AUTOMATIC GENERATION CONTROL SYSTEM: THE IMPACT OF BATTERY ENERGY STORAGE IN MULTI AREA NETWORK

MUHAMMAD FIRDAUS BIN SUHAIMI

BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

FINAL FYP 2

ORIGINALITY REPORT

17%	9%	10%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universiti Teknikal Malaysia Melaka Student Paper	5%
2	Chunyu Chen, Kaifeng Zhang, Kun Yuan, Xianliang Teng. "Tie-Line Bias Control Applicability to Load Frequency Control for Multi-Area Interconnected Power Systems of Complex Topology", Energies, 2017 Publication	<1%
3	Aurobindo Behera, Tapas Kumar Panigrahi, Prakash K. Ray, Arun Kumar Sahoo. "A novel cascaded PID controller for automatic generation control analysis with renewable sources", IEEE/CAA Journal of Automatica Sinica, 2019 Publication	<1%
4	Submitted to Universitas Negeri Semarang Student Paper	<1%
5	www.imperial.ac.uk Internet Source	<1%
	Submitted to University of Nottingham	

AUTOMATIC GENERATION CONTROL SYSTEM: THE IMPACT OF BATTERY ENERGY STORAGE IN MULTI AREA NETWORK

MUHAMMAD FIRDAUS BIN SUHAIMI

A report submitted
in partial fulfilment of the requirements for the degree of
Bachelor of Electrical Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled "AUTOMATIC GENERATION CONTROL SYSTEM: THE IMPACT OF BATTERY ENERGY STORAGE IN MULTI AREA NETWORK" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : FIRDAUS

Name : MUHAMMAD FIRDAUS BIN SUHAIMI

Date : 4/7/2021

APPROVAL

I hereby declare that I have checked this report entitled “AUTOMATIC GENERATION CONTROL SYSTEM: THE IMPACT OF BATTERY ENERGY STORAGE IN MULTI AREA NETWORK” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature	:	
Supervisor Name	:	DR. NORHAFIZ BIN SALIM
Date	:	4th JULY 2021

DEDICATIONS

I dedicate this to my mother and father. Because of all the effort they have made, brings me to where I am now. If not because of their effort I cannot do this final year project. Lastly, for both of my parents and my siblings, thank you for always being there for me, praying the best for me.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to my main project supervisor Dr Norhafiz bin Salim for his encouragement, guidance, and support in writing this report. This project would not have been the same as the one shown here with all assistance and interest. I really appreciate all of my classmates and those who have helped on several occasions. Your insights and recommendations are truly valuable. Unfortunately, given this short area, it is not feasible to mention all of them.

ABSTRACT

As renewable energy sources (RES) are rapidly expanding, the provision of auxiliary facilities within the device operation will be increasingly difficult. Battery energy storage systems (BESS) have been recognised in recent literature as an effective method for adding control capability. This study presents the Automatic Generation Control (AGC) system with the impact of BESS in multi-area network. AGC is difficult to maintain the frequency in power generation, particularly at peak loads. The aim of this study is to investigate the AGC for frequency control in power system network with the aid of BESS. Furthermore, the effectiveness of BESS in improving the frequency control in multi-area network is verified. The simulation of AGC and BESS will be modelled in MATLAB Simulink. The analysis of comparison of frequency control method are carried out.

ABSTRAK

Oleh kerana sumber tenaga boleh diperbaharui (RES) berkembang pesat, penyediaan kemudahan tambahan dalam operasi peranti akan semakin sukar. Sistem penyimpanan tenaga bateri (BESS) telah diakui dalam literatur baru-baru ini sebagai kaedah yang berkesan untuk menambahkan kemampuan kawalan. Kajian ini menyajikan sistem kawalan penjanaan automatik (AGC) dengan kesan penyimpanan tenaga bateri dalam rangkaian pelbagai kawasan. Kawalan penjanaan automatik (AGC) sukar untuk mengekalkan frekuensi dalam penjanaan kuasa, terutamanya pada beban puncak. Tujuan kajian ini adalah untuk mengkaji kawalan penjanaan automatik untuk kestabilan frekuensi / kawalan dalam rangkaian sistem kuasa. Reka kaedah kawalan untuk sistem simpanan tenaga bateri. Juga, untuk mengesahkan keberkesanan penyimpanan tenaga bateri dalam meningkatkan kawalan frekuensi dalam rangkaian pelbagai kawasan. Simulasi AGC dan penyimpanan tenaga bateri akan dimodelkan dalam MATLAB Simulink. Analisis perbandingan kaedah kawalan frekuensi dijalankan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AGC	-	Automatic Generation Control
BESS	-	Battery energy storage system
TSO	-	Transmission system operator
UC	-	unit commitment
PID	-	Proportional Integrative Derivative
LFC	-	Load frequency control
AVR	-	Automatic voltage regulator
FFC	-	Flat frequency control

