DETERMINATION OF AVAILABLE TRANSFER CAPABILITY UNDER DYNAMIC CONDITION

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DYNAMIC CONDITION

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This project report is dedicated to my beloved mother, father, my wife, family and in-laws including my children; daughter Nalumansi Aeshah Twaha and son Abdul-Hafiz Anwar Twaha Ssennoga.

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ABSTRACT

ATC is an index which is determined by considering both static and dynamic constraints. Several researchers have proposed various methods for determining SATC, including DC load flow based, stochastic, continuation power flow, to mention but a few considerations of dynamic constraints. The methods to determine dynamic ATC include the use of neural networks, and so on. The existing methods are quite complicated and considerably slow in determining ATC especially when TSA is involved in the process. In this project, a method to determine ATC under dynamic condition using Fast Decoupled Power Flow Solution has been proposed and developed. This technique is a powerful analytical tool involving numerical analysis based on a famous Newton Raphson method which is used for routine solution. Matlab has been used as a programming tool. MATLAB is a high-level technical computing language with interactive environment for algorithm development, data visualization, data analysis. The developed program has been tested on IEEE 30 bus practical power system. The results obtained from the tests have been compared with the results from the previous study on dynamic ATC. The results show that the proposed technique is comparably accurate and faster than the existing method.

ABSTRAK

ATC merupakan indeks yang ditentukan oleh mengingati kedua-dua kekangan statik dan dinamik. Beberapa penyelidik telah mencadangkan pelbagai kaedah untuk menentukan SATC, termasuk aliran beban berasaskan DC, stokastik, kuasa aliran kesinambungan, menyebut tetapi pertimbangan beberapa kekangan yang dinamik. Kaedah-kaedah untuk menentukan dinamik ATC termasuk penggunaan rangkaian neural, dan sebagainya. Kaedah semasa yang agak rumit dan kurang cepat dalam menentukan ATC terutamanya apabila TSA yang terlibat dalam proses. Dalam laporan projek ini, satu kaedah untuk menentukan ATC di bawah keadaan dinamik menggunakan Kuasa Fast dipisahkan Aliran Solution telah dicadangkan dan dibangunkan. Fast decouple adalah alat yang berkuasa analisis melibatkan analisis berangka yang berdasarkan kaedah Newton Raphson terkenal yang digunakan untuk penyelesaian rutin. Matlab telah digunakan sebagai alat pengaturcaraan. MATLAB adalah bahasa peringkat tinggi pengkomputeran teknikal dengan persekitaran interaktif untuk pembangunan algoritma, visualisasi data, analisis data. Program yang dibangunkan telah diuji ke atas IEEE 30 kuasa sistem bas praktikal. Keputusan yang diperolehi daripada ujian telah dibandingkan dengan keputusan daripada kajian sebelumnya dinamik ATC. Keputusan menunjukkan bahawa teknik yang dicadangkan comparably tepat dan lebih cepat daripada kaedah yang sedia ada.

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LIST OF ABBREVIATIONS

ACPTDF   −   AC Power Transfer Distribution Factor

ATC   −   Available Transfer Capability

CEED −   Combined economic emission dispatch

CIGRE−   Conseil International des Grands Reseux Electriques

COI   −   Center of inertia

DATC −   Dynamic Available Transfer Capability

DC PTDF−   DC Power Transfer Distribution Factor

IEEE   −   Institute of Electrical and Electronics Engineers

MVA   −   Mega volt ampere

MW   −   Mega watt

NERC −   North American Electric Reliability Council

NRLF −   Newton Raphson Load Flow method

SATC −   Static Available Transfer Capability

SO   −   System Operator

TDS   −   Time domain simulation

TRM   −   Transmission Reliability Margin

TSA   −   Transient Stability Analysis

TSM   −   Transient stability margin

TTC   −   Total Transfer Capability

LIST OF SYMBOLS

PeΔ   −   Change in electrical load

δΔ   −   Change in the rotor angle

P_e −   Electrical Power

P_m −   Mechanical Power

ω_o −   Angular velocity

T_{elect} −   Electric torque

T_{mech} −   mechanical torque

Tnet   −   Net torque

$\Delta\delta$ −   Phase angle deviation

$\Delta\omega$ −   Deviations of the angular speed

P_l −   The transmission line loss

P_i −   The active power injection at bus i

Pgi   −   The active power generation, and

P_{loadi} −   Active load at bus i

NG   −   Total number of generator buses (or PV buses)

