DETERMINATION OF ATC AND SECURITY FOR POWER SYSTEM USING AI TECHNIQUE

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To my beloved mother, brothers and sister

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ABSTRACT

Available Transfer Capability (ATC) has recently gained the interest of power industry and deregulated environment. To achieve efficiency and precision in utility operation, the determination and calculation of ATC are important. There are many technical challenges that are involved in computing ATC values. This includes the total transfer capability calculation, transmission capability margins and probabilistic ATC calculation. In power system deregulation, the Independent System Operator (ISO) is responsible to control the power transactions and also to avoid overloading of the transmission lines beyond their thermal limits. The ISO has to determine the ATC index periodically in real time to enable market participants to reserve the transmission service. To test the performance of the methodologies and programs for IEEE-30 bus system, the proposed computation procedure of ATC with margins using conventional technique has been developed . The results have been compared with a developed fuzzy model using the data sets that are not used for training purpose. The data set, line number and the relative error have been recorded for analysis. The results suggest that ATC can be accurately estimated by using fuzzy logic for various load levels.

ABSTRAK

Jumlah keupayaan pemindahan tenaga (ATC) adalah satu konsep yang baru dan makin mendapat tempat di dalam industri pembekalan kuasa. Dalam sistem penghantaran kuasa pada hari ini, keupayaan pemindahan tenaga tersedia (ATC) adalah penting untuk memastikan kecekapan system dan operasi yang kompetitif.. Pengiraannya melibatkan banyak faktor teknikal termasuk pengiraan jumlah keupayaan penghantaran, margin penghantaran dan keberangkalian keupayaaan penghantaran. Dalam industri kuasa, pengendali sistem bebas (ISO) adalah bertanggungjawab untuk mengawal transaksi kuasa dan juga perlu mengelak penghantaran kuasa melebihi had. ISO perlu mempunyai indek dalam waktu semasa untuk membolehkan transaksi kuasa berlaku. Dalam projek ini, pengiraan keupayaan pemindahan tenaga pada IEE-30 bus telah dijalankan. Pengiraan telah ditentukan agar selari dengan situasi pada persekitaran keaadaan. Keputusan dan data yang diperolehi dibandingkan dengan model fuzzy yang dibangunkan.

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LIST OF SYMBOLS AND ABBREVIATIONS

$P\Delta$	Real power change
$Q\Delta$	Reactive power changes
$V\Delta$	Changes in the voltage magnitude
$\delta\Delta$	Changes in the phase angle

ATC	Available Transfer Capability
TTC	Total Transfer Capability
TRM	Transmission Reliability Margin
CBM	Capability Benefit Margin
NERC	North America Electric Reliability Council
OASIS	Open Access Same-time Information System
FERC	Federal Energy Regulatory Commission
RTO	Regional Transmission Organizations
LODF	Load Open Distribution Factor.
PTDF	Power Transfer Distribution Factor.
GSF	Generation Shifting Factor.
CPF	Continuation Power Flow.
OPF	Optimal Power Flow.

CHAPTER 1

INTRODUCTION

1.1 Project Background

Electricity industry around the world is currently facing major changes and is moving towards deregulation to create a more competitive market in trade electricity which can pose new challenges for market participants and power system researchers. It requires non-discriminatory open access to transmission resources for transmission systems,

Besides that, the structure, management and operation of this industry are also changing making it very difficult to continue using the old regulated structures. To rise up to the challenge of the new market, a shift has to be made to the management styles as well as decomposing the power companies in two main component namely the Generation Company and the Transmission Company. To ensure precision and effectiveness, the methods used in the operation must be adopted to flexible optimization and negotiation techniques that can handle changes in the system conditions.

Today, it is already possible for long distance power transfer to be made available to remote areas through power trading activities in case of any blackout event. For this reason, power can be considered as a business commodity. During annual generator or transmission line maintenance, power could be bought from other owner's generator control areas to serve native loads instead of interrupting the loads.

Sometimes, power is bought by a certain control area from others simply because the selling price is lower than generation costs of the current time. In general, the deregulated structure has made power industry much more complex and competitive than before. To operate more efficiently, many power companies have made maximized utilization of generators and transmission lines their main aim. However, the transmission system has set up a limit on the amount of power transfer. The transfer capability is maximum amount of power that can be transferred from one point to another. The system Available Transfer Capability (ATC) is calculated to further trading activities over the committed transactions without compromise to the system security and reliability,

Under the new regulations from the North America Electric Reliability Council (NERC), every new transaction made and most updated ATC values must be posted on the Open Access Same-time Information System (OASIS) by all interconnected power companies. Therefore, the ATC calculation is a necessary operational tool for daily routine operation. It is also very effective for interpreting the power system's performance besides being economical and efficient. If a system can facilitate a large amount of multi-area transfer, the system would normally be flexible, in good condition and more secured than a system which has limited transfer. Transfer capability can also be used to predict improvement for future transmission.