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 General

Load demand usage is something that cannot be control and will be varied from time to time. Therefore, when load demand is increase suddenly especially at peak loads. It will be affecting the frequency in power generation and power quality. To over comes the problem, Automatic Generation Control (AGC) system will be used in the power system network. The AGC system main function is to balance the real power between power supply and demand. Also, to maintain the frequency of power supply which is at 50Hz [1],[2].

1.2 Motivation

The motivation of this study is to increase my knowledge and explore more information in this study field. Also, to improve performance of power generation in term of frequency stability control by using the automatic generation control (AGC) with the support of BESS system. In order to make the power system becomes more effective. Increase in performance of power generation will makes the power system generation operates more smoothly and can supply better quality of power. Therefore, it will make the consumers more satisfied with the service they get. Also, to store the balanced energy that have been produced in low demand condition.

1.3 Problem Statement

Automatic Generation Control (AGC) having difficulty maintaining the frequency in power generation, particularly at peak loads. As an example, sudden increase of demand at high load happened. The AGC will makes the generators to spin faster to match with the increasing demand. Furthermore, AGC is having a hard time with a slower conventional power plants. As an example, the hydropower plant is much slower compared to the gas turbine combined cycle. So when the sudden increase of demand happened and AGC makes the generator to spin more faster to match with the load demands but the hydropower plant cannot spin as fast as GTCC to match with the sudden increase of load demand [1].

1.4 Objective

i. To investigate the automatic generation control for frequency control in power system network.
ii. To design a control method for battery energy storage system.
iii. To verify the effectiveness of battery energy storage in improving the frequency control in multi-area network.

1.5 Scope

To achieve the objective, several scopes were outlined:

i. Design a 20MW Li-ion Battery which have fast charging and discharging functionality.

ii. This project mainly focuses on the power generation part and existing generators as the power sources.

iii. Main focuses of automatic generation control system are for the load frequency control.

iv. 50 Hz will be set as references frequency.

v. Frequency deviation of the system is in the range of ±0.5 Hz.

1.6 Conclusion

In conclusion, problem statement is managed to be highlight from previous literature and from that objective are managed to be listed. Therefore, to achieve the objective several scopes managed to be listed.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The variety application of the AGC and BESS will be presented in this chapter. To maintain the power balance of supply and demand, the automatic generation control system will be discussed. Study of previous work related to the automatic generation control system from different journals is presented and evaluation is determined on the basis of the previous work.

2.2 Automatic Generation Control System

For the reliability and safety of the power grid in real-time activities, automatic power generation control (AGC) is paramount. As the power output and load demand are diverged, AGC is responsible for adjusting the grid generation in order to ensure that electricity supply and demand are matched in real time and to track the system frequency. In [2], a study on the AGC of a major hydropower project to guarantee the reliability, and protection power grids have been made. The approach is developed to overcome the load distribution and unit commitment (UC) at AGC. In advance, this approach defines all possible compounds under various water heads and decides permissible operating areas using combinatorial mathematics. Next in [3], Automatic Generation Control (AGC) is provided in the paper with a redesigned cascade controller and renewable sources. A modern hybrid scheme is used for the optimization of controller parameters for better teaching, learning based on optimization-differential evolution (hITLBO-DE). Compared with hITLBO-DE tuned cascaded controllers with complex load shift, a Proportional Integrative Derivative (PID), Integral Double Derivative (IDD) and PIDD are used. In [4], the article is using a PID controller with automatic generation control and automatic voltage controller loops for two areas of power grid. Two field power systems with PSO integrated PID controller were investigated. The analogy with the proposed PSO-based controller indicates the best dynamic solution for a change in the load for the proposed controller. Figure 2.1 illustrate basic system of LFC and AVR.

