CHAPTER 1

INTRODUCTION

1.1 GENERAL

The New and Renewable Energy resources are proposed by Ministry of New and Renewable Energy sources and Energy Development agencies to balance the need for the energy in the forthcoming years. The exploitation and development of various forms of energy and making energy available at affordable rates is one of the major thrust areas.

Conversion of energy resources, environmental protection and sustainable developments are the three major changes of the world. One important issue is to satisfy the energy needs of people without causing rapid depletion of natural energy resources and degradation of the environment. Now-a-days wind energy has the most exploitable potential of renewable energy and has attracted great interests in recent years. Large wind farms have been installed or planned around the world and the power rating of the wind turbines are increasing. Wind generator is the crucial equipment to use wind energy.

Generation of electricity has emerged as the most important application of wind energy worldwide. The concept is simple; blowing wind rotates the blades of a turbine and causes electricity to be produced in generator unit. It is environmentally benign and does not emit greenhouse gases. Induction generators are more commonly used in Wind Energy Conversion Systems (WECS). An induction generator is an induction motor operating above its synchronous speed. Due to its simple construction the induction generator is well suited for many industrial co-generation applications.
Voltage stability is a relatively recent and challenging problem in power systems engineering. Severe and increasing strain has been observed in the power system in recent years due to incongruence between the generation and transmission infrastructure. Environmental issues, change in energy portfolio and deregulated energy markets are some of the prime factors. The kind of stress developed in the system has caused concerns for voltage instability. Voltage stability refers to the ability of a power system to maintain steady voltages at all buses in the system after being subjected to a disturbance.

1.1.1 MOTIVATION

The motivation of this thesis is to elaborate on the methods to maintain voltage stability. The proposed controllers should be fast and accurate such that control signals can be sent to appropriate locations quickly and effectively. Even though the rotor speed varies within the specified range the terminal voltage should be maintained stable and also due to variations in the load side the load voltage should be maintained stable. Hence, it is proposed in the thesis about the enhancement of the power generation and voltage stability using various modern schemes.

1.2 LITERATURE SURVEY

Liu Lingshun, Hu Yuwen and Huang Wenxin (2005) suggested about the Optimal Design of Dual Stator Winding Induction Generator with Variable Speed based on Genetic Algorithm. The optimization theory of excited capacitors to minimize reactive power of control winding in the variable speed is discussed in this paper. Bansal R.C (2005) discussed about the comprehensive literature review on the important aspects of the SEIG such as the process of self-excitation and voltage buildup, modeling, steady state and transient analysis, reactive power control, and parallel operation. Mária Imecs, Csaba Szabó, János Jób Incze (2007) discussed about the Stator-Field-oriented Control of the Variable-excited Synchronous Machine. The paper deals with the modeling of the synchronous Machine with exciting and damper

Louze L et al (2009) discussed a simple control structure based on the sliding mode algorithm for an isolated-loaded induction generator. Ali Ozturkand Kenan Dosoglu (2010) discussed the voltage stability of the bus load in various static and dynamic load systems that are fed by a wind farm. Paulo Fischer de Toledo (2005) proposed the analysis of a configuration consisting of a Wind Farm based on conventional fixed speed Induction Generator. The generator was magnetized with fixed capacitor banks for unit power factor operation during steady state conditions. The STATCOM was introduced to increase the transient stability conditions of the generator. Sharaf.M and Ismail H.Altas (2007) discussed the STATCOM controller for reactive Power compensation in distribution networks. This paper presented a multi loop dynamic error driven controller based on the d-q voltage and current tracking system.

Yuan-Rui Chen Norbert C. and Cheung Jie Wu(2004) discussed about H\(_\infty\) Robust Control of Permanent Magnet Linear Synchronous Motor in High-Performance Motion System with Large Parametric Uncertainty. In this paper, the authors proposed to use an H\(_\infty\) robust-controller to overcome the load uncertainty problem. Tomonobu Senjyu (2007) discussed about the Stabilization Control for Remote Power System by using H\(_\infty\) Decentralized Controllers. This paper presented a methodology for controlling grid frequency and terminal bus voltage. Kenichi Tanaka Toshihisa Funabashi, Tomonobu Senjyu (2009) discussed about the balancing Control of PV Power and Dispersed Generators using H\(_\infty\) Control. This paper proposed the control system to achieve balancing control and interconnection point power flow control by using fuel cell and ultra-capacitor based on H\(_\infty\) control theory. Research in
enhancement of voltage stability indicates a need to maintain stable voltage in wind power generation system for efficient operation.

1.3 WIND TURBINE CALCULATION

In wind parks, many wind turbines are equipped with fixed frequency induction generators. Thus the power generated is not optimized for all wind conditions. To operate a wind turbine in its optimum speed, the wind turbine should be operated at its maximum power coefficient (Cp-optimum = 0.3 to 0.5). To operate around its maximum power coefficient, the wind turbine should be operated at a constant tip-speed ratio, which is proportional to the ratio of rotor speed to the wind speed. As the wind speed increases, the rotor speed should follow the variation of the wind speed. In general, the load to the wind turbine is regulated as a cube function of the rotor rpm to operate the wind turbine at the optimum efficiency. The aerodynamic power generated by wind turbine can be written as:

\[ P = 0.5 \rho A C_p V^3 \]  \hspace{1cm} (2.1)

where the aerodynamic power is expressed as a function of the specific density of the air, the swept area of the blades (A) and the wind speed (V). To operate the wind turbine at its optimum efficiency (Cp-optimum), the rotor speed must be varied in the same proportion as the wind-speed variation. To track the wind speed precisely, the power can also be expressed in terms of the rotor speed.

