MODELLING OF MICRO HYDROELECTRIC SYSTEM DESIGN

NOOR AZLIZA BT IBRAHIM

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ABSTRACT

Hydropower is emerging as a major contributor to the world energy requirement. It's inexhaustible, clean and has many other benefits as it does not encounter the problems of population displacement and environmental problems. Stand-alone Power System (SPS) or formerly known as Remote Area Power Supply System (RAPS) is the power system not connected to the grid. Today, there are many rural areas still not readily accessible of grid power due to constraints of distance and terrain. Small (SPS) of renewable energy are targeted to the areas since there is not economic and environmental friendly by obtaining electricity from diesel generators. This project is describing model design of stand-alone micro hydropower system. The models simulation is achieved by using MATLAB SIMULINK software.

ABSTRAK

Hydropower adalah penyumbang kepada keperluan tenaga dunia. Ia adalah bersih dan mempunyai kelebihan seperti tiada masalah pencemaran alam sekitar. *Stand Alone Power System (SPS)* atau dikenali *Remote Area Power Supply Power System (RAPS)* adalah sistem kuasa yang tidak bersambungan pada jaringan. Pada masa kini, banyak kawasan pedalaman masih lagi tidak mempunyai kuasa jaringan yang disebabkan oleh jarak dan faktor bentuk muka bumi. *SPS* kecil dari sumber tenaga yang boleh diperbaharui adalah sasaran pada kawasan ini kerana ia lebih ekonomi dan mesra alam daripada penjanaan elektrik dengan menggunakan penjana diesel. Projek ini adalah untuk mereka bentuk model *Stand Alone Micro hydropower system* dengan menggunakan perisian MATLAB SIMULINK.

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LIST OF ABBREVIATIONS

AC	Alternate current
At	Proportionality factor
AWS	Average Wind Speed
CHP	Combined heat power
CO_2	Carbon dioxide
Ce	Resistance torque
Cp	Snubbers capacitance
Ct	turbine torque (pu)
DC	Direct current
DG	Turbine damping
EPS	Existing power system
Eq	Internal voltage
GUI	Graphical user interface
g	Gravity constant
H	Head
HPS	Hybrid power system
He	Effective high
Htn	Nominal fall
hr	Rated turbine head
ht	Effective fall in pu

I_L	Current line to line
I_a	Phase a line current
I_b	Phase b line current
I_c	Phase c line current
I_d	Direct stator current
I_q	Quadrate stator current
JΔ	Combines moment of inertia of the generator and turbine
Kp	Proportional gain
Ki	Integral gain
Kd	Derivative gain
kW	Kilo watt
L	Internal inductance
MG	Micro grid
MHPS	Micro hydropower system
MHPP	Micro hydropower plant
MW	Mega watt
MWPT	Micro wind power turbine
m	report of V_1 and V_2 the water speed at the axis of the buckets
nm	Speed (rpm)
nt	Turbine speed (pu)
P	Active power
PID	Proportional integral derivative
Pm	Input power of synchronous generator
Pmec	Mechanical power
Pt	Turbine power (W)
Ptn	Nominal turbine power (W)

Pu	Per unit
PV	Photovoltaic
Q	Water flow
Qc	Capacitive reactive
QL	Inductive reactive
Qt	Water flow of turbine (m^3/s)
Qtn	Nominal speed of the turbine (m^3/s)
qnl	No load flow
qr	Rated turbine flow
qt	Turbine flow (pu)
R	Internal resistance
RAPS	Remote area power supply system
Rp	Snubbers resistance
Rt	Ray of the turbine
S	Complex power
SPS	Stand- alone power system
SRG	Synchronous reluctance generators
s	Second
V	Voltage
VA	Volts amperes
V_L	Voltage line to line
Va	Terminal voltage
V base	Base voltage
Vf	Field Voltage
Vfd	Exciter voltage
Vt	Drive speed of turbine

