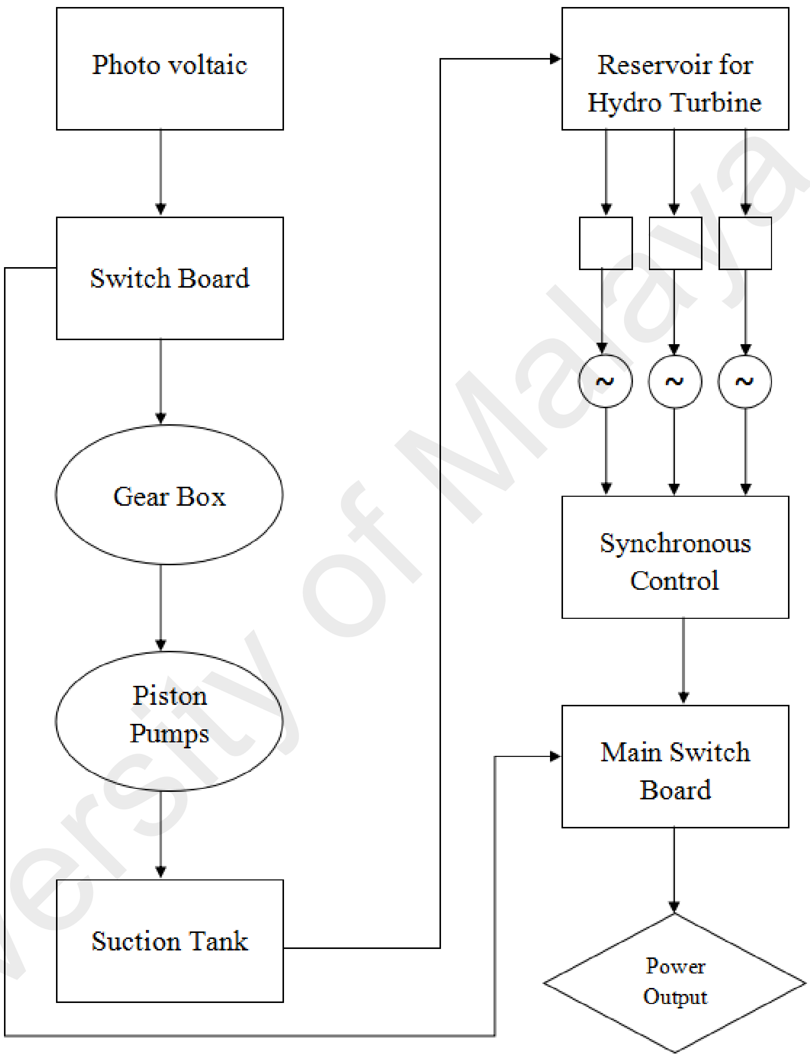


Figure 3.1: Flow Chart of HRES - Micro Hydro Turbine and PV

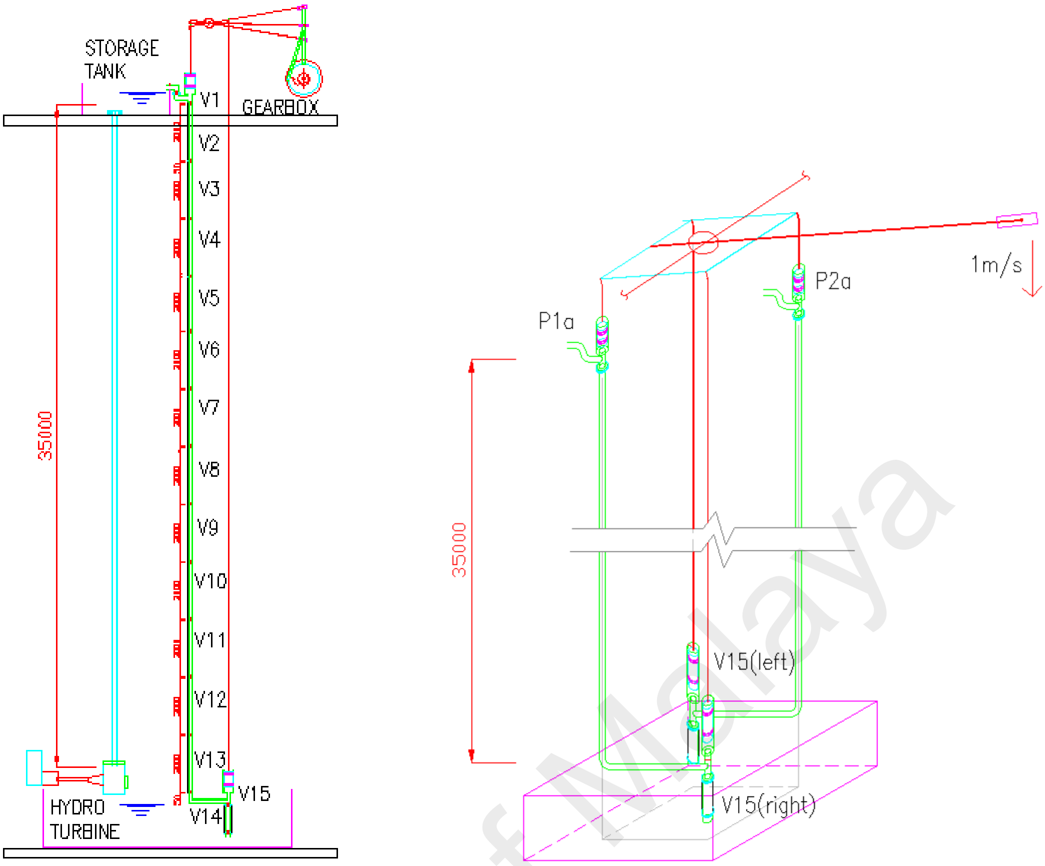


Figure 3.2: The Design of Micro Hydro Turbine and PV

A complete set of micro hydro turbine to be built as per figure 3.2. The volume of water, V1 to V15 is equal capacity inside the cylinders (PVC pipes) and pistons. The total volume of water is 15V and the weight of water is tabulated in Table 3.1.

Components for experiment:

1. A gearbox which is turning a drum acting as flywheel with 0.5m radius at 30rpm, and to pull and push a long arm.
2. The long arm is connected to two pairs of piston pumps for lifting water.
3. Piston pumps with diameter 760mm and to be moved at 200mm for lifting a volume of water about 90.74 liters.
4. 13 nos vertical cylinder with 194mm inner diameter for transferring water from suction tank to reservoir and control by a ball valve at each section. Each section will transfer water at 90.74 Liters @ 3m/s in velocity.

Figure 3.3: Fabrication of Piston Pump

Figure 3.4: One way ball valve inside cylinder

