INVESTIGATION ON SMALL PUMPED STORAGE INSTALLATIONS FOR LOAD BALANCING AND BACK-UP WATER STORAGE APPLICATION

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DECLARATION

I, the undersigned, hereby declare that this report is my own independent work except as specified in the references and acknowledgements. I have not committed plagiarism in the accomplishment of this work, nor have I falsified and/or invented the data in my work. I am aware of the University' regulations on Plagiarism. I accept the academic penalties that may be imposed for any violation.

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ABSTRACT

Pumped Storage Installations are build all over the country to help with power generation and storage. In Malaysia there are yet to be any pumped storage plants built. This could be due to the high initial capital costs usually associated with pumped storage installations. This paper produces a design of a modular pumped storage power plant based in Malaysia that could potentially be beneficial to the country. The methods used to do this involve using PAT, or pumps as turbines in order to reduce the overall costs of these facilities. This paper also provides a cost prediction based on the main components of a pumped storage plant which are the reservoir, pumps, turbines, motors, generators and pipelines. The final result produces a pumped storage plant design which is suitable for the location chosen. The plant was then optimised to the locations conditions and an operation schedule made.

ACKNOWLEDGEMENTS

I would like to thank my family for supporting me through my time studying abroad. I would be nothing without them. I would also like to thank my friends in INTI for fighting the good fight with me these last four years. Lastly I would like to thank my lecturers and supervisors for guiding me during my time studying to become a Mechanical Engineer.

DEDICATION

This thesis is dedicated to my family and friends and anyone who has helped me along the way.

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PSI	Pumped Storage Installation
PAT	Pump as Turbine
BEP	Best Efficiency Point
MAG	Motors as Generators

NOMENCLATURE

Symbol	*Definition*
Q_t	Flow in turbine mode (m^2/s)
Q_p	Flow in pump mode (m^2/s)
H_t	Head in turbine mode (m)
H_p	Head in pump mode (m)
η_t	Efficiency in turbine mode
η_p	Efficiency in pump mode
P_p	Power in pump mode (watt)
P_t	Power in turbine mode (watt)
K_Q	Coefficient of Flow
K_H	Coefficient of Head
K_η	Coefficient of efficiency
P	Power (W)
η	Efficiency
ρ	Water Density (Kg/m^3)
Q	Flow Rate (m^3/s)
G	Acceleration due to Gravity (m/s^2)
H	Head (m)
h_f	Head Loss (m)
f_D	Darcy Friction Factor
L	Length of Pipe (m)
D	Inner Diameter of Pipe (m)
V	Average Velocity of Fluid Flow (m/s)

CHAPTER 1

INTRODUCTION

1.1. Background

Malaysia is a developing country with ever increasing demands for energy for its growth. An energy consumption analysis report done by EIA (2014) shows that the primary sources of energy in Malaysia's for 2012 was petroleum (and other liquids) and natural gas producing 40% and 36% respectively. Biomass (and waste) and hydroelectricity only contributed 4% and 3% respectively to the overall energy source. Also in the report, it shows that since 2000, the amount of net electricity generation in Malaysia from fossil fuels has increased from 60 billion kilowatt-hours to around 134 billion kilowatt-hours in 2012. That is an increase of more than double in a span of 12 years, while electricity generation from other forms of energy sources remain almost unchanged. The report also states that the primary source of power demand is from the industrial sector which used around 45% of the total generated electrical energy with commercial and residential demands of 33%.

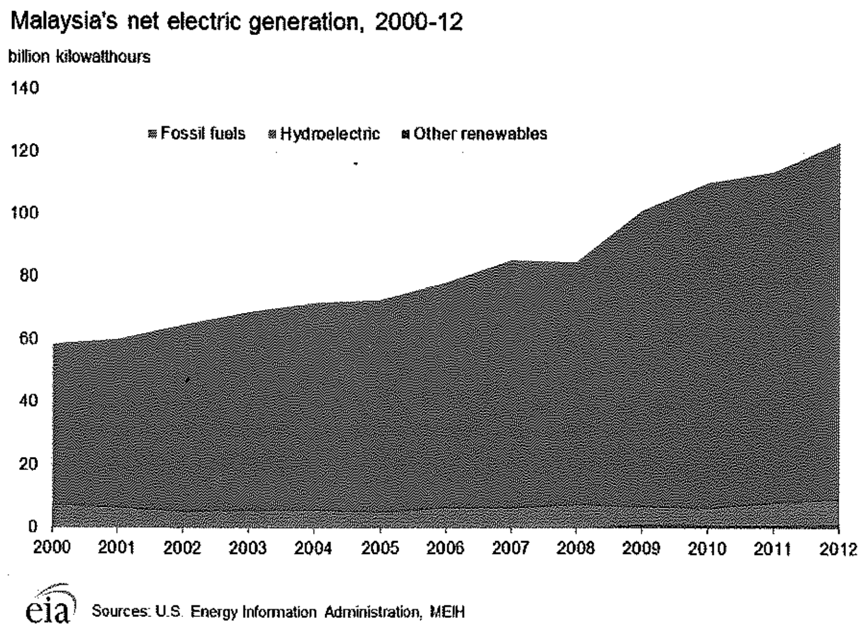

Figure 1.1 Malaysia's Net Electric Generation (2000 - 20012)
(Source: Malaysia; EIA, 2014)