V_1	Water speed in the contact of the jet with buckets
V1	Jet speed (pu)
V1n	Nominal speed of the jet (m/s)
Wh	Watt hour
X	Reactance
Xd	Direct reactance
Xq	Quadrate reactance
$\Delta\omega$	Deviation speed
θe	Electrical angle of the rotor
θ	The power factor angle
Ψ	The angle of Eq
δ	The torque angle
ρ	Water density (1000 kg/m^3)
β	Angle between V_1 and V_2
Ωtn	Nominal speed of turbine (rd/s)
τapp	Input torque
ωm	Speed (rad/s)

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CHAPTER 1

INTRODUCTION

Micro Grid (MG) is a small network of power generators to transform the electricity network in the way that the net changed distributed communication. The Micro Grid formed from the renewable energy resources. The efficiency of a standalone Micro Grid in reliability and economy as well as environment was assessed. The environment efficiency was evaluated considering the amount of CO_2 discharge that was reduced by using installed MG power system renewable energy [1].

The potential economic benefits of micro grid operation are summarized as:

i. Reduced network congestion and line losses
ii. Reduced transmission and distribution cost
iii. Potentially higher energy efficiency
iv. Promoting small individual investment, thus reducing the Huge Capital Expenditure
v. The low capital cost enables low cost access into a viable market

The technologies that play a major role in micro grid operation are:

a) Renewable energy resources
   i. Solar photovoltaic arrays
   ii. Wind energy park
   iii. Small capacity hydro units

iv. Ocean energy

v. Biogas plants

b) Non-renewable energy resources

i. Micro turbine

ii. Fuel cell

iii. Combined heat power (CHP) turbine

iv. Internal combustion engines

Renewable energy includes resources that are constantly present, which never run out. There are various types of renewable energy available in Malaysia as shown in Figure 1.1. However, among these sources, biomass, hydro and solar becomes the most potential renewable energy in Malaysia. Malaysia has tremendous biomass resources available such as oil palm wastes from oil palm mills and plantations, agricultural crops, agricultural crop residues, woods and woods residues, rice husks from rice mills, molasses and bagasse from sugarcane refineries and municipal wastes from landfill and from household. For example, in Sarawak, palm oil industry and agricultural industry emerged to be the largest biomass sector, which both for direct production of energy fuels and use of wastes for biomass generated electricity for sale or own industry usage.