Table 3.1: Volume of water inside cylinders and Pistons.

Volume of Water inside Pistons and cylinders				
Cylinder	Diameter	Area	Volume	Height
No.	m	sq.m	cu.m	m
P1a	0.76	0.4537	**0.09074**	0.200
C1a	0.76	0.4537	0.01134	0.025
C1b	0.194	0.0296	0.01478	0.500
C1c	0.194	0.0296	0.02956	1.000
C1d	0.194	0.0296	0.03505	1.186
V1			**0.09074**	
V2	0.194	0.0296	**0.09074**	3.069
V3	0.194	0.0296	**0.09074**	3.069
V4	0.194	0.0296	**0.09074**	3.069
V5	0.194	0.0296	**0.09074**	3.069
V6	0.194	0.0296	**0.09074**	3.069
V7	0.194	0.0296	**0.09074**	3.069
V8	0.194	0.0296	**0.09074**	3.069
V9	0.194	0.0296	**0.09074**	3.069
V10	0.194	0.0296	**0.09074**	3.069
V11	0.194	0.0296	**0.09074**	3.069
V12	0.194	0.0296	**0.09074**	3.069
V13	0.194	0.0296	**0.09074**	3.069
C1e	0.194	0.0296	0.01478	0.500
C1f	0.194	0.0296	0.03548	1.200
C1g	0.194	0.0296	0.01774	0.600
C1h	0.194	0.0296	0.02275	0.769
V14			**0.09074**	
V15 (right)	0.76	0.4537	**0.09074**	0.200
Total V			**1.36111**	
P2a (V top)	0.76	0.4537	**0.09074**	0.200
V15 (left)	0.76	0.4537	**0.09074**	0.200
Total weight			1.54260	

