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# Energy Management Using PTDF in a Deregulated Electricity System

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**Abstract**: Customers and power producers use a shared transmission network to transport generated electricity to the customer end in a deregulated power system. In an open market setup, all parties may try to acquire electricity from the cheapest source to achieve large profit margins, which may cause congestion and overloading of a few transmission corridors. This might lead to voltage, line flow, and stability limitations being violated, compromising system security. As a result, utilities must assess their available transfer capability (ATC) to maintain system dependability. This research article defines the process of determination of ATC which is based on power transfer distribution factor (PTDF) on DC load flow model. The research was done for the IEEE 5 bus Test System using MATLAB.

Keywords: Energy, Management, ATC, Deregulated, PTDF, Stability, Congestion

## 1. Introduction

The viable energy market provides customers with an unbiased and open communication network, resulting in recurrent transmission system overloading. To address the inadequacy of electricity generation, researchers have proposed lowering expenses and prices. Because of the changes in the environment, supervisory organizations have been urged to develop and restructure the power business. The provider and customers in a deregulated energy market utilize shared networks to deliver power from one location to another [1)]. In an open-access market, everyone wants to acquire electricity at a lower price and maximize profit margins. Due to this violation of voltage limitations, transmission networks may become congested, and stability limits may be reached, affecting the electrical system's security [2)]. As a result, ATC is critical in determining what is causing the system to fail. Without breaking any particular limits, the ATC determines the incremental power (MW) transfer feasible in 2 parts of an energy system. The ATC value is an important measure of how much power is remaining in the system.

The inter-area tie lines in a vertically integrated market are solely meant to handle system dependability, system security, and system restoration. In the deregulated era, this integration of diverse systems becomes a market requirement. As a result, inter-area tie lines become a frequent source of bulk power transfers from low-cost sources to sink areas. To put it another way, deregulation has shifted the paradigm of grid integration away from regional self-sufficiency and toward optimal resource use over large geographic regions [3)]. As a result, it is necessary for the system operator to quantify the network's ATC and assign it to market players in a timely way. Non-market based techniques, in general, rely on knowledge about the ATC to make a choice while allowing the next series of transactions to proceed. As a result, in such market setups, calculating ATC becomes extremely important [4)]. The ATC values for the next hour and every hour after that would be posted on the website called the "Open Access Same-time Information System" (OASIS), which was possibly run by the ISO in the early days of deregulation in the US. Anyone intending to transmit a transaction of electrical power through the transmission system of ISO would go to the OASIS website and utilize the information of ATC to see if the system can handle the power operation and to book the appropriate transmission service[5].

The paper discusses the estimation of ATC using PTDF in an open electricity market system. The paper has various sections, Sec-B presents availability transfer capacity terminologies. Sec-C discusses about the power transfer distribution factors, in Sec-D, we conducted experiment on IEEE 5 bus and presented results. Finally, paper is concluded in in Sec-E.

## 2. ATC Terminology Definitions

ATC: It's an estimation of how much transfer capacity within the actual transmission system is ready for marketable activity beyond what's previously been committed to. The "Total Transfer Capability" (TTC) is deducted from the "Transmission Reliability Margin" (TRM), and the total of current transmission commitments (specifically retail consumer service) are deducted from the "Capacity Benefit Margin" (CBM).

$$\mathbf{ATC = TTC - TRM - ETC}$$

Where:

ETC= Existing Transmission Commitments with CBM. TTC: The amount of power generation is known as TTC. It can be carried reliably above an interconnected transmission system while meeting all post and pre contingency network environments[6].

TRM: The volume of transmission transfer capacity is called as TRM. It is essential to ensure the safety of the connected transmission network within a predefined range of system uncertainties.

CBM: It is distinct as the volume of transmission transfer capacity set aside by load serving organizations to guarantee that linked system fulfill generating consistency standards[7].

The distinction between "transfer capability" and "transmission capacity" is highlighted in the NERC study. According to this report, 'capacity' refers to the equipment's rating, such as the conductor's ampacity. The 'capability,' on either hand, is determined by generation, consumer demand, and transmission line conditions throughout one specific time period. As a result, a circuit's 'capacity' may not change dramatically over time. Though, the 'capability' constantly varies through the time by virtue of changes in network situation.

