A FREQUENCY CONTROLLER USING FUZZY IN ISOLATED MICROGRID SYSTEM

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Dedicated to my beloved father, Subri B Ismail, and my mother, Asma Bt Manan for their undying love, invoking, supporting, encouragements and advice which always became a guiding light in my life and for me to complete studies

And

All my beloved brothers and sisters (Kamarul Iszuwandi B Subri, Mohd Al-Muzammel B Subri, Khairunisa Bt Shaaban, Norasma Bt Ahmad, Nirman Iszaudin B Subri, Mohd Faisnor B Subri, Nur Zaidatul Adila Bt Subri).

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ABSTRACT

Nowadays, the potential of micro-hydro power plant has stand out as the one of the alternative generation replacing the conventional grid generation. The main factor that contributed to this development of alternative sources is causes of the global warming, depletion of the conventional source and high cost to construct the grid especially in remote areas. Therefore, the standalone hydropower plant is the appropriate choice for the rural electrification with less investment and time where the supplying grid electricity is not economical. Many previous research works has been conducted to develop a control system for micro-hydro power plant but most of the works have problems in term of frequency and power at the load. For controlling the frequency, the electronic load controller has been used, but there is a dissipation of large amounts of water especially during low power requirement. Additionally, a fixed control system from the previous study doesn't offer the dynamic performance of micro-hydro power plant under different operating time when the load demands are varied. This report proposes a combination of fuzzy controller and PI controller for frequency control of micro-hydro power plant and supervises the power generated onto the load. A micro-hydro power plant has been modelled and simulated using the MATLAB/Simulink software. The comparison between fuzzy control system and conventional PID controller in term of dynamic performance has been determined. The results obtained show that fuzzy controller is more effective which is two times faster transient response comparable to conventional PID controller in terms of settling time and overshoots with respect to increase of load demand.

ABSTRAK

Pada masa kini, potensi janakuasa mikro-hidro semakin menonjol sebagai salah satu sumber alternatif janakuasa menggantikan janakuasa grid yang sedia ada. Antara faktor yang mendorong kepada pembangunan sumber alternatif adalah pemanasan global, kepupusan sumber konvensional dan kos yang tinggi diperlukan untuk membina grid terutamanya di kawasan pedalaman. Oleh itu, ketidakkebergantungan janakuasa hidro adalah pilihan yang sesuai untuk penjanaan elektrik terutamanya di kawasan pedalaman dengan pelaburan dan masa yang sedikit. dimana penggunaan grid adalah tidak ekonomi. Kebelakangan ini, terdapat banyak penyelidikan yang telah dijalankan untuk membina sistem kawalan untuk janakuasa mikro-hidro tetapi ia masih mempunyai masalah dari segi frekuensi dan kuasa pada beban. Bagi mengawal frekuensi, kawalan beban elektronik telah digunakan tetapi terdapat sejumlah besar air telah dibazirkan terutamanya apabila permintaan kuasa yang sedikit. Tambahan pula, sistem kawalan tetap daripada penyelidikan yang sebelum ini tidak menunjukkan prestasi janakuasa mikro-hidro dibawah masa operasi yang berbeza apabila beban berubah. Laporan ini mencadangkan kombinasi kawalan fuzzy dan kawalan PI untuk mengawal frekuensi janakuasa mikro-hidro dan memantau kuasa yang dijana akan kepada beban. Janakuasa mikro-hidro telah dimodelkan dan disimulasikan dengan menggunakan perincian MATLAB/Simulink. Perbandingan diantara sistem kawalan fuzzy dan kawalan PID konvensional telah ditentukan dari segi prestasi dinamik. Keputusan yang diperolehi menunjukkan bahawa sistem kawalan fuzzy adalah efektif iaitu dua kali lebih cepat tindak balas berbanding sistem kawalan konvensional PID dari segi lonjakan maksimum dan masa pengenapan terhadap peningkatan kepada permintaan beban..