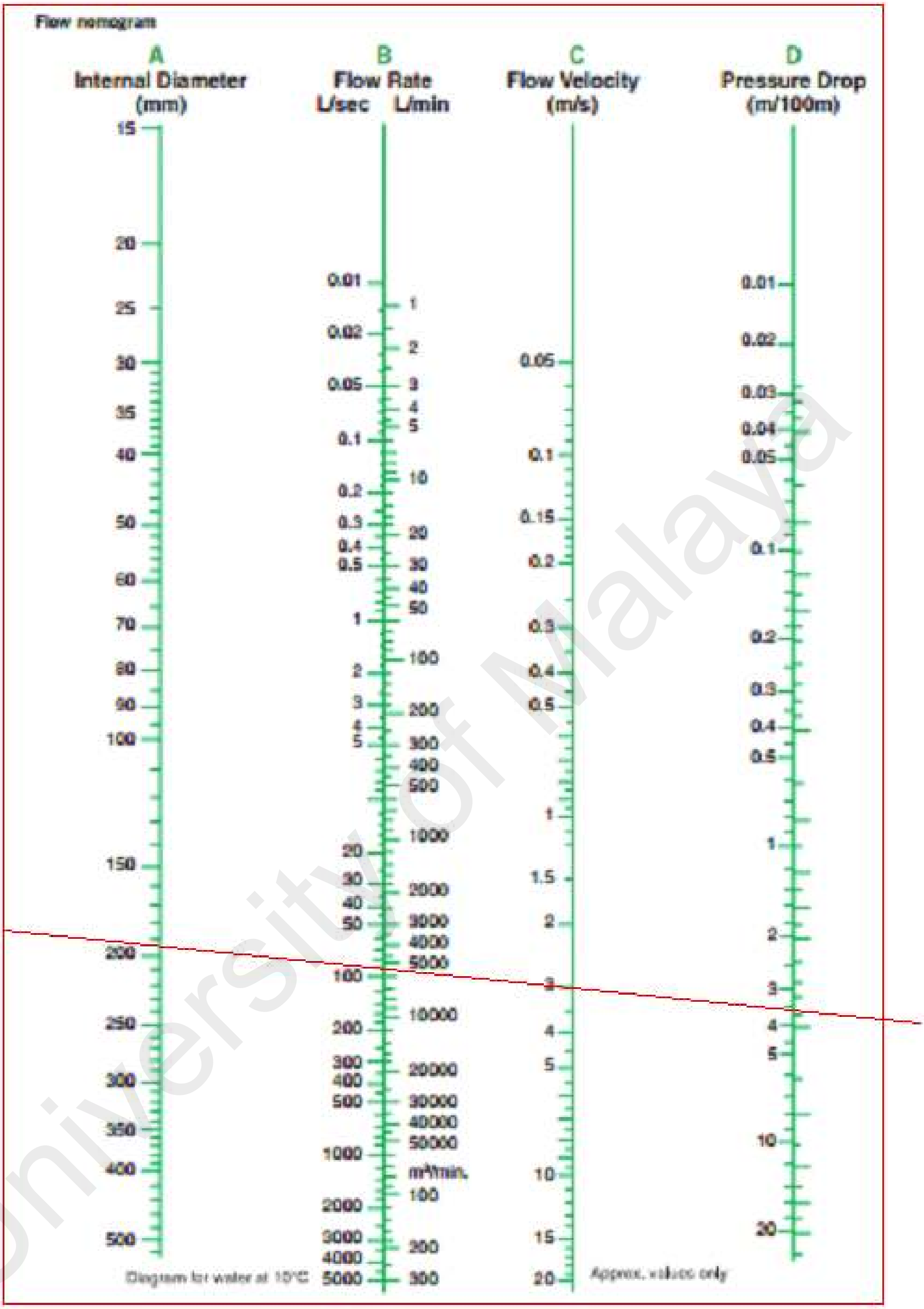


Figure 3.5: Nomogram chart for pipe selection

Calculation of Power for Piston Pumps and electrical pump:

1. $Load = 1.5426m^3 = 1542.6\ kg$
2. $Load\ at\ the\ end\ of\ arm = \frac{1542.6}{4} = 385.65\ kg\ (ratio = 1:4)$
3. $Force = 385.65\ kg\ x\ 10N = 3856.5N$
4. $Turning\ Diameter\ of\ Gearbox = 1.0m, Radius = 0.5m$
5. $Turning\ of\ Gearbox = 30rpm$
6. $Formula\ of\ Torque = radius\ x\ Force = 0.5\ x\ 3856.5 = 1928.25\ NM$
7. $Formula\ of\ Gearbox\ Power = \frac{Torque\ x\ rpm}{9550}$
8. $Estimated\ extra\ load\ inside\ cylinders = \ 1006kg$

(Water flow in the cylinder at 3m/s, total weight of water = (1542kg x 9.81) / 3

= 1260kg – 385.65kg = 875kg + 15% losses = 1006kg)

9. $Estimated\ Gearbox\ power = \ 21.85\ kW$

$Using\ water\ pump,$

$a). Flow\ rate, Q = \frac{90.74L}{S}$

$b). Head, H^m = 35m$

$c). Estimated\ losses = 20\% = 7m$

$d). Effieciency, \eta = 75\%$

$e). Calculation$

$P_{BKW} = (Q(m^3/s)\ x\ (H^m)\ x\ gravity)/\eta$

$$= \frac{90.74\ x\ 42\ x\ 9.81}{1000\ x\ 0.75} = 49.85kW$$

$Pump\ power, P = P_{BkW} x\ 1.25 = 62.3\ kW$

Piston Pumps vs Electrical Transfer Pump = 28.85kW : 62.3kW (ratio = 1:2.2)

Calculation of Power Generated by Micro hydro Turbine:

Flow rate : 0.09074 (m^3/s)