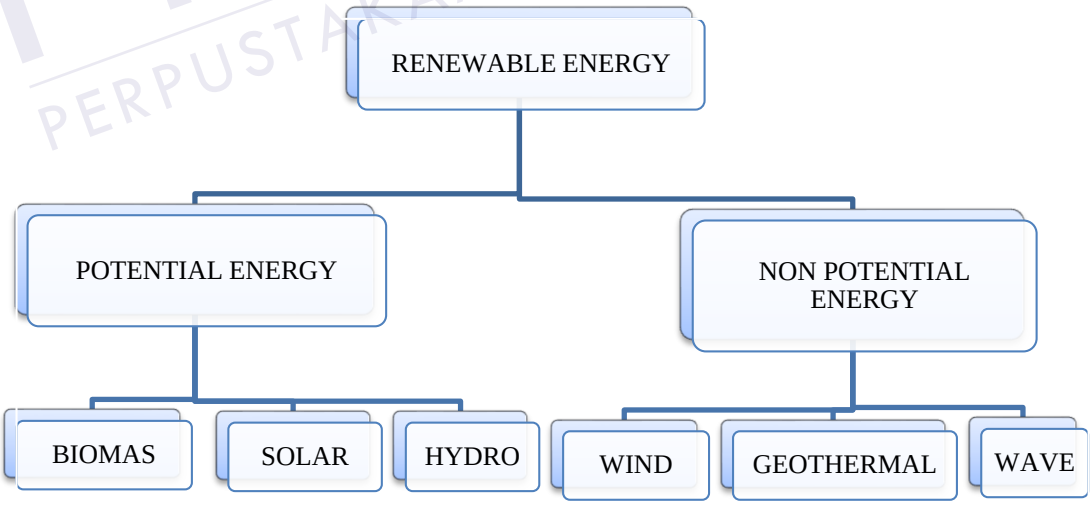

Figure 1.1: General renewable energy sources in Malaysia

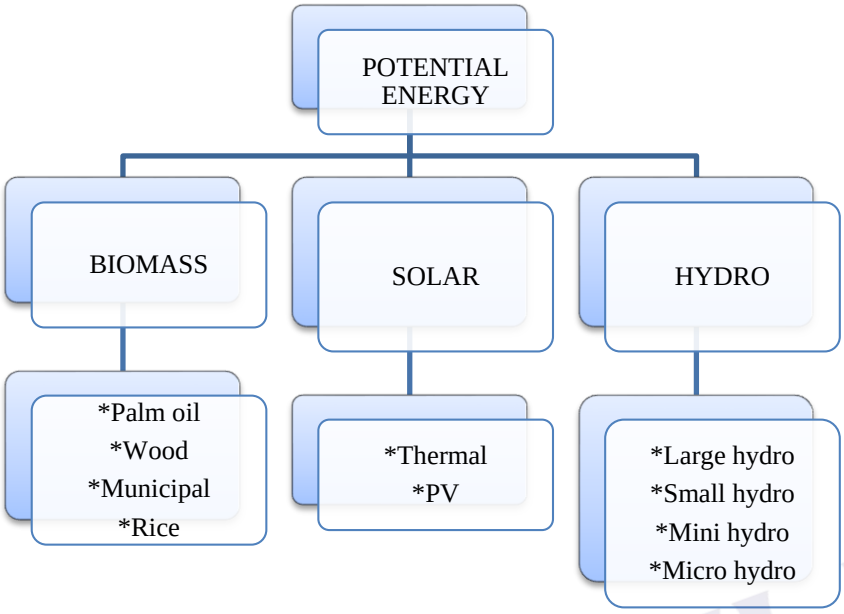

Figure 1.2: Potential energy in Malaysia

Hydropower is currently the world largest source of electricity, accounting for 6% of the world's energy supply or about 15% of the electricity generated. Hydropower is attractive because it is a renewable energy source that can never be exhausted. However, depending on seasonal changes and silt accumulation in large dams, the large reservoirs tend to function less effectively. Unlike large scale hydro, micro hydro or small-scale hydro does not interfere significantly with river flow and is therefore one of the most unobtrusive energy conversion methods available.

1.1 Classification of hydropower plants

Water can be harnessed on a large or a small scale. The categories which are commonly used to define the power output form hydropower are outlined as follows [2,4]:

i. Large-hydro: more than 100 MW and usually feeding into a large grid
ii. Medium-hydro: 15 - 100 MW and usually feeding a grid
iii. Small-hydro: 1 - 15 MW and usually feeding into a grid [3]
iv. Mini-hydro: between 100 kW and 1 MW; either standalone schemes or more often feeding into the grid
v. Micro-hydro: ranging from a few hundred watts for battery charging or food processing applications up to 100 kW, providing power for a small community or rural industry in remote areas away from the grid [1-6].

Micro hydropower system (MHPS) is one of the popular renewable energy sources in the developing countries. Most of the MHPS operate in isolated mode supplying the electricity in the local rural area where the population is very small and sparsely distributed and the extension of grid system is not financially feasible because of high cost investment required for transmission line. Hydroelectric power is the technology of generating electric power from the movement of water through rivers, streams, and tides. Water is fed via a channel to a turbine where it strikes the turbine blades and causes the shaft to rotate. To generate electricity the rotating shaft is connected to a generator which converts the motion of the shaft into electrical energy. Advantage of using water resources is that hydraulic works can be made simple and large constructions, such as dams, are not usually required. Dams, which exploit the kinetic energy of water by raising small quantities of water to heights through the use of regulated pressure valves, can provide water for domestic uses and for agriculture in areas that are moderately higher than adjacent water courses. Generally, in an autonomous micro hydropower system is designed to operate in parallel with local power grids. The main reasons are to obtain economic benefit of no fuel consumption by micro hydro turbines, enhancement of power capacity to

meet the increasing demand, to maintain the continuity of supply in the system, etc. In a micro .hydropower system, frequency deviations are mainly due to real power mismatch between generation and demand.