A transmission expansion is easier to be justified to increase the transfer capability instead of improving other alternatives that can bring less advantage to the companies involved.

The transfer capability calculation of transmission system has been discovered as early as 1970 (e.g. Landgren *et. al* (1972)), but the research did not receive researcher's interest until Federal Energy Regulatory Commission (FERC) mandated the order 888 and 889 in 1996. The mandate required that the ATC information of the transmission network should be calculated and posted on OASIS. They claimed that the public utility had to open its transmission grid for use by participants of market and. Shortly later in the same year, NERC brought the industry together to establish a framework for ATC definition and evaluation.

ATC was defined by NERC to be the transfer capability remaining in the physical transmission network for further commercial activity over and above already committed uses. Determination for ATC involves a huge system database and excessive computational time. According to NERC definition, ATC is the difference between Total Transfer Capability (TTC) and the sum of the Transmission Reliability Margin (TRM), Capability Benefit Margin (CBM), and the existing transmission commitments.

The total TTC is considered as the real power transfer at the first security violation without including the existing transmission commitments. TRM is defined as the essential amount of the transmission transfer capability to make sure that the interconnected network is secure under a reasonable range of uncertainties in system conditions. CBM is the amount of transmission transfer capability reserved by load serving entities to ensure access to generation from interconnected system to meet generation reliability requirement. Limited transfer case is determined by gradually adding the amount of transfer starting at the base case transfer until the first security violation is encountered from a secure base case transfer (which includes existing transmission commitments). The Available Transfer Capability can also be defined as:

$$ATC = TTC - TRM - CBM - \text{Existing transmission commitments} \quad (1.1)$$

Furthermore, each ATC calculation may be checked by screening a short-listed contingency, and the minimum value of all calculated ATC values is used to exercise further trading activities with an insurance of the system security and reliability.

The definition of TTC [1] between any two areas or across particular paths or interfaces is direction specific. TTC is the amount of electric power that can be transferred over the interconnected transmission network in a reliable sequence.

i) For the existing or planned system configuration and with normal (pre-contingency) operating procedures in effect, all facility loading are within normal ratings and all voltages are within normal limits.

ii) The electric systems are capable of absorbing the dynamic power swings, and remaining stable, following a disturbance that results in the loss of any single electric system element, such as a transmission line, transformer, or generating unit.

iii) After the dynamic power swings subside following a disturbance those results in the loss, the any single electric system element as described in 2, and after the operation of any automatic operating systems, but before any post-contingency operator-initiated system adjustment is implemented, all transmission facility loading are within emergency ratings and all voltages are within emergency limits.

iv) With reference to condition 1, when pre-contingency facility loadings reach normal thermal ratings at a transfer level below that at which any first contingency transfer limits are reached, the transfer capability is defined as that transfer level at which such normal ratings are reached.

v) In some cases, individual system, power pool, sub-regional, or regional planning criteria or guides may require consideration of specified multiple contingency, such as the outage of transmission circuits using common towers or right-of-way, in the determination of transfer capability limits. If the resulting transfer limits for these multiple contingencies are more restrictive than the single contingency considerations described above, the more restrictive reliability criteria or guides must be observed.

These terms, particularly the ATC, form the basis of a transmission service reservation system that will be used for reserving transmission services, scheduling recallable and non-recallable energy transactions and arranging emergency transfers between areas of an interconnected power network in the competitive electricity market. Concerning both operating horizon and planning horizon, the mathematical definition and relationships of TTC, ATC and related terms in the transmission service reservation system are depicted in Figure 1.1 as below