Efficiency , $\eta = 90\%$

Height of reservoir to hydro turbine, H = 35m

$$P_{Gen,kW} = (Q(m^3/s)\ x\ (H^m)\ x\ gravity\ x\ \eta$$

$$= \frac{90.74\ x\ 35\ x\ 9.81x0.9}{1000} = 28kW$$

Piston Pumps vs Hydro Turbine = 28.85kW:28kW

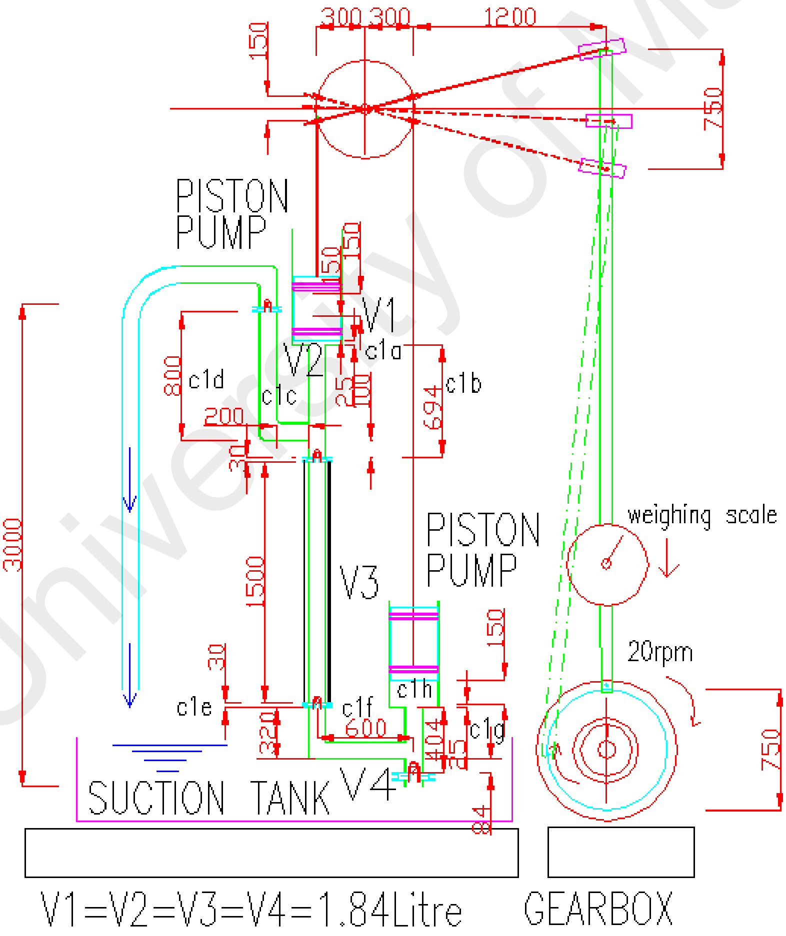


Figure 3.6: Prototype for Micro Hydro Turbine (for 3m height)

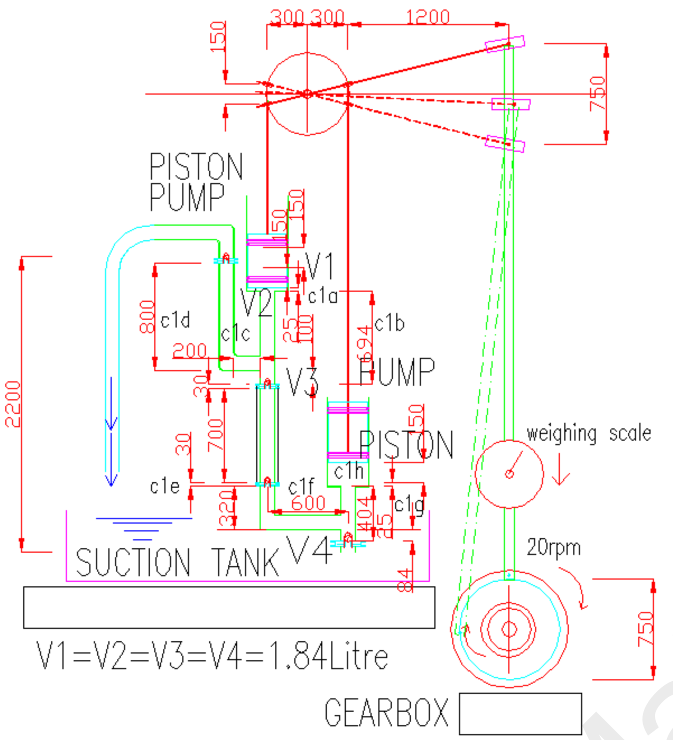


Figure 3.7: Prototype for Micro Hydro Turbine (for 2.2m height)

Components used for prototype as listed below:-

1. 2 nos 125mm diameter by 150mm length piston pumps.
2. 4 nos check valve with adaptor.
3. 39mm inner diameter PVC pipes with tee and elbow.
4. 1 set 20rpm gear box (1 hp. 3 phase motor)
5. 1 no. weighing scale.
6. Steel structure support and brackets.
7. 1 no. HDPE suction tank.
8. 1 no. Steel rod as moving arm
9. Bolt and nuts, accessories, etc.