Today, most of rural area in Malaysia are still not readily accessible of grid power. Regarding to distance and terrain, the cost of connection to the electricity supply grid can be high and the common low load which caused to low payback have escalating the constraint for electric utility to connect power grid into the remote areas. Therefore, generally people in rural area will obtain electricity supply by using diesel generators which operated by using fossil fuel. This seems to be the easiest conducted solution due to the obstacle. However, world's supply of fossil fuels is now becoming scarce and depleting with increasing hazard of global warming. As a result, people in rural area have to afford high cost of electricity generation of diesel generators. Furthermore, the high transportation cost has worsened the situation. Concerning to this situation, an alternative means of energy production should be explored further. Among the available alternative energy sources, interest is focused on clean and environmentally friendly sources that are renewable energy sources such as wind, solar, hydro and so on.

Due to location of rural area, and common low load demand, interest is focused on Stand Alone power systems (SPS) such as micro hydro which is easy been constructed and maintained. SPS formerly known as Remote Area Power Supply systems (RAPS) is the power system that are not connected to the grid. Study has proving that small scale hydro system will only bring very slight side effects on environment compared to large scale hydro power plant. This is because, micro hydroelectric power system can be installed in small rivers or streams while large scale hydroelectric power system requires huge dam or reservoir to store water which will destroying huge area of rainforest thus cause to ecology problems.

The main components of a Micro Hydroelectric Power Plant (MHPP) may be classified into two groups such as the hydraulic system components and the electric system components formed by the synchronous generator and his control system. The water's flow is fixed at the maximal value to guarantee the maximal mechanical power. The upstream hydraulic part of the MHPP consists of water supply from a river, a feeder canal, a regulation basin, a pressure pipeline whose section is accorded

to the flow and the available power. Nozzles direct water jet against a series of spoon shaped buckets mounted around the edge of a turbine. The system ensures the hydraulic energy transformation into mechanical energy. The wheel of the turbine is coupled to a synchronous generator. The general diagram of this system is represented in Figure 1.3. The Pelton turbine is used for the high falls and small flows. It Consists of a set of specially shaped buckets mounted on the periphery of a circular disc. It is turned by jets of water discharged from one or many nozzles which strike the buckets which is shown in Figure 1.4. By a mobile needle inside the nozzle we can adjust the flow. It's moved by an electric servo motor, this servo motor must be relatively slow to minimize the water hammers effect [7].