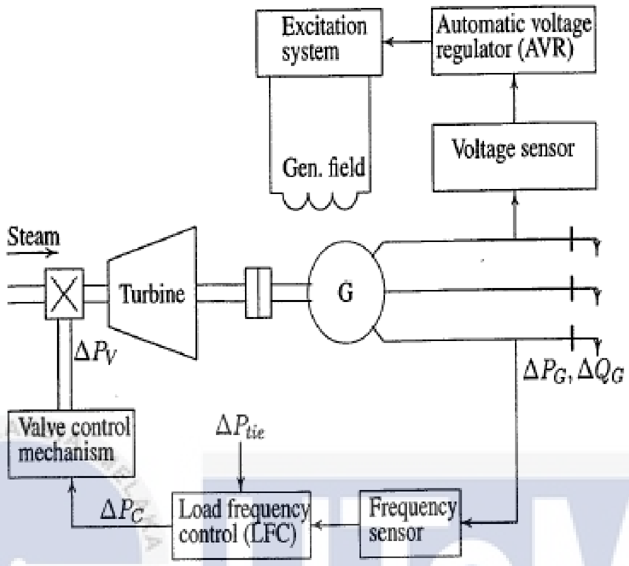

Figure 2.1: The LFC and the synchronous engine AVR schematic diagram [4]

Lastly, in paper [5] Automatic Generation Control (AGC) system is providing with an optimum frequency control Scheme for an integrated power grid, in real-life operating conditions, based on the regulator's saturation, generating rate limits, communications delays, and unfulfilled feed forward disturbance, for a state confined distribution model prediction (SCDMPC). It proposes a solution algorithm in case of contradictions, of state and input limitations within the SCDMPC Scheme.

2.2.1 Automatic Voltage Regulator

In [6], the contrast of a standard PI and PID controller is performed with a fuzzy logic controller. The intelligent controller which is fuzzy controller is better than the PI and PID. The measurement of the frequency variations in relation to time and the change in AGC and voltage governor control in the AVR time can be achieved with MATLAB software. In order to improve the transient power system stability limit, in [7] this work focuses on the design and realization of PNN-based AVR. In this project AVR has been developed in MATLAB/Simulink using various control schemes. The output of AVR is analyzed using normal controller, PID and PNN. This paper [8] introduces and is optimized for an automatic Voltage Control System a new proportional, integral, derivative and acceleration controlling device (PIDA). The parameters of the controller are constructed by using a harmony search algorithm to minimize square error.

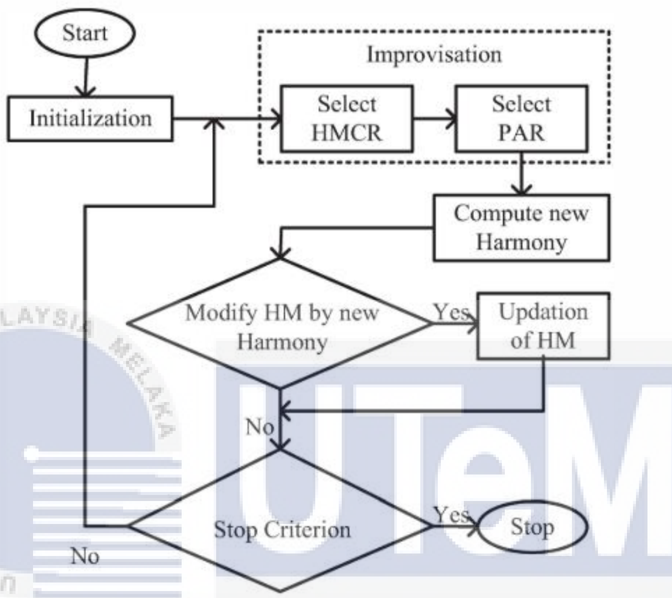

Figure 2.2: Harmony Search Algorithm [8]