Figure 3.8: Photo of Prototype for Micro Hydro Turbine

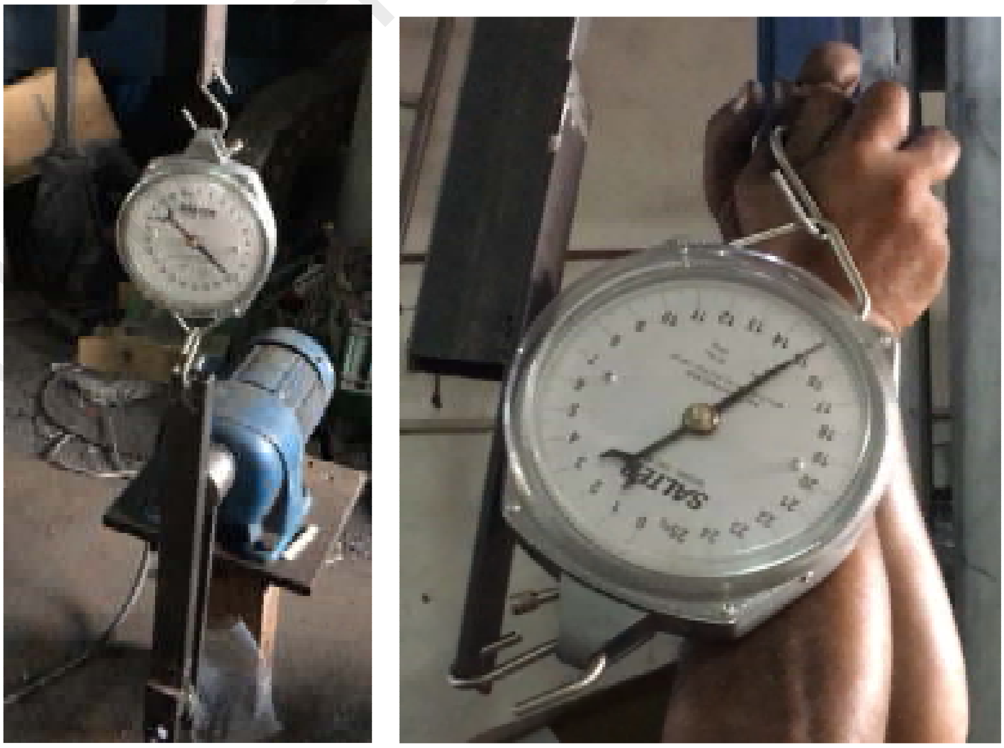


Figure 3.9: Manually Measure Using Weighing Scale

Table 3.2: Experiment 1-Volume of water inside cylinders and pistons

Experiment No.1 - for 3m height

Cylinder No.	Diameter m	Area sq.m	Volume cu.m	Height m
P1a(V1)	0.125	0.01227	**0.00184**	0.150
C1a	0.125	0.01227	0.00031	0.025
C1b	0.039	0.00119	0.00048	0.400
C1c	0.039	0.00119	0.00024	0.200
C1d	0.039	0.00119	0.00082	0.684
V2			**0.00184**	
V3	0.039	0.00119	**0.00184**	1.541
C1e	0.039	0.00119	0.00038	0.320
C1f	0.039	0.00119	0.00067	0.560
C1g	0.039	0.00119	0.00048	0.404
C1h	0.125	0.0123	0.00031	0.025
V4			**0.00184**	
Total Load (V1,V2 & V3)			**0.00552**	

Calculation for experiment No.1:

1. $Load = 0.00552 = 5.52\ kg$

2. $Load\ at\ the\ end\ of\ arm = \frac{5.52}{4} = 1.38\ kg\ \ (ratio = 1:4)$

3. $Force = 1.38\ kg\ x\ 10N = 13.8N$

4. $Turning\ Diameter\ of\ Gearbox = 0.75m$

   $Radius = 0.375m$

5. $Turning\ of\ Gearbox = 20rpm$

6. $Formula\ of\ Torque = radius\ x\ Force = 0.375\ x\ 13.8 = 5.175\ Nm$

7. $Formula\ of\ Gearbox\ Power = \frac{Torque\ x\ rpm}{9550}$

8. $Measured\ by\ manual\ pulling\ load = \ 4\ kg$

9. $Estimated\ Gearbox\ power = 0.0314\ \ kW$

$Using\ water\ pump,$

$$a).\ Flow\ rate, Q = \frac{1.84L}{1.5\ sec}$$

$$b).\ Head, H^m = 3m$$

$$c).\ Estimated\ losses = 20\% = 0.6m$$

$$d).\ Effieciency, \eta = 60\%$$

$$e).\ Calculation$$

$$P_{BKW} = (Q(m^3/s)\ x\ (H^m)\ x\ gravity)/\eta$$

$$= \frac{1.23\ x\ 3\ x\ 9.81}{1000\ x\ 0.6} = 0.006kW$$

$$Pump\ power, P = P_{BkW} x\ 1.25 = 0.075\ kW$$

Piston Pumps vs Electrical Transfer Pump = 0.0314 : 0.075 (ratio = 1: 2.4)

Table 3.3: Experiment 2-Volume of water inside cylinders and pistons

Experiment No.2 - for 2.2m height

Cylinder No.	Diameter m	Area sq.m	Volume cu.m	Height m
P1a(V1)	0.125	0.01227	**0.00184**	0.150
C1a	0.125	0.01227	0.00031	0.025
C1b	0.039	0.00119	0.00048	0.400
C1c	0.039	0.00119	0.00024	0.200
C1d	0.039	0.00119	0.00082	0.684
V2			**0.00184**	
V3	0.039	0.00119	**0.00084**	0.700
C1e	0.039	0.00119	0.00038	0.320
C1f	0.039	0.00119	0.00067	0.560
C1g	0.039	0.00119	0.00048	0.404
C1h	0.125	0.0123	0.00031	0.025
V4			**0.00184**	
Total Load (V1,V2 & V3)			**0.00452**	

Calculation for experiment No.2:

1. $Load = 0.00452 = 4.52\ kg$

2. $Load\ at\ the\ end\ of\ arm = \frac{4.52}{4} = 1.13\ kg\ \ (ratio = 1{:}\,4)$

3. $Force = 1.13\ kg\ x\ 10N = 11.8N$

4. $Turning\ Diameter\ of\ Gearbox = 0.75m$

$$Radius = 0.375m$$

5. $Turning\ of\ Gearbox = 20rpm$

6. $Formula\ of\ Torque = radius\ x\ Force = 0.375\ x\ 13.8 = 5.175\ Nm$

7. $Formula\ of\ Gearbox\ Power = \frac{Torque\ x\ rpm}{9550}$

8. $Measured\ by\ manual\ pulling\ load =\ 3\ kg$

9. $Estimated\ Gearbox\ power = 0.0236\ \ kW$

$Using\ water\ pump,$

$a). Flow\ rate, Q = \dfrac{1.84L}{1.5\ sec} = 1.23\text{L/s}$

$b). Head, H^m = 2.2m$

$c). Estimated\ losses = 20\% = 0.6m$

$d). Effieciency, \eta = 60\%$

$e). Calculation$

$P_{BKW} = (Q(m^3/s)\ x\ (H^m)\ x\ gravity)/\eta$

$= \dfrac{1.23\ x\ 2.2\ x\ 9.81}{1000\ x\ 0.6} = 0.044kW$

$Pump\ power, P = P_{BkW} x\ 1.25 = 0.055\ kW$

Piston Pumps vs Electrical Transfer Pump = 0.0236kW : 0.055kW (ratio = 1: 2.3)

3.3 Conclusion

To ensure an accurate load in kg at the terminal of arm, few times of taking measurement is needed and an average result is estimated for reference. Eventually, we can size up the gearbox with a proper capacity in hose power. The theory calculation for gearbox is estimated within 25kg in weight for the prototype. In order to get a more accurate measurement and calculation, the height of prototype should be increased to 12m or higher.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter will briefly explain the gearbox power and the variable turning speed of gearbox in rpm and related to the moving speed of piston pumps. The higher speed of gearbox required more electrical power and the turning speed can be controlled by inverter in order to accommodate the power generated by photo voltaic (PV) panels which conventional transfer pump speed is fixed. The results obtained through the prototype can be implemented into a real installation for HRES.