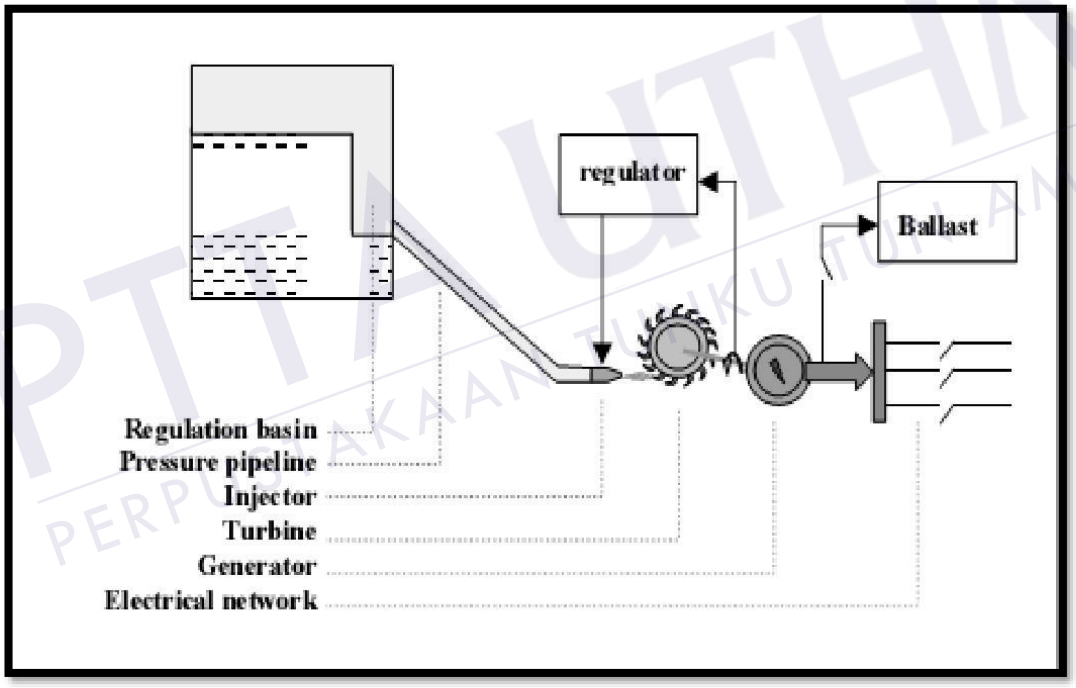

Figure 1.3: Synoptic diagram of a MHPP .

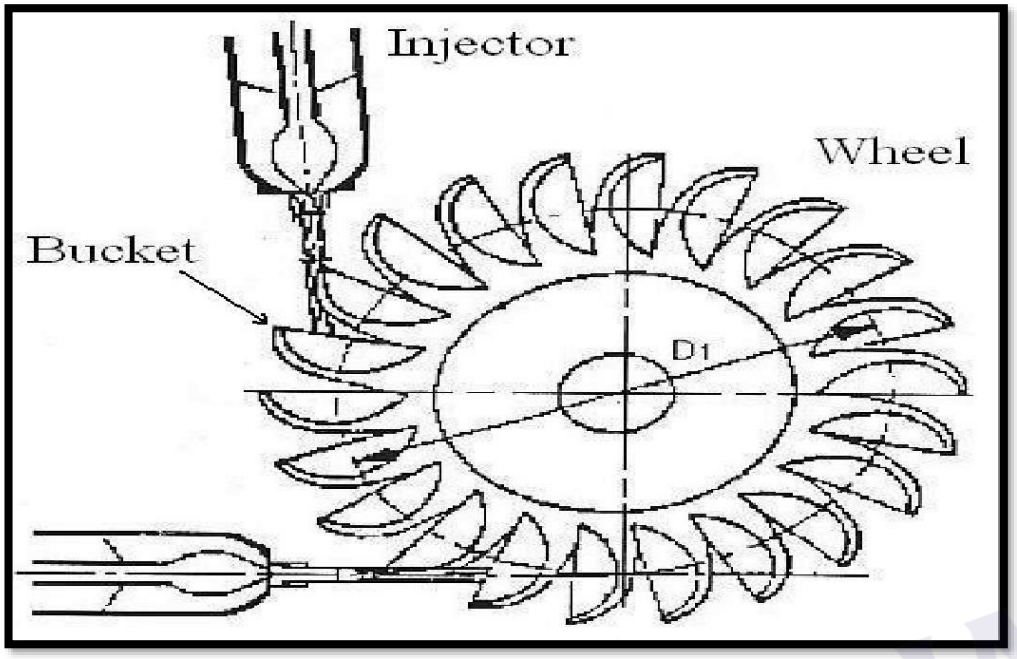

Figure 1.4: The geometrical shape of a Pelton turbine.

1.2 PROJECT BACKGROUND

This research is using the MATLAB SIMULINK software to build the modelling and regulation of the output power of a micro hydroelectric power system. This modelling is built depends on the real parameters which are setting first such as the voltage, frequency and so on to produce the power output is less than 100 kW.

1.3 PROBLEM STATEMENT

In the light of increasing electricity demand, international agreements to reduce greenhouse gases limiting the use of fossil energy and environment problems. As an environmental problem of the global warming, reducing the discharge of greenhouse

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