Mathematical Modelling of ATC using RPF Method

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Abstract: The power grid has been expanding in recent days as the demand for electrical energy has increased. With rising electricity consumption, whether the present transmission network can handle the increased load has arisen or how much electricity can be transported without violating any limits via the transmission network. Before any planned electricity transmission to customers, the network's capabilities must be adequately tested for this reason. Available Transfer Capability (ATC) refers to the quantity of electricity that may be transmitted across the network more than an excess of what has already been committed without violating any constraints is referred to as Available Transfer Capability (ATC). As a result, precise ATC computation is critical for system operators to avoid blackouts. In this article, ATC was estimated using RPF while considering various network situations such as line outages, etc.

Keywords- Power, Available Transfer Capability, Repeated Power Flow, Congestion

1. INTRODUCTION

In the existing electricity market, the sustainability and competitiveness of the industry is promoted continuously. It enhances the transfer capacity of transmission network as an emerging area for researchers the electricity producer and consumers share the same transmission network and they try to generate electricity from cheaper sources to make more profits which may lead the system congestion, violation of voltage and thermal limits, system securities threats [1][4][9].

In competitive power, the market is open access and fair for users, which results in regular overloading of transmission system facilities. The government pleaded a cause of deregulation in electricity markets. And they want to recognize the prominent aim of consumer preferences in electric power markets. Deregulation in the power industry wants competition in energy production [2]. The main aim of deregulation is to restructure the electricity market so the production of energy and retail sales is competitive, while delivery is still regulated.

Typically, energy markets in the United States were controlled, limiting customer choice. In the 1970s, the theory of deregulation became a reality [3] with the enactment of the Public Utilities Regulatory Policies Act. The energy industry entered a period of transition as a result of this act. In 1992, as a result, the route of the Energy Policy Act more expanded the market. The purpose of the Energy Policy Act was to boost the use of clean energy and enhance sustainability [1]. It gave utilities more options and established new rate-setting guidelines. Deregulated energy markets have extended throughout several states since then, but what are the distinctions and what does the future hold for electricity markets

2. DEREGULATED ELECTRICITY MARKET

A “deregulated energy market” allows rivals to purchase and sell electricity by enabling market contributors to spend in transmission lines and power plants. Generator proprietors then sell the wholesale power to retail sellers [5]. Customer pricing is determined by retail energy suppliers, which is generally referred to as the "supply" component of the power bill. Customers typically profit from it by permitting them to match the pricing and services of several third-party supply firms (Energy Service Companies - ESCOs) & by providing a variety of contract types (e.g. fixed, indexed, hybrid) [6]. Initiatives to promote renewable energy and green pricing. The structure of the deregulated industry is shown in figure 1 below Generators, Transmission and Distribution (T&D) utilities, and merchants connect with International Organization for Standardization (ISO). The client communicates with the store the bulk of the time, which requires energy. The retailer contacts the generating company purchases the power and transports it to the customer's location through regulated T & D lines [7][8].

Variations occur throughout market structures in terms of how each entity is defined and what role it performs in the market structure. However, as seen in the image, the main entities can be identified in a general figure 2.