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LIST OF ABBREVIATION

WEO	:	World Energy Outlook
EC	:	Energy Commission
MG	:	Microgrid
MHPP	:	Micro-Hydro Power Plants
Emf	:	Electromagnetic fields
PID	:	Proportional Integral Derivative controllers
PI	:	Proportional Integral Controller
OS	:	Overshoot
Ts	:	Settling Time

LIST OF SYMBOLS

η	:	Efficient factor
Q	:	Volume per second of water fall down in (m3/s)
g	:	Acceleration due to gravity (9.81m/s2)
H	:	Available head in (m).
d	:	d axis quantity
q	:	q axis quantity
R	:	Rotor quantity
s	:	Stator quantity
I	:	Leakage inductance
m	:	Magnetizing inductance
f	:	Field winding quantity
k	:	Damper winding quantity
RPM	:	Revolution per minute
f	:	Frequency (Hz)
P	:	Number of poles
Q	:	Flow rate (m^3/sec)
G	:	Gate opening (rad)
H	:	Net head (m)
A_t	:	Turbine gain
$\overline{g_{fl}}$	:	Full load gate opening (pu)
$\overline{g_{nl}}$	:	No load gate opening (pu)
Q_{nl}	:	No load flow rate (m^3/sec)
U	:	Velocity of the water in penstock
K_u	:	Constant of proportionality

a_g	:	Acceleration due gravity
L	:	Length of penstock
T_w	:	Water starting time at rated load
Q_r	:	Rated water flow rate
H_r	:	Rated Head
P_L	:	Fixed power loss in turbine due to friction
U_{NL}	:	No load speed
T_m	:	Mechanical torque
J	:	Friction coefficient
B	:	Moment of inertia
$u(t)$	:	Control signal
$e(t)$	:	Error signal
Pd	:	Power dissipate in load
Pe	:	Electrical power
Pm	:	Mechanical power

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CHAPTER 1

INTRODUCTION

1.1 Background

Globally, based on the World Energy Outlook (WEO) electrification rates database up to years 2011's showed that over 1.3 billion of peoples are estimated without electricity facilities and 95% group of that peoples are either originates from sub-Saharan African or developing Asia and mostly 84% of its comes from rural areas which can be classified according regional aggregates as shown in Table B.1 at Appendix B [1]. This includes Malaysia as one of new developing country which can be split into two primary areas that are Peninsular and Sabah and Sarawak that splinted by the South China Sea as shown in Figure 1. Based on the Table B.2 in the appendix sections made by WEO up to 2013's shows there's still lacking 1% of peoples without electricity in rural areas compared to urban area which are already reaching 100%. The Energy Commission (EC) bodies provide statistic data up to 2012's [2] which shows the total installed generation capacity, total electricity generation and total electricity consumption are 28,824MW 134,077GWh and 115,118GWh respectively in the whole state has increased year by years as the request demand of the nation especially in industrial, commercial and domestics sectors has been increases. The detailed data for electricity generation are presented in Appendix B.

Figure 1.1: Malaysia’s map [7]

In Malaysia, conventionally there are several types of resource such as natural gas, coal, diesel, oils and etc. are used either to rotate the turbine or use as source. Nowadays, the presently developing countries like Malaysia has come out with an ideas to locally researches an available of renewable energy such as solar, hydro, biomass, biogas and wind as a back-up or an alternative source especially at rural area which is far from grid utility known as microgrid (MG). This is due to an extending use of established sources as an increase of electricity demand with regard to the rapid increase of population without an increase of installed generation capacity to sustain the required demand and increase cost of grid extension [3, 4]. These systems are presented as one way of electricity generation to replace the conventional gas-fired generation due to the depletion of gas and oil in these recent decades. It also indirectly can overcome the cost flow, which can lead to increases of economic and thus offer a sustainability and environmental friendliness of the environments [3, 4]. Although the employment of renewable energy has proven by many industrialized nations, particularly in Europe, but the carrying out of this technology still news and under researches in Malaysia as the high capital costs of implementation, service and maintenance this technology has become a major reason to slow development of renewable energy.

In Malaysia, the application of micro-hydro power plants (MHPP) works is one of the earliest small scale renewable energy technologies was developed and it still a significant source of energy today as it has got the prospective to produce an important share of power more than solar or wind pressure with a low price. Due to the high potential of generation capacity ranges from 0.2KW to 100KW, micro hydropower plants could take on a positive role towards accelerating rural electrification process. There are a lot of run of river as Johor are nearest to South China Sea. Additionally, there are a number of micro-irrigation, earth dam has already built for other purposes such as flood control, water abstraction for a big city, recreation area and etc. but it is possible can be uses to generate electricity. But the main problem in utilizing the power from the river is how to complement the present operating plan to the intended power generation. Micro hydropower plants are characterized by parameter variation like damping constant of generator with load changes which makes conventional controller with fixed gains inefficient.

In power system, the one of the most essential parts to determine whether the system stabilizes or not is frequency. Frequency is a parameter indicating the balance of generation and expenditure in a power system [4]. Conventionally, the frequency is control of the distributed control scheme that works on the imbalance between load and generation through measuring the frequency deviation.

