OPTIMAL LOCATION FOR SOLAR ENERGY STORAGE SYSTEM (SES) ON GRID CONNECTION

WAN IZZUDDIN BIN CHE WAN NOR AZIZI

A report submitted in partial fulfillment of the requirements for the degree of Electrical Engineering (Power Industry)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2013

"I hereby declare that I have read through this report entitle "Optimal Location For Solar Energy Storage System (SES) On Grid Connection" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature : ________________________

Supervisor name : NORHAFIZ BIN SALIM

Date : 19 JUNE 2013

" I declare that this report entitle " Optimal Location Of Solar Energy Storage System (SES) On Grid Connection " is the result on my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidaturee of any other degree "

Signature : ___________________________

Name : WAN IZZUDDIN WAN AZIZI

Date : 19 JUNE 2013

ACKNOWLEDGEMENT

First of all, I would like to give my thanks to the Almighty Allah, for giving me the strength and the ability to complete the project wholeheartedly. Without it I possibly cannot finish the project in a timely manner.

Secondly, I wish to hand a million thanks to this final year project supervisor En. Norhafiz Bin Salim for his encouragement guidance and consistent support in finishing this final year project.

For my beloved father and mother that very concern about my project, I really appreciate all of those supports and idea which both of you give to me. Thank you so much.

Lastly, to all the peoples that have whether directly or indirectly involved and contributed for the realisation of this project. Friends, librarians, I appreciate your help and involvement.

ABSTRACT

This report covers a method for Optimal Location of Solar Energy Storage System (SES) in grid network. Power line system consist a lot of system, therefore identification of the Optimal Location to plug the Solar Energy Storage System (SES) is needed. In this project, technique for Optimal Location of Solar Energy Storage (SES) has been proposed by using residue method. The parameter of residue method was considered the Jacobian Matrix and State Matrix. In order to identify the optimal location of the system, the Eigenvalue Analysis is performed. The effectiveness of the applied method of placement is demonstrated on grid network that consist 9 bus for small scale and 14 bus for large scale. For small scale system, Solar Energy Storage System (SES) is installed at bus 2 and for large scale system, Solar Energy Storage System (SES) is installed at bus 8. The applied placement technique is an effective method for the optimal allocation of Solar Energy Storage System (SES). In modern technology, residue method with Eigenvalue Analysis can be replaced by frequency response with Eigenvalue Analysis in order to simulate simultaneously the optimal location and the performance of the system.

ABSTRAK

Laporan ini meliputi kaedah untuk Lokasi Optimum Sistem Penyimpanan Tenaga Suria (SES) dalam rangkaian grid. Sistem talian kuasa mengandungi banyak basbar dan pengenalan lokasi yang optimum untuk Sistem Penyimpanan Tenaga Suria (SES) diperlukan. Satu teknik untuk menentukan lokasi yang paling optimum telah dicadangkan. Menggunakan kaedah sisa, lokasi dan kestabilan sistem telah dioptimumkan secara serentak. Elemen untuk kaedah sisa yang telah dipertimbangkan termasuk sistem Matrik Jacobian dalam sistem kuasa. Dalam usaha untuk mengenal pasti lokasi yang paling optimum, analisis nilai eigen telah dilakukan. Keberkesanan kaedah yang digunakan diaplikasikan pada rangkaian grid yang terdiri daripada 9 bas untuk sistem berskala kecil dan 14 bas untuk sistem yang berskala besar. Teknik penempatan yang digunakan adalah satu kaedah yang dilihat berkesan bagi menentukan lokasi yang paling optimum untuk Sistem Penyimpanan Tenaga Suria (SES).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF ABBREVATIONS

