RISK-BASED AVILABLE TRANSFER CAPABILITY (ATC) ASSESSMENT INCLUDING NON-DIASPATCHABLE GENERATION.

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To my beloved parents,

Mortaza Khosravifard, Mehri Tavalla

Brothers and Sister,

Mehrdad Khosravifard, Mina Khosravifard

And all my Friends

All my teachers and lecturers,

For their encouragement,

Support and motivation

Through my journey of education.

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ABSTRACT

Available Transfer Capability (ATC) is a measure for assessing the capability between different areas of the power systems which are governed by non-linear power flow equations. ATC contains different complicated parts. Total transfer capability (TTC) and two margins; transmission reliability margin (TRM) benefit margins (CBM) are the main parts which have to be considered for accurate calculation. This report conducts the ATC evaluation with the main part, TTC, by a continuation power flow algorithm (CPF). CPF is an attractive method for non-linear equations and specially is used as the solution to power flow equations due to its capability for solving the power flow algebraic equations at the bifurcation nose point. CPF algorithm has been compared with other types for power flow equation solution algorithms and obtained based on its superior characteristics over them. Integration of wind farms into the IEEE 30-bus test system at a different location was successfully done. non-dispatchable generation impacts on ATC value has been checked by considering the probabilistic method for wind turbine power output, while both thermal and voltage system limitations have been applied. Results show that, available transfer capability is dramatically declined by considering these power system limitations. In addition, integrating of the wind farm into the test system has increased the power system loading parameter and similarly ATC. It was shown that by changing the location of injected wind power into the power system, ATC is changed. This change firmly depends on the voltage profile level of the connected bus into the wind farm and also weather conditions in the wind farm.

ABSTRAK

Krupayaan pemindahan penyadiaan (ATC) adlah pengiraan untuk mengenalpasti keupayaan perbezaan antara kawasan dalam system kuasan samaada linear dan bukan linear aliran kuasa persamaan. ATC mempuuyai perbezaan bahagian yang rumit. TTC dan TRM dan CBM adalah bahagian utama yang perlu mensenalpasti ATC melalui TTC yang mana mengunakan CPF algoritma. CPF adalah kaedah yang menarik untuk bukan linear persamaan dan dikhususkan dala persamaan aliran kuasa disebabkan oleh kaedah ini sesuai dalam persamaan graf PV leuskuy CPF algoritma telah dibandingkan deusan kaedah lain. Menssunakan kebun angina dalam IEEE 30 bus system telan Berjaya dilakukan kesan keatas ATC telah diperiksa mensgunakan kaedank ebaranskalian kuasa turbin angina dan turut mengambilkira had maksima voltan dan haba dalam system kuasa. Keputusan menunjukkan ATC barjaya dihapuskan melalui system kuasa kadar had maksima. Hal ini menunjukkan melalu pertukaran tempat kuasa angina dalam system kuasa, ATC belah berelban. Perabahan ini bergantung pada profil paras voltan dalam perhubuagan titik beban kepada kebun ansin dan bergantung pada keadaan cuaca dalam kebun angin.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLES

K	-	Shape Factor.
C	-	Scale Factor.
$f(u)$	-	Frequency of Occurrence of Wind Speed.
u	-	Frequency Distribution.
λ	-	Load Parameter.
$P_{Li\,0}$	-	Original Active Load at Bus i
Q_{Lio}	-	Original Active Load at Bus i.
K_{Li}	-	Multiplier to designate the rate of load change at bus i.
$\emptyset_i$	-	power Factor at bus i.
I_t	-	Current for To End Side.
I_f	-	Current for From End Side.
Y	-	Admittance Matrix.
γ_h	-	Weighting of the participation factor for each generator.
C_ρ	-	Curve power coefficient.
ρ	-	Air Density.
σ	-	Solidity.
k_G	-	Participation Factor.