4.2 Theoretical Experiment for Gearbox power

Theoretically, from literature reviews in Chapter 2 and the analysis through calculations, we can estimate the total load at terminal of arm. Therefore, we can determine the capacity of gearbox. From the experiment, we can calculate the hydro power to be generated and we can size up total PV panels and the capacity of water storage tank.

4.3 Results

The experiment was conducted based on the methodology that was described from the calculation. The fabricated prototype can be used for estimate the power for gearbox and also power to be generated. Therefore, the different power consumption by electrical transfer pump and gearbox can be calculated also. The results for both components as stated below (by the above calculations):-

A: Piston Pumps vs Electrical Transfer Pump:

By methodology calculation = 28.85kW : 62.3kW (ratio= 1:2.2)

By experiment No.1 : 0.0314kW : 0.075kW (ratio = 1: 2.4)

By experiment No.2 : 0.0236kW : 0.055kW (ratio = 1: 2.3)

B: Piston Pumps vs Hydro Turbine:

By methodology calculation = 28.85kW : 28kW

4.4 Discussion

The results obtained through the experiment No.1 and No.2 showing that the piston pumps has better performance compared to electrical transfer pump. In order to obtain a better accuracy, prototype has to be built about 6m height with bigger flow rate through the cylinders. More data need to be taken from level to level by increasing the height of piston pumps. Hydro power generator only can be installed if the height of reservoir can be achieved at least 12m. The efficiency of power generation can be improved if the height of reservoir increased. The prototype for this project can be built in cascaded method for transferring water to the reservoir.

4.5 Error of Analysis

The error of analysis for this experiment was done through the measurement of the moving arm by weighing scale in order to understand the reasons of error occurred throughout the experiment. The weight of the steel rod and steel arm are the main factors of load measurements and few assumption need to be considered i.e. friction loss of check valves, pipes, moving components, etc. The error of analysis for each time of measurement will getting an average results eventually.

4.6 Summary

This chapter has featured the results that have been collected for Micro hydro turbine combined with photo voltaic. The electrical power required for moving the gearbox with a drum as flywheel which connected to a moving arm can be calculated and the Photo voltaic panels can be sized up to meet the energy required for the project.

CHAPTER 5: CONCLUSION

5.1 Introduction

In this chapter, the objectives and scope that was mentioned for this study are analyzed and discussed briefly. Problems that has been highlighted throughout this experiment are also analyzed and recommendations for improving this study are also included stated in this chapter.

5.2 Conclusion

This study proposed to use piston pumps for lifting water compared to electrical transfer pump. Through the experiment, we can calculate the power required for moving the piston pumps or running an electrical transfer pump for lifting water to the reservoir and install a mobile micro hydro turbine for hydro power generation by the excessive energy from photo voltaic panels. The advantages of using piston pumps is the components are robust, less maintenance, cheaper in installation and less power compare to electrical transfer pump. The water storage at reservoir acting as potential for hydro power generation which is better than batteries.

Mobile micro hydro turbine combine with photo voltaic panels can be built at anywhere and the storage water as potential for hydro power generation is a totally green energy compare to others and water is the cheapest in cost. The green energy by this HRES is meet the friendly environmental concept.

5.3 Recommendation for Future Project

The suggestion and recommendation for future works is to build more sets and bigger in sizes for generate bigger capacity of hydro power. To convert energy from photo voltaic into hydro power can be done by this method. The storage water can generate electricity with non-stop operation when water storage is enough in the reservoir and the water is circulating in a loop without wastage. The evaporation of water is so little.

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