N   −   Total number of buses

|Vi| −   Voltage magnitude of the i-th bus

|Vk| −   Voltage magnitude of the k-th bus

δi   −   Voltage angle of the i-th bus and

δk −   Voltage angle of the k-th bus (bus number 1 is the slack bus)

Hi −   Inertia constant of each generator

Ht −   Total inertia constant of the generators

θi −   Rotor angle with respect to COI

θ_i^{cl} −   Rotor angle of i-th generator at fault clearing

t_{cl} −   Time of clearing the fault

T −   Short period after fault clearing

$Ybus$ −   bus dmittance matrix

E −   Generator excitation voltage

Δmin −   Minimum allowable generator angle

Δmax −   Maximum allowable generator angle

tcr −   Critical clearing time

CHAPTER 1

INTRODUCTION

1.1   Background

The transition of power industry to a market free economy in power industry has raised a concern for power consumers to have more choices than ever before. Open-access non-discriminatory transmission services are a necessity to ensure these customer choices. An index called Available Transfer Capability (ATC) is necessary to be evaluated continuously for managing the transfer capability between the generation and the power distributors for success handling of power transactions. However, while evaluating ATC (Shin, Kim, Kim, & Singh, 2007), it is desirable to quantify the uncertainties such as load deviations and transmission outages in ATC calculation as a safety margin so that the power system will remain secure despite the uncertainties.

ATC is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above already committed uses(Reliability, 1996). The ATC between two areas provides an indication of the amount of additional electric power that can be transferred from one area to another for a specific time frame under a specific set of conditions. ATC calculations may need to be periodically updated from time to time to ensure the correct allocation of transmission capacity for a given transaction to avoid network interruptions which may result. Because of the influence of conditions

throughout the network, the accuracy of the ATC calculation is highly dependent on the completeness and accuracy of available network data.

While determining ATC, both static conditions like voltage limits, thermal limits, reactive power limits as well as dynamic constraints such as three phase faults may have to be considered to ensure maximum possible accuracy and reliability of the transmission system. However, ATC can also be determined separately under dynamic or static conditions depending on the nature of the system being analysed.

Many researchers have proposed techniques (D.-M. Kim, Bae, & Kim, 2010; Vol, Wen-Juan, Lei, & Qiu-Lan, 2008; Westermann & Sauvain, 2009) to determine ATC based on static constraints with little if any, consideration of dynamic constraints. A novel fast computational method to determine ATC was proposed in. The ATC limiting factors considered in the method are, line thermal limits, bus voltage limits and Generator reactive power limits. Mum Kyeom K et al presented a method to determine ATC using multi-objective contingency constrained optimal power flow with post-contingency corrective rescheduling taking voltage and reactive power limits as the static constraints. A novel method for computing ATC in a large-scale power system in was also presented in which full details for determining ATC was based on only three input variables through fuzzy modelling. A fast and accurate method was proposed in (Busan, Othman, Musirin, Mohamed, & Hussain, 2010) by applying Ralston's method to predict the two trajectory points of voltage magnitude, power flow, and maximum generator rotor angle difference. Ref (Hahn, Kim, Hur, Park, & Yoon, 2008) proposed a faster method to estimate ATC using fuzzy logic with voltage magnitudes and power limits as the constraints. Kumar. A. et al carried out ATC assessment in a competitive electricity market by using bifurcation approach. In this method, it was assumed there are no static and dynamic security violations and the system operator (SO) simply dispatches all the requested transactions and charges for transmission services(Kumar, Srivastava, & Singh, 2009).

All the above methods determined a type of ATC known as static ATC which is called so because the ATC value is determined based on static constraints such as line flow limits, bus voltage limits, thermal limits, generator real and reactive power limits. The limiting condition on some portions of the transmission network can shift among thermal, voltage, and stability limits as the network operating conditions change over time. Such variations further complicate the determination of transfer capability limits but must be addressed in order to come up with relatively accurate value of ATC as well as guaranteeing the security in the transmission system for reliability reasons(Natarajan et al., 1992).