As previously stated, the network system's capacity to supply power reliably is restricted by its physical and electrical features. Thermal, Voltage, and Stability are the three limitations. One of these constraints has an important role in determining the capability of power transfer during the various conditions of the power system. Determining which limit is binding at any given time is difficult, making ATC computing a time-consuming process[8]. The ATC has been calculated using a variety of approaches. The approaches vary depending on the power flow model used, the system elements taken into consideration, the compelling restrictions that must be addressed, and a few other considerations. The sort of restriction considered, such as the, Voltage limit, or Angular stability limit, thermal limit, is a wide way of identifying techniques. In this article PTDF method is used to determination of ATC[9].

## 3. Power Transfer Distribution Factor (PTDF)

An electric power transaction is a precise quantity of electricity inserted into the network by a generator for one bus and withdrawn from the system by a load at some other bus. The coefficient of a linear association in the amount of an operation and the flow along a line is termed as the PTDF. Because this connects the total of one change - to another change - transaction amount - line power flow - it's also known as sensitivity[10].

Sensitivity analysis is the most recent approach proposed for calculating estimated ATC.

$$\mathrm{ATC_{mn}} = \min\{\mathrm{T_{ij,mn}}\} \text{.......}(1)$$

Where $T_{ij,mn}$ is transfer capability for each bus.

The transaction amount that possibly gives birth to a certain power flow, like an interface limit, has been determined using the dc power flow model's linearity property. DCPTDF stands for DCPTDF, which is a PTDF defined by a dc load flow relationship. The true power flow on a network linking buses i to j is provided by, using dc power flow and the assumptions connected with it.

$$P_{ij} = \frac{1}{x_{ij}}(\theta_i - \theta_j) \ldots \ldots (2)$$

Now, $PTDF_{ij,mn}$ is the percentage of a transaction from m (bus) to n (bus) that passes via a network linking buses i and j.

$$\mathrm{DCPTDF_{ij,mn}} = \frac{\mathrm{x_{im}\text{-}x_{jm}\text{-}x_{in}+x_{jn}}}{\mathrm{x_{ij}}} = \left(\frac{\Delta \mathrm{P_{ij}^{new}}}{\mathrm{P_{mn}^{new}}}\right) .(3)$$

Where,

$x_{im}$ Values in the $i^{th}$ row and $m^{th}$ column of the bus reactance matrix X

$x_{ij}$ Reactance of a line linking i and j bus,

The variation in power flow $\Delta P_{ij}^{new}$ linked with a new transaction $P_{mn}^{new}$ is then,

$$\Delta \mathrm{P_{ij}^{new}} = \mathrm{DCPTDF_{ij,mn}} * \mathrm{P_{mn}^{new}} \text{..........}(4)$$

Because the PTDFs form a linear connection, the new actual power flows in the lines may be computed by superimposing those corresponding to the individual transactions in the event of a multilateral transaction. The thermal overloads for each line are precisely defined in ATC in the basic scenario between buses m and n1).

$$T_{ij,mn} = \begin{cases} \dfrac{P_{ij}^{max} - P_{ij}^{0}}{PTDF_{ij,mn}} & ; PTDF_{ij,mn} > 0 \\ \propto (inf) & ; PTDF_{ij,mn} = 0 \\ \dfrac{-P_{ij}^{max} - P_{ij}^{0}}{PTDF_{ij,mn}} & ; PTDF_{ij,mn} < 0 \end{cases}$$

Where
$P_{ij}^{max}$ =the line's thermal limit in buses i and j,
$P_{ij}^{0}$ = base case power flow in line among buses i & j.

## 4. IEEE 5 Bus Test System and Results

In this article, we'll look at the 5-bus of IEEE experiment organization. The bus and line data, as well as the maximum power flow limit, should be considered. Figure 1 shows the IEEE-5 bus system, which contains one slack bus, one generator bus, and three load buses1).