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

Now a day's electrical markets have taken some steps to deregulate the power system environment to make the system more competitive and reliable. As a result, customers have an enough opportunity to select between different suppliers subject to price and reliability [1]. According to deregulated structure, electrical systems should use the maximum capability of the transmission line system to fulfill deregulation goals. Relevant to this idea, transfer capability of Transmission lines has been an interesting issue for several years. In the context of transmission open access, there is a need for flexible use of power grids in order to allow a non-discriminatory access of generators and loads to the transmission system. Environmentally, construction of new transmission lines would be a problem for many governments, which persuade electrical companies to work on increasing the transmission line capability instead of constructing new transmission lines. In isolated or radial electrical systems, capability calculation would be an easy task, because voltage drop and thermal rating should be considered. When the system changes to interconnected system, other important issues should be considered. There are several parameters in the interconnected system that we should consider for capability calculation; which are divided into the following issues:

- Voltage limits

- Stability limits
- Thermal limits [2]

Generally, one of the famous parts in capability calculation is calculation of available transfer capability (ATC) which is a very efficient way to get the accurate capability. ATC is divided into the several parts including Total Transfer Capability (TTC), Transfer Capability Margin (TRM), and Cost Benefit Margin (CBM). Each part considers several electrical system parameters and by considering all parts, ATC would be calculated in the best way.

1.2 Background of Study

For several years capability was an interesting subject among the researchers, and several methods and parameters have been issued. In 1996 the North American electric reliability council (NERC) issued the paper regarding to ATC definition and determination which is the first reference to formalized ATC definition. Latter several journals and papers have been published relating to the ATC calculation based on different methods and algorithms. Also NERC distinguished between the exact definition of capability and capacity in the power system. Capability is a transmission parameter which is related to the stability, voltage, and also thermal limits and it is a directional measure which means the capability of transferring power from Area A to Area B is not equal to capability of transferring power from Area B to Area A. On the other hand, capacity just related to the thermal rating and direction is meaningless for capacity. Capability also should be checked time by time or frame by frame because its constraints will change over time, as it is shown in the Figure 1, where totals transfer capability (TTC) varies. It could change based on the power system condition and also constraints and it is the main reason for checking the ATC periodically.

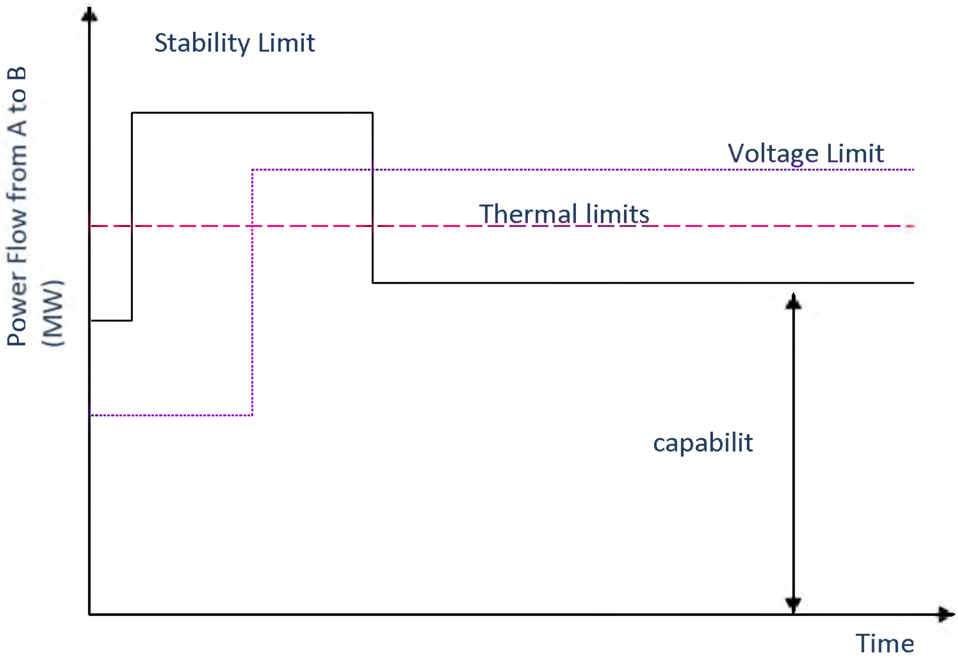

Figure1 Total transfer capability changes in different time frames.