It is therefore desirable to determine ATC by considering dynamic constraints such as small disturbance (small signal) rotor angle stability and large-disturbance rotor angle stability or transient stability. ATC determined with the additional dynamic constraints is termed as dynamic ATC (DATC).

Some papers have been presented in literature in which DATC has been determined. Dynamic ATC has been calculated using energy function based Potential Energy Boundary Surface (PEBS) method (D.M.V.Kumar and C. Venkaiah, 2009), in which ATC was computed for real time applications using two different neural networks; Back Propagation Algorithm (BPA) and Radial Basis Function (RBF) Neural Network. The limitation with neural networks is that they require high processing time and are also expensive to operate. In (Yue Yuan, J. Kubokawa, 2004), by establishing a novel method for integrating transient stability constraints into conventional steady-state ATC problem, the dynamic ATC problem was successfully formulated as an optimal power flow- based optimization problem and ATC was further determined by integrating transient stability constraints into ATC calculation. However this method is not suitable for large systems because there are many power flow path due large number of buses which may affect the fuzzy determination of ATC, since it requires less inputs. Structure-preserving energy function model, which retains the topology of the network, along with transient stability limit, was used to compute dynamic ATC for bilateral as well as multilateral transactions in an electricity market (ain T., Singh S.N., 2008). The authors presented a hybrid method of computing dynamic ATC by utilising both direct and time TDS methods to reduce the computational burden involved in the TDS. However, this method proves to be complicated since it involves the computation of several indices and algorithms to determine ATC. Enrico. D et al introduced a static optimisation approach, based on nonlinear programming techniques, for assessing Dynamic ATC in real-time environment. This method evaluated ATC with full representation of the power system dynamic behaviour on the transient time scale (De Tuglie, Dicorato, La Scala, & Scarpellini, 2000). Another paper was presented in (Xuemin Zhang, Song Y.H., 2004) where dot product was used as a criterion for rotor angle stability and an algorithm based on control variable parameterization was implemented to solve the formulated dynamic-constrained optimization problem. A differential evolution algorithm (IDE) was established where ATC was calculated based on transient stability constrained optimal flow (TSCOPF) (Jun Wang and Xingguo Cai and Dongdong Wang, 2009). The model adopted the hybrid method to judge the transient stability of the system, which solved imprecision problem in confirming boundaries of the

rotor angle relative the center of inertia when the power-angle restriction was made as the stability criterion.

1.2   Project objectives

The objectives of the projects are;

i.   To develop the methodology for determining ATC under dynamic constraints

ii.   To test the developed methodology by using a standard IEEE power system

iii.   To validate the proposed technique using by comparing with the existing techniques

1.3   Problem statement

Although some methods have been used to determine DATC, they are very few and have a limitation of complexity and are considerably slow. ATC computation requires a simple and faster computing technique since it has to be updated every time due to the dynamic nature of power systems. In this project therefore ATC determination has been formulated using Fast Decouple power flow solution. Its advantages are that it iterates very fast, a common method in power system(Gomez & Betancourt, 1990) and simple to implement. It is a powerful analytical tool involving numerical analysis based optimizing a famous Newton Raphson method which is used for routine solution. Numerical methods are very powerful and efficient because they incorporate the physical properties of the system being studied. MATLAB software has been used as a programming language. MATLAB is a high-level technical computing language with interactive environment for algorithm development, data visualization, data analysis, and numeric computation.

1.4   Project Scope

The project scope consists of the following;

i.   The general scope was to determine ATC under dynamic constraints.

ii.   The dynamic constraint that was considered is the variations in the rotor angle to analyze the transient stability condition.

iii.   Type of transient stability considered is the small signal stability

iv.   The project involves determining ATC by considering area to area transfer capability without considering multilateral transactions.

1.5   Outline of the Project report

This Project report consists of five chapters;

Chapter 1 gives the background of the problem under this research from which objectives, problem statement, scope and the limitation of the project are stated.

Chapter 2 is about the literature review; it gives a brief context of the theories and methods used in accomplishing this research. It deals first with theoretical background of the concepts and finally gives the critical review of some selected research papers relevant to Project report title.

Chapter 3 is about methodology of the project. It explains briefly the modifications that were done on the primary theories and methods to come up with the design and implementation of the project.

Chapter 4 gives the results, analysis, testing and validation of the results of this Project report.

Finally chapter 5 concludes the Project report as well as the further work related to this research.

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