GUI	-	Graphical User Interface
PV	-	Photovoltaic
CSP	-	Concentrated Solar Power
REs	-	Renewable Energy
MINLP	-	Mixed Integer Non-Linear Programming
AHP	-	Analytic Hieracy Program
GA	-	Genetic Algorithm
TCSC	-	Thyristor Controlled Series Capacitor
SVC	-	Static VAR Compensator
SES	-	Solar Energy Storage
PSAT	-	Power System Analysis Toolbox
SYN	-	Synchronous
FACTS	-	Flexible Alternate Current Transmission System
AC	-	Alternate Current
DC	-	Direct Current

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

In electrical grids, power system network integrates transmission grids, distribution grids, distributed generators and loads that have connection points called busses. It means the grid network system have many busbar . In conventional , there are many system have been installed in the grid network such as FACTS controller and other stabilizers to solve the power system instabilities. Renewable energy sources such as solar energy and energy storage technologies could be combined, to provide a stable power system. Nowadays, solar energy system is the system that suitable to be use as an element in the grid network. Solar energy is the cheapest energy that can reduce the cost compare to other energy such as oil and gas. In modern electric power utilities , solar energy system basically have two Solar Energy Storage (SES). There are battery energy storage and supercapacitor storage.

Optimal location need to be consider in the Solar Energy Storage (SES) placement to make sure the grid system can running with specified and stable condition. The best location in pluggin the SES can increase the grid connection performance. The allocation of Solar Energy Storage System (SES) device to get the most effective stabilisation of system modes is a complex problem that require some factors consideration. Basically, there are three major part in power system grid connection which is generation, transmission, and distribution. Different part in power system means different operating condition need to be considered in order to find the optimal location of SES. The proposed algorithm is an effective and practical method for optimal allocation of SES in the grid network.

Similarly to most renewable energy sources, the solar energy source is characterised by an intermittent availability. To ensure the required level of operation continuity, proper storage systems must be provided. In particular, conventional batteries can be used to store energy. However, depending on the load characteristics, the battery ageing can reduce the component lifetime dramatically and increasing the costs. In case of large and highly variable electrical loads, the possibility to substitute part of the battery pack with a supercapacitor bank can be considered.

The project is using the application of residue method in Power System Analysis Toolbox (PSAT) for optimal location of Solar Energy Storage System (SES). The jacobian matrix algorithm technique from residue method is applied. This technique used to find optimal location of Solar Energy Storage System (SES) to achieve the maximum system stability.

1.2 Objective

The objectives of this project are :

i. To identify the optimal location to place Solar Energy Storage System (SES) in grid network.

ii. To design a technique for optimal location of Solar Energy Storage System (SES) using residue method.

iii. To analyze the performance of Solar Energy Storage System (SES) depend on its location.

1.3 Scope of Project

The scope of this project are:

i. The capacitance rating of Solar Energy Storage System (SES) for the system is 1000 Farad (F).

ii. The design and analysis for this project will be use application of Power System Analysis Toolbox (PSAT) in MATLAB software.

iii. The Eigenvalue Analysis will be perform to the system to get the optimal location.

1.4 Problem Statement

Existing power line consist many of busbar. The identification of busbar and branch is needed to locate Solar Energy Storage System (SES) in grid network. In conventional method, there are some difficulties in installing the system at the exact location compared to the applied method, as the conventional method implemented trial and error technique. On the other hand, power stabilizer component also need more control element and feedback signal. However, with Solar Energy Storage System (SES), it is vice versa.

1.5 Report Organization

In this report, it consists of 5 chapters altogether. Chapter 1 will brief introduction about the project. Chapter 2 contained full description of the project. Chapter 3 consisting of the project methodology especially about the project flow and how its organized. Chapter 4 will presenting the result and discussion, while the conclusion and recommendation presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed an overview of the method in identification of Optimal Location of Solar Energy Storage System (SES). The basic principle of Solar Energy Storage System (SES) and the energy storage technique also will be discussed. Two main commercial ways of conversion of sunlight into electricity also be included. It would also include brief overview of the Flexible AC Transmission System (FACTS) and Solar Energy Storage System (SES) device. Eigenvalue Analysis method also fully brief in order to find the optimal location to place the system. Lastly, the reviews of related power system analysis in order to analyze the performance of the system also be attached.