In [9], simulation model AVR Controller developed by the power system based on the National Electricity Provider (PLN) real data (Tello Power Plant Makassar case). Under normal conditions, the AVR controller's reaction time is roughly neutral, and the loading time is approx. 15 seconds. Adjusting the PID controls would allow the regulating reaction time to adjust loads quicker and change the device voltage by +/-5 percent of the nominal tension with a voltage stabilization cap. The PID AVR controller is very useful for regulating the power generating device voltage due to load change.

2.2.1.1 Exciter Model

In [8] and [10] both paper are using the PID controller in the automated voltage regulator AVR system and designed the exciter block model by using the equation as stated below. K_E and T_E demonstrate the gain and time constants respectively.

$$\frac{V_f(s)}{V_r(s)} = \frac{K_E}{T_E S+1} \qquad (2\text{-}1)$$

2.2.1.2 Amplifier Model

A magnetic amplifier, a rotating amplifier or a new electronic amplifier may become an entertaining unit. In [11] and [12] both paper are using the PID controller in the automated voltage regulator AVR system and equation 2-2 demonstrates the amplifier's model in the AVR system. Constants of gain and time as seen by K_A and T_A.

$$\frac{V_t(s)}{V_u(s)} = \frac{K_A}{T_A S+1} \qquad (2\text{-}2)$$

2.2.1.3 Generator Model

The synchronous generator generated by emf is a system magnetization curve function and depends on the generator load. In [13] A Fuzzy-FOPID controller is used in the automated voltage regulator AVR system. While in [14] PID controller is used in the AVR system. K_G gain and T_G time constants will express the conversion function of the generator terminal voltage to its field volume. Equation 2-3 presents the representation function of the generator model in the AVR framework.

$$\frac{V_t(s)}{V_f(s)} = \frac{K_G}{T_G S+1} \qquad (2\text{-}3)$$

2.2.1.4 Sensor Model

In [15] and [16] both paper presents a new tuning design by using the new time-domain performance criterion Cuckoo Search (CS) algorithm of the proportional integer derivative (PID) controller in the automated voltage regulator(AVR) system. The sensor model is a basic transfer function in the first order, as defined in Eqn. 2-4. The K_R is gain, and the T_G is time constant.

$$\frac{V_S(s)}{V_T(s)} = \frac{K_R}{T_R S+1} \qquad (2\text{-}4)$$

2.2.2 Load Frequency Control

In [17], this paper uses auto load frequency control (ALFC) of a variety power sources. PID is uses to monitor AGC in multi-area and multipurpose practical power system without and with DC connection between two areas. However in [18], a modern hybrid fuzzy-PID controller is used for LFC. In [19], this article introduces a new PID controller architecture process based on the DS method to frequency domain controller design.

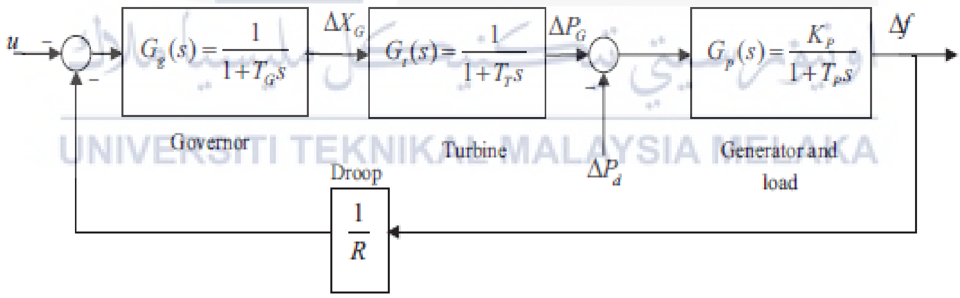

Figure 2.3: Block diagram of single area power system [19]

In [20], AGC simulated framework in the Mi-Power program is used to handle a two area network. The 'Mi-Power' detailed power system analysis software was used for network modelling and for load-flow and transient stability studies, including the AGC control systems block.