Figure 1.1 above shows a graph of how much dependant Malaysia is on fossil fuels for energy generation. The EIA (2014) report mentions that according to the Malaysian states, the demand for electricity is expected to grow by more than 3% through the year 2020. However by looking at the graph trend lines in Figure 1.1, it can be predicted to be considerably more than 3%. While fossil fuels are the easiest and readily available source of energy production, many modern countries are adopting alternative power sources to reduce their overall reliance on fossil fuel burning. One such alternative power source is the pumped storage system.

1.1.1. Pumped Storage Installations

Pumped storage installations (PSI) are a type of energy storage system used by electrical power systems for load balancing. PSIs operate on the principle of storing gravitational potential energy. A PSI can quickly generate electricity by harnessing the stored potential energy and also stock large quantities of energy for later use. The PSIs main components are an upper water reservoir/basin, a lower water reservoir/basin, a pump-turbine and a motor-generator. The motor-generator is connected to the power grid in order to contribute or consume electricity. This is illustrated in Figure 1.1 below.

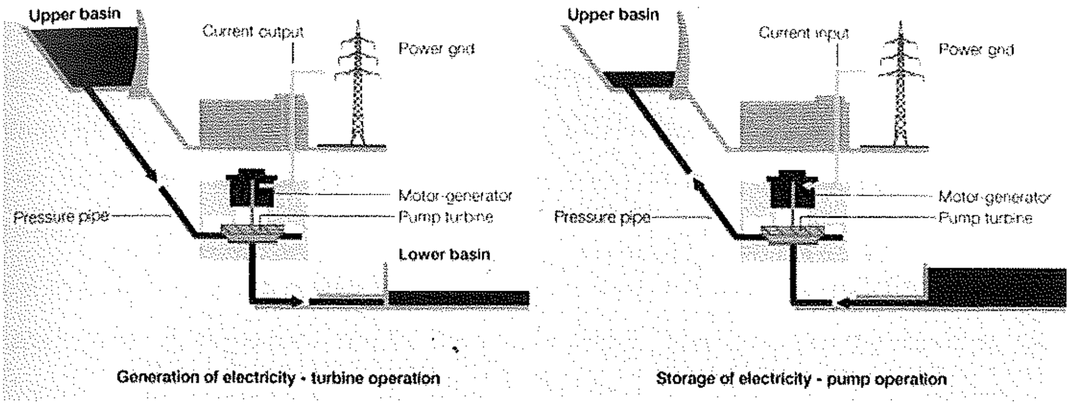

Figure 1.2 Pump Storage power plants

(Source: Pump Storage power plants, Special Focus; Hydro Equipment Association, n.d. image, viewed 16 October 2014, <http://www.thehea.org/hydropower/special-focus/pump-storage-power-plants/>)

Figure 1.1 above shows the basic layout and main components of a typical PSI and also how it would operate. During the generation of electricity process – turbine operation, water from the upper reservoir is released and will flow to the lower reservoir due to the height difference. This occurs through the pressure pipe which is connected to the pump-turbine. The flow of water will rotate the pump-turbine blades (operating as a turbine only during generation process) and cause electricity to be generated. The reverse process has the water pumped 'back up' from the lower reservoir to the upper reservoir by the pump-turbine (now operating as a pump only) which is powered by the electrical power grid. This process is made more cost effective by taking advantage of peak and off-peak electric power prices. Energy is generates exclusively during peak hours to maximise the revenue from producing/selling electrical power as peak hours have much higher tariffs. In contrast, during off-peak hours, energy is stored by consuming/buying electricity at lower tariffs. PSIs can be quite efficient as energy storage systems with some PSIs regaining up to 85% of the stored energy (Levine, 2003). This makes it possible for PSIs to generate revenue based on tariff differences even if overall they consume more energy than they produce.

PSIs also provide a cleaner and more efficient method for load balancing. Load balancing is a method used to store excess electricity during low demand periods which is then returned when demand rises. This allows other energy generating sources which have substantial variability in the energy they produce to operate at optimum