2.2 Method for identification optimal location

The residue method have been calculated for the appropriate operating condition to obtain optimal and suitable placement of a device or controller element for complex analysis. Basically, modal analysis techniques of residue method is based on the calculation of participation factors, transfer function residue, controllability and matrix indices. Basically, residue method is proposed in order to identify optimal locations for some controller such as Static Var Compensator (SVC) and Thyristor Controlled Series Capacitor (TCSC) [1]. Residue is compared to Genetic Algorithm (GA) and Analytic Hieracy Programming (AHP) method, where GA method is a method for finding the optimal location of a system controller in order to minimizing the overall system cost. A VC++ coding is developed for genetic algorithm and its shown this method is more complicated [2]. For Analytic Hieracy Programming (AHP), the Mixed Integer Non-Linear Programming [MINLP] has been used in this method [3]. The AHP method clearly indicate the ranking of optimal location for various kind of REs by provides the optimal location at various load serving node and ranking optimal bus location for the system [3].

2.3 Energy storage technique

For stand alone renewable energy system, certain energy storage device must be added into the system in order to provide power in demand. In conventional there are many technique of energy storage have been used. There are Molten Salt Energy Storage, Superconducting Magnetic Energy Storage, Underground Thermal Energy Storage and Supercapacitor Energy Storage [4]. In order to achieve the maximum charging capacity, Supercapacitor Energy Storage has been use because it can receive charge efficiently compared to other energy storage likes Molten Salt Energy Storage and Superconducting Magnetic Energy Storage [7]. Supercapacitor utilize the large surface area of electrode with thinner dielectric to achieve the greater value of capacitance and energy densities [4]. For Molten Salt Energy Storage, it is commonly used in solar concentrating thermal turbine. The main disadvantage of Molten Salt Energy Storage is low energy densities and very large amount of molten salt storage facility is require to store energy [7]. For Superconducting Magnetic Energy Storage, it has unlimited cycle of charging and discharging charge in short time but the large current is produced in conductor that can affect the superconducting material. Other disadvantage of Superconducting Magnetic Energy Storage are large cooling losses and fairly large investment cost [4]. It means Supercapacitor Energy Storage is more suitable to be use compared to Molten Salt Energy Storage and Superconducting Magnetic Energy Storage.

2.4 Solar Energy Storage System

There are two common types of energy storage in solar system. There are battery and supercapacitor. Solar energy storage like supercapacitors are the energy storage devices that are introduce by the same fundamental equations as conventional capacitors but it have higher surface area of electrode and thinner dielectrics to produce the higher capacitances. This storage can achieve value of capacitance up to 5000F [4]. It means their energy densities is greater than conventional capacitors and battery where battery can absorb and deliver both real and reactive power with sub-second response times [5]. Depends on their ability, battery storage systems can solve some case in solar power generation as ramp rate, frequency, and voltage issues [5]. However, depend on the load properties, the battery energy storage can reduce the component lifetime , and the cost will be increase. For the issue of large and highly variable electrical loads, the idea to change the part of the battery energy storage with a supercapacitor can be considered. In conventional, common grids that contain the electrical load suggests the uses of supercapacitors, to reduce the battery ageing and to extend the storage system lifetime [6]. The supercapacitor can receive charge efficiently much quicker than the battery. Besides that, the ability of supercapacitor to be charged and discharged thousands of times without any adverse effect on operating life is increase rapidly, and it can function well in bad condition such as in cold temperatures [7].