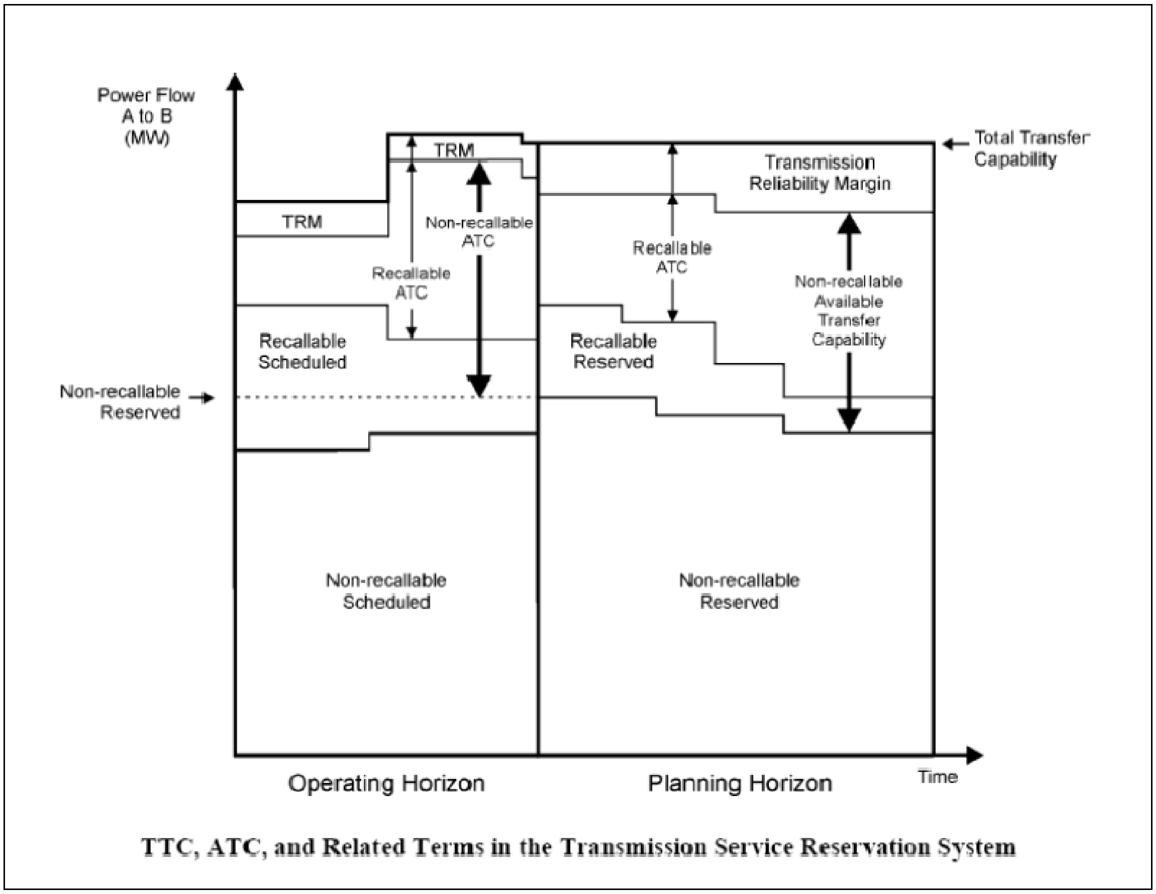

Figure 1.1: Relationships of ATC and related terms in the transmission service reservation system.

1.2 Problem Statement

To overcome any weaknesses in power transmission capability and increasing demand of power need, new transmission lines could be added. Nonetheless, setting up or expanding transmission lines need to match the different power demand profile in different areas and accommodate a volatile fuel cost structure. In addition, environmental effect consideration must also be taken into account before setting up new transmission lines.

Besides that, the construction of generation facilities and transmission lines needed might be prevented or delayed for a long time due to the cost and regulatory difficulties that are necessary in running new projects.

As there is large investment involved in power market and environmental effects in constructing new transmission lines, enhancing the Available Transfer Capability (ATC) of the existing transmission lines is one the best solutions available. Hence, the best and most reliable approach and compensation technique to cope with existing problems should be chosen to deal with the problems.

It is important to accurately and efficiently calculate the available transfer capability (ATC) of the transmission system in deregulated power system. The ATC will be evaluated by using both the proposed quadratic sensitivity method and the AC power flow method. Point-to-point transfer and the area-to-area transfer will also be considered when evaluating the ATC. To define the critical lines in the systems which will be considered in the ATC assessment, contingency screening and ranking techniques are used in the first stage. There are many simulations that have been executed out to calculate the ATCs by considering the voltage and line security limits as well as the voltage stability limits. Simulation results were analyzed based on the effectiveness and accuracy of the proposed quadratic sensitivity and the AC power flow methods.

1.3 Objectives

The objectives of this project are:

1. To develop the Available Transfer Capability computational technique using power flow method for power system
2. To implement the methodology using MATLAB and PowerWorld software.
3. To test the methodology using AI technique which is Fuzzy Logic and benchmark with computational technique using power flow method.

1.4 Scope of Study

The scopes of the study are:

- To find information in identifying the Available Transfer Capability (ATC) calculation methodologies are essential in order to proceed to the next stage.

- For the purpose of this project, the IEEE test system chosen to analyse the ATC is the 30 bus. For medium scale, the 11 bus IEEE test system is chosen for analysis. While for the large scale system, the IEEE test system chosen to be analysed are the 26 bus and 30 bus test system. All the analysis includes calculations of the ATC value without any contingency at the system.

- For the load flow of the IEEE test system for this project, the fast decoupled method is used as it is fast in solution, and could decouple between mismatches of real power and reactive power.

- AI implementation in ATC and potential AI applications to power system operations will be explored. The result obtained using AI would compare to the calculation method..

1.5 Thesis Organization

This thesis is divided into five chapters as follows:

Chapter 2 presents the literature review on the determination and calculation of the Available Transfer Capability (ATC).

Chapter 3 describes in detail about the methods are used to calculate ATC and design fuzzy model in this project. This chapter also describes the step-by-step methods to obtain ATC and other related parameters.

In Chapter 4, the results of this project were discussed. It also describes the details of the IEEE test system besides including all the important data. The analyses of the test system include all the scale of power system.

Chapter 5 of this thesis provides space for conclusions and a few recommendations that might serve as the contributions of the author.

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