ATC is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above already committed uses [3]. Mathematically, ATC = TTC – TRM – Existing Transmission Commitments (including CBM). Total Transfer Capability (TTC) is the amount of electric power that can be transferred over the interconnected transmission network in a reliable manner based on all the specific conditions. Transmission Reliability Margin (TRM) is the secure operation of the interconnected transmission network to accommodate uncertainties in system conditions and finally Capacity Benefit Margin is the access to the generation of interconnected systems to meet generation reliability requirements [3].

1.3 Statement of Problem

Today, with the introduction of new technologies, electrical generation has improved and renewable energies like wind turbine, solar cell, and etc. become popular in the electrical system. These energies are clean and help our environment a lot, but these types of generations have a big problem. These types of generation are known as the non-dispatch generation. This weakness is due to the wind speed and sunshine fluctuation which can effect on the output power of generation. In the ATC world, this phenomenon could cause a huge impact on ATC calculation and also makes our algorithm more complicated. On the other hand, several algorithms have been introduced for calculating the ATC by different authors. They analyze and compare all methods to find the best one. Lastly, risks associated with the different system operating conditions for calculating the ATC would be considered to evaluate the renewable-energy influences upon electrical system risks.

1.4 Objective

This study contains three main objectives, which are outlined below:

a) Analysis of Available Transfer Capability (ATC) and total transfer capability (TTC) algorithms for finding the proper methods to calculate of TTC and ATC.
b) Understand the characteristics of non-dispatchable generation, wind and solar-energy systems, and how they impact the ATC calculation.
c) Develop a framework to evaluate the ATC considering risks associated with various system operating conditions, particularly those related to non-dispatched renewable generation.

1.5 Significance of the Study

Although the major portion of electricity generates by conventional generation station, but due to the fuel costs and environmental issues, development of non- dispatchable generation's farms are in the first priority of the industrialized countries in the power generation aspect. ATC analysis is one of the important aspects of those countries whom have been replacing non-dispatchable energy with conventional generation type. System Characteristics in each country define ATC calculation algorithm method, which can affect calculation and analysis time duration. Countries like Norway and England with long distance between generation and load have special characteristics in voltage stability issues, and their stability would be on the edge when non-dispatchable specially marine and wind turbine's farms form approximately more than 25% of the energy sector. This study shows the effect of appropriate method for ATC calculation in these countries.

1.6 Scope of Project

This study is simulated by using the IEEE 30-bus system. ATC algorithm is formed by means of Matlab Software. The algorithm includes drawing the appropriate P-V curve for specified, calculating the maximum lambda in that bus, calculating the voltage of other bus respects to the maximum lambda, inserting the line flow and voltage constraints, specifying the participating factor for distributed generation, inserting wind turbine into the system, and finally calculating the ATC and its risk over the system.

1.7 Project report Outline

This project report consists of six major parts, which could be categorized as below:

1. **Introduction** in which provides and prepares the outline of ATC study and also the overall background of the non-dispatchable generation of the power systems.
2. **Literature review** in which I took a critical look at the existed literature for making the comparison between methods to calculate the TTC and find the best method for specified power systems. Also parameters for implementing distributed slack have been analyzed and eventually the literature regarding wind turbine impacts on ATC calculation has been studied.
3. **Theoretical Analysis** refers to the mathematical part of this project report. Several equations have been used to justify our calculation and used algorithm. In this section, I will show the different steps of continuation power flow mathematically. An approach to getting transmission line flow and Y_{Bus} with the Y_{Branch} . Distributed slack bus has been evaluated and its equation with participation factor consideration has been shown. To continue, mathematical models of wind turbines and wind speed have been defined. And finally, the equation regarding ATC was represented.
4. **Methodology** starts with an introduction and continues by introducing the Power System Tool (PSAT) and then modelling power system data in the PSAT. Finally, three main scenarios introduce for IEEE 30-bus test system.
5. **Result and discussion** which conduct the result of three scenarios in the previous chapter and will discuss about these results in the separate parts.
6. **Conclusion and recommendation** which refer to conclude the overall results and a look for future tasks.

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