2.5 Types of solar energy conversion

Concentrated Solar Power systems (CSP) systems is use as the solar energy system (SES). Concentrated Solar Power (CSP) comprises a series of technologies devised for the transformation of the direct component of solar radiation into high temperature thermal energy by means of concentrators based on mirrors or lenses [9]. CSP can easily stored a large amount of energy with minimal losses. This system are very promising for substantial modification of energy and for the improvement of efficiency. CSP shown the cost reduction for future solar energy production but a large area of power plant is needed to place this system in the grid network rather than Photovoltaic (PV) panels that has been used today in many applications [9]. With the rapid development of photovoltaic system installations and the increased number of grid connected power system, it has become important to develop and efficient grid interfacing instrumentation and the storage system for power demand that suitable for photovoltaic system. Grid network system use a photovoltaic array to generate electricity, which is then fed to main grid via an inverter [8]. This system include photovoltaic solar panel, one inverter, one charge controller and a storage bank. The output power of photovoltaic varies with solar isolation, module temperature and load change has also increase in recent years about 24% to 30% [8].

2.6 Flexible AC Transmission System (FACTS) and Solar Energy Storage System (SES)

In conventional, many application of FACTS controller has been used in power network. Flexible AC Transmission Systems (FACTS), provide proven technical solutions for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time compared to the construction of new transmission lines [10]. On the other hand, FACTS controller need more control element and equipment compared to SES. There are some examples of conventional equipment of FACTS for enhancing power system control which is series capacitor for impedance contol, switched shunt-capacitor for voltage control and phase shifting transformer for angle control [10]. By using SES, the amount of control equipment can be reduce. Supercapacitors Energy Storage are the electrical device that contain double layer capacitors with no dielectric. The flow of charge is by ions dissolved in an electrolyte. Differ to conventional capacitor, this capacitor are "super" because the containing of large surface area of their porous carbon electrodes up to 2000 to 3000m2/gm, and the very small separation distance between the positive and negative charge, measured in Angstroms. The electrodes of the supercapacitor contain a porous separator between them and the value of capacitance is proportional to the surface area of the carbon electrodes [11]. Supercapacitor is choosen because its control element is little bit rather than FACTS.

2.7 Eigenvalue Analysis and Contigency Analysis

The Eigenvalue Analysis is proposed based on the well known of inverse iteration method and involve the direct use of power system jacobian matrix. In traditional, the first successful attempt to calculate the dominant eigenvalue of large power system has the quite complex computing procedure. By using the formation of the power system jacobian matrix, a package of computer program is developed in order to calculate some parameter of Eigenvalue Analysis. Its include the calculation of the exact eigenvalue closest to a specified point in the complex plane, an associated eigenvector, exact eigenvalues associated with the dominant modes of oscillation of the system and full eigensolution of the power system state matrix [12]. In order to identify the optimal location for a system, Eigenvalue Analysis is prefer to be used compared to Contingency Analysis. Its is because, Contingency Analysis is performed to detect and rank the severest line faulted contingencies in a power system. Contingency Analysis is one of the most important functions performed in power systems to establish appropriate preventive and corrective actions for each contingency. Contingency Analysis procedure consists of line contingency analysis, contingency selection, detection of overloaded line, low bus voltage violations, and ranking of the severest contingencies cases [13]. Its shown Contingency Analysis is more complicated rather than Eigenvalue Analysis.

2.8 Power flow

Power flow is important in order to determine the best operation of a power network. The electrical parameter such as magnitude and phase angle of the voltage at each bus, real power and reactive power can be analyze simultaneously from power flow study. There are three common power flow method that usually have been use in power system analysis. Its include Gauss-Seidel method, Newton- Raphson method and Fast-Decoupled Load Flow method. Gauss-Seidel method shows the slower rates of converges and cannot solve a matrix system compared to Newton- Raphson method that has the better rate of converges and can solve a matrix system [13]. Besides that, Newton- Raphson method also is an outstanding power flow algorithm that has the higher precision in the main network. Its shown Newton- Raphson method rather to be use in power system analysis compared to Gauss-Seidel method [14]. For Fast-Decoupled Load Flow method, its is more complicated