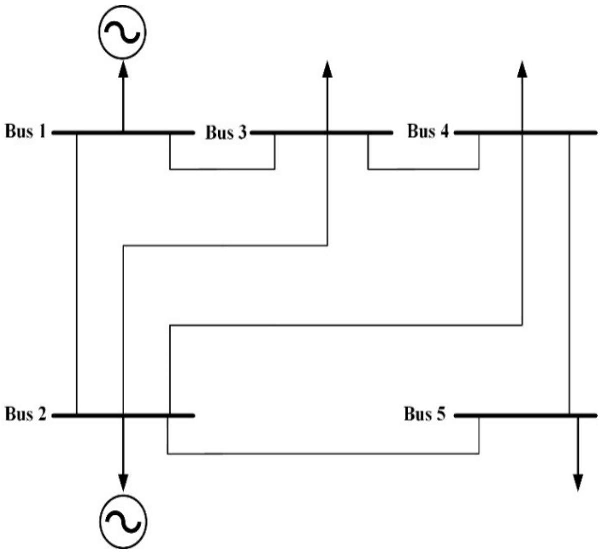


**Fig. 1:** Single line diagram IEEE 5 bus system

In MATLAB, the specified issue is solved. The data was collected using the IEEE-5 system. We compute PTDF among all the lines for different transactions, as well as real line flows flowing through different lines, to comprehend Sensitivity Analysis and ATC computation of the System. The first step in calculating PTDF is to get the reactance matrix, often known as the X) matrix. When the susceptance matrix is a line reactance function, one node is designated like the indication node by setting its direction degree to zero and removing the associated column and row, and the inverse of that matrix is generated. We receive PTDF values among all the lines for different transactions after computing the reactance matrix. For IEEE-5 bus system the unlike transactions are selected for IEEE-5 bus trial system is as below. There are two different kind of transactions are considered.

T1: seller bus 1 to buyer bus 2.

T2: seller bus1 to buyer bus 3.

Table 1 show the transaction T1 and transaction T2 PTDF values.

Table1: PTDF values of T1 and T2

| Lines | PTDF | |
|---|---|---|
| | T1 | T2 |
| 1-2 | 0.8476 | 0.6095 |
| 1-3 | 0.1524 | 0.3905 |
| 2-3 | -0.0571 | 0.2286 |
| 2-4 | -0.0636 | 0.2540 |
| 2-5 | -0.0317 | 0.1270 |
| 3-4 | 0.0952 | -0.3610 |
| 4-5 | 0.0317 | -0.1270 |

At lines 1-2,1-3,2-3,2-4,2-5,3-4, and 4-5, we first establish the PTDF for transaction T1. Table 1 shows that the values ranged for PTDF between positive and negative in this fashion. Figure 2 shows, when transaction T1 is used, the result of transaction T1 and T2 on lines in relation toward buses.

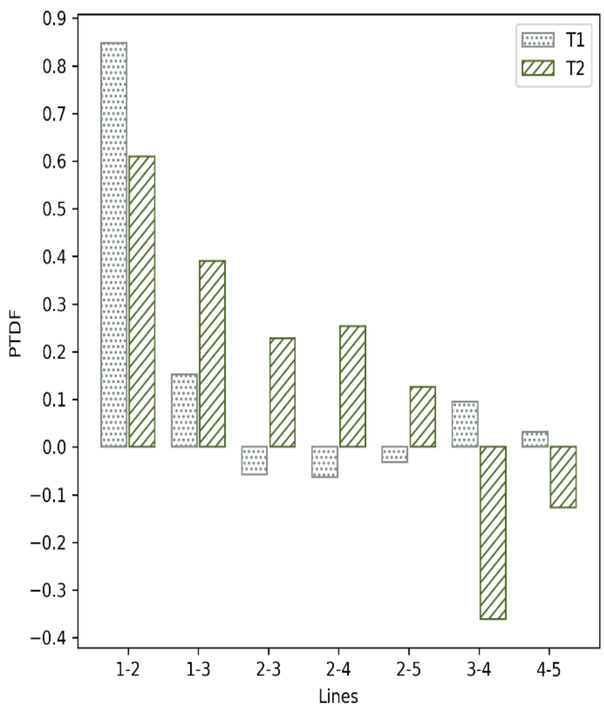


**Fig. 2:** PTDF for T1 and T2

We are able to determine the ATC value for that transaction after computing the PTDF. The network's ATC value is the least volume of transfer capability between all lines in a specific transaction. The ATC value also indicates the presence of a limiting line element.

Table 2: ATC for different transaction

| Transaction | ATC (MW) | Limiting lines |
|---|---|---|
| 1-2(T1) | 45 | 1-2 line |
| 1-3(T2) | 62 | 3-4line |

We can see that the value of ATC varies depending on the transaction. As a result, ISO must compute the value of ATC each 60 minutes as if the loading situation or transaction changes, the value of ATC changes as well.

## 5. Conclusion

It is critical to accurately determine Available Transfer Capability in order to assure system security and dependability, as well as to relieve congestion while supporting a diverse variety of bilateral power transactions. In a real-time computation, getting a rapid result of a multitude of probable power transfers and outages becomes extremely challenging. The linear sensitivity based DC-PTDF approach is one of the simplest ways to obtain a rapid computation, and it is also fewer time intense because it is a non-iterative technique. Once the value of PTDF for a given system has been specified, the operator may easily compute the value of ATC in the event of a change in loading and post the value of ATC on the OASIS website. As a result, calculating the ATC is critical in order to provide improved services and ensure reliable operation in this restructuring power system.

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