\[ P = K \text{ rpm}^3 \]  \hspace{1cm} (2.2)

The power described by equation (2.2) will be called P ideal that is the power to be generated by the generator at different rotor rpm. One way to convert a wind turbine from fixed speed operation to variable-speed operation is to modify the system from a utility-connected induction generator to a self-excited operation. Ideally, if the inertia of the wind turbine rotor is negligible, the rotor speed can follow the variation of the wind speed and the output power of the generator is controlled to produce the power-speed characteristic described in equation 2.2. Thus the wind turbine will always operate at Cp-optimum. In reality, the wind turbine rotor has a significantly large inertia due to the blade inertia and other components.
The main drawback in induction generator is its need of reactive power means to build up the terminal voltage and the drawback is not an obstacle today where PWM inverters can accurately supply the induction generator with its need from reactive power. The minimum terminal capacitor required for induction generator to build up is the main concern. Most of previous work uses numerical iterative method to determine this minimum capacitor. But the numerical iteration cannot be used online because it takes long time and divergence may occur.

1.4 OBJECTIVE OF THE THESIS

The research objective of this thesis is to design various controllers for stable power generation and stable load voltage for the Self excited Induction Generator which are summarized as follows

i. To design the optimum value of capacitance using the GA method

ii. To design the optimum value of capacitance for the excitation using the proposed simple algorithm

iii. To estimate the stator flux from the monitored stator terminal voltage and stator current using d-q equivalent model and to maintain the terminal voltage

iv. To develop STATCOM controller to maintain the terminal voltage stability using d-q equivalent model

v. To develop Sliding mode controller for the load voltage stability

vi. To develop $H_{\infty}$ controller for the load voltage stability

vii. To provide Combined Sliding mode- $H_{\infty}$ controller for the load voltage stability

1.5 PROPOSED PROBLEM DEFINITION FOR THE STABLE WIND POWER GENERATION

**Approach 1**: Optimum Excitation Capacitance (EC) for the SEIG is designed using,

i) GA method

ii) Parameter Optimization method
The GA method approach is based on the GA technique to find the optimum value of EC required exciting SEIG. GA based modeling has been proposed to find the optimum value of the capacitance for SEIG. Also, Parameter Optimization method is proposed to determine the Optimum EC for SEIG online with minimum time.

**Approach 2**: Terminal voltage stability of the SEIG is enhanced by Stator flux oriented vector control using d-q axis equivalent model.

The approach is based on the Stator flux oriented vector control of SEIG using d-q axis equivalent model. The terminal voltage of the SEIG is controlled using the vector control technique.

**Approach 3**: Load side voltage stability of SEIG is enhanced using the following:

i) Basic STATCOM controller  
ii) STATCOM controller using d-q axis equivalent model of SEIG  
iii) Sliding mode controller using DC-DC Converter  
iv) $H_{\infty}$ controller  
v) Combined Sliding mode -$H_{\infty}$ controller

The approach is based on the voltage stability of the load side of the SEIG. The STATCOM controller and STATCOM controller using d-q axis equivalent model are proposed to control the voltage generated from an isolated SEIG.

Sliding mode, $H_{\infty}$ controller and combined Sliding mode-$H_{\infty}$ controller are also proposed for the robust control of wind power generation systems for the load voltage stability. The load voltage can be maintained constant with even large variation in the output of the induction generator.

### 1.6 ORGANIZATION OF THE THESIS

The chapter 2 consists of the formula to calculate optimum value of capacitance by using nodal analysis, algorithm to calculate optimum value of capacitance for the induction generator, application and results, D.C output voltage for various ranges of
capacitances, characteristics of D.C output voltage for various ranges of capacitances, stator flux versus capacitance, capacitance versus rotor speed and conclusion.

- Genetic Algorithm method
- Parameter optimization method

The chapter 3 consists of d-q axes induction machine model, implementation of stator flux oriented vector control, results consisting of the characteristics of output for excitation using three capacitors, Excitation using inverter, Voltage controlled SEIG, DC voltage output and conclusion.

- Stator flux oriented vector control using d-q axis equivalent model.

The chapter 4 consists of Introduction, Problem Statement, Basic model of STATCOM, Basic STATCOM control scheme, STATCOM based load voltage stability of SEIG, Design of basic STATCOM controller for the load voltage stability of SEIG, STATCOM controller to enhance the terminal voltage stability using d-q equivalent model, System configuration and control scheme, Modeling of control scheme of STATCOM, Quadrature component of reference source currents, In-Phase component of reference source currents, Total reference source currents, PWM current controller, Modeling of STATCOM, Modeling of SEIG, Results and Conclusion.

- Basic STATCOM controller
- STATCOM controller using d-q axis equivalent model

The chapter 5 consists of Introduction, Problem Statement, Sliding Mode Control, Sliding Mode Control for Boost Converter, Design of Sliding Mode Controller, Simulation Diagram for Sliding Mode Controller, Results, H Infinity Controller, H Infinity problem formulation, Design of $H_\infty$ controller for the load voltage stability, Stabilization control for wind generator using $H_\infty$ controller, Outline of H-Infinity controller design, Results, Sliding Mode H infinity controller for load voltage stability, Block diagram of SEIG using SMC and H infinity controller, Results and Conclusion.