1.2 Motivation and Problem

The motivation of this thesis works is difficulties of poor communities to access the electricity in the current environment as the tremendous growth of demand year by year due to growth of population in many developed countries leaving in a very hard situation. The dependence and higher price on available energy like fossil fuels also contribute to this problem. Thus, the regime and government bodies must go in together and plays initiative to advance the awareness and promote the people equally in order to coordinate group and mobilize resources toward funding community power projects. This contribution can directly bring benefit to individual and speed up the way to accomplish the goal of clean, reliable and sustainable energy which next bring the growth in the economics of the country.

Today, most of the remote areas in Malaysia are still not readily accessible of grid power. This is due 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 escalated the constraint for electric utilities to connect power grid into the remote areas. Thus, mostly people in rural region will obtain an electricity supply by using diesel generators which operated by using fossil fuel. This appears to be the easiest conducted solution due to the obstruction. Nevertheless, the world's supply of fossil fuels is now getting scarce and depleting with increasing risk of worldwide heating. As Y.B. DATO' Sri Dr. Lim Keng Yaik the Ministry of Energy, Water and Communications had said that *"…The conventional fossil fuel supplies that we are so dependent on and have taken for granted for so long, are not only becoming very costly but are also limited in supply and being depleted…"* during National Renewable Energy Forum on 21st September 2006 [5]. Concerning to this situation, an alternative means of energy production should be explored further. Among the existing alternative energy sources, interest is focused on clean and environmentally friendly sources that are renewable energy sources (i.e. wind, solar, hydro and etc.). Regarding the location of rural area and common load demand, interest is focused on standalone MHPP which easily been constructed and maintained.

In power system, the uninterrupted supply of electrical power is a significant aspect when building a system. Thus, the output of MHPP system must be well-organized in order to endure an uninterrupted power while maintain the rated frequency. In order to achieve this purpose, there are several controllers has been used to sustain the frequency by the governing the gate opening position of servomotor. Therefore, the water flow can be set by the mechanical-hydraulic governors, but it's still can't the solved the issues, especially when taking a big variance in small grids which can have the systems become instable. In the other hand, the parameter variation such as damping constant with operating points must be hired into consideration when designing frequency controllers for MHPP. Previous studies have shown that conventional controller could not handle the effect of parameter variation which varies with the operating point. Based on the previous research, the governor takes a long time to stabilize the output signal due a slow response of servomotor and when the turbine gate opening is retained in the same position to maintain the flow of water.

In these works, the fuzzy controller that acts as a self-controller has been developed for controlling the position gate of servomotor in order to control the flow of water by maintains the rated frequency in spite of changing user loads. First, maintain the frequency of the system with a short time taken for the system to reach steady state for any operating conditions, even a change of power in users load. Second, the controlling of the gate opening of servomotor can save the water by managed the power dissipated on load. The gate will open if the load wants more ability than the specified and vice versa. Thus, it's can reduce the maintenance cost for a generator and expand the life of MHPP generator.

1.3 Project Objectives

The objectives of the project are:

1. To design a frequency controller by fuzzy control system of the standalone microgrid system.
2. To simulate the fuzzy control system on the standalone MHPP using Simulink/MATLAB.
3. To design and optimize the fuzzy controller to obtain good dynamic performance in term of steady state performance in the standalone microgrid system.
4. To compare the fuzzy control system with the conventional PID controller.

1.4 Project Scopes

i. The works is focused on modelling and designing a frequency controller by using fuzzy scheme for nonlinear turbine in standalone MHPP system. The used of nonlinear turbine is for a large variation in power output.

ii. The aspect that taken into a consideration are an area of penstocks, sizes of head, flow rate of water and the require demand.

iii. The comparison between fuzzy scheme and conventional PID scheme transient response in term of settling time and overshoot are determined with respect to various load rejections in order to select the best scheme that can use to supervise the MHPP system.

1.5 Report Outline

There are five chapters in this report.

Chapter 1 presents the background of energy review in Malaysia, background of MHPP systems, motivation and problem, objectives of this study.

Chapter 2 presents literature review on MHPP components, previous works of controller system, and fuzzy logic control as the frequency controller. The brief related works are discussed.

Chapter 3 deals with the detailed model of MHPP using Simulink/MATLAB. The detailed model of modelling the synchronous generator, hydraulic turbine, and servomotor and frequency controller are described in this chapter.

Chapter 4 shows the simulation result and analysed the simulated result. Then, discussions on the findings are presented.

Chapter 5 presents conclusion of the works and gives suggestions for future works to improve or further these works.

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