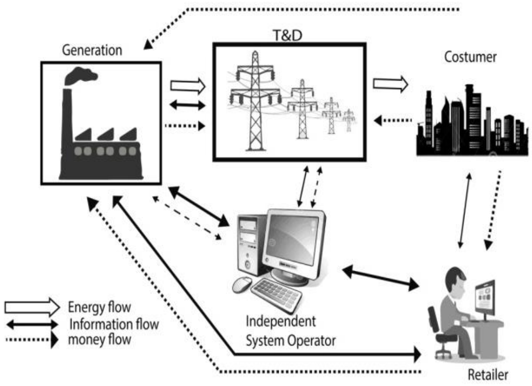

Figure 1: Structure of Deregulated Industry

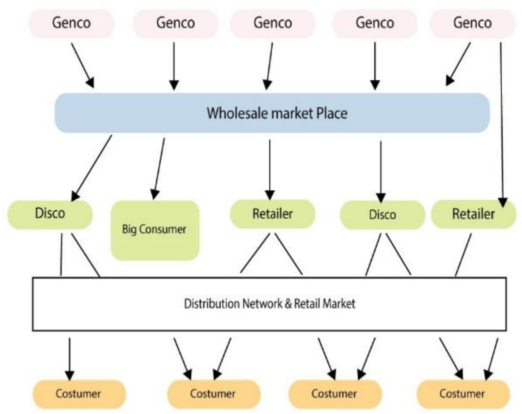

Figure 2: Different entities of deregulation market

3. CONGESTION MANAGEMENT

Before we go into the specifics of these strategies, let's take a look at the various stages of the overall congestion management process on a timetable [6][15][18]. This is seen in Figure 4.1 As transactions continue to commit, the system operator regularly changes the available transfer capability across the system's different regions/areas/nodes. This is important because, when the day-ahead (or spot) market approaches, the operator must be aware of the network bandwidth available for market settlement. In a coordinated market, transmission network capacity allocation might be explicit or implicit. In other words, transmission capacity reservation might exist as a distinct market or as part of the coordinated market [9].

It should be emphasised that capacity allocation systems often award transmission capacity ex-ante, before actual energy delivery. Methods of congestion relief, on the other hand, are referred to as remedial activities. The process of allocating capacity begins with the measurement of ATC [8][15][20]. In the next part, we will go through some of the specifics of ATC computation.

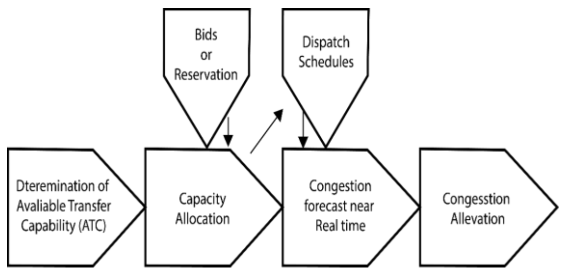

Figure 3: Phases of network access with respect to congestion

4. ATC COMPUTATION

There are several methods to calculate ATC. One of them is the repeated power flow (RPF) method. This approach is based on solving the power flow equations repeatedly. For ATC calculations, a couple of source and sink buses are chosen, & energy producer is raised at the source bus while energy demand is raised at the sinking bus in stages [22]. Each phase calculates the power flows across the lines. This procedure will continue until a binding limit is achieved [29]. Once the binding limit is reached, the procedure is terminated. The energy generation at the source bus is increased in steps, and the equal amount of load power should be increased at the sink bus for each step [23]. In each stage, the real power flow over the transmission line is determined using DC power flow. When any of the transmission lines hits its thermal limit, the operation comes to a halt. Consider $\boldsymbol{P^{base}}$ to be the power injected at bus a without any amount of generated or load, $\boldsymbol{P^{new}}$ and to be the power supplied at bus an after any power line reaches its thermal line. Then ATC is formulated as:

$$\mathrm{ATC} = \mathrm{P^{new}} - \mathrm{P^{base}}$$

In chosen bilateral trade, the line hits its thermal limit, which is the limiting element for a power transaction. The limiting factor is determined by the load level, generation dispatch, and network state, among other things [17].

5. MATHEMATICAL FORMULATION OF RPF METHOD

The flow diagram in figure 4 shows the steps for the repeated power flow method considering:

1. When an RPF algorithm is not initiated, P_a^0 is the base case power injected at bus a. Bus should be either a load or a generator bus.
2. During performing RPF method, the P_a^k is the power produced at bus after a certain step k. k is the number of steps including the formulation of RPF.

3. When any of the system's transmission lines exceeds its thermal limit, k equals k maximum.
4. And the RPF method terminates after the k maximum number.
5. ATC can be obtained for a specific bilateral transaction as ATC.

$$ATC = P_a^{k\,max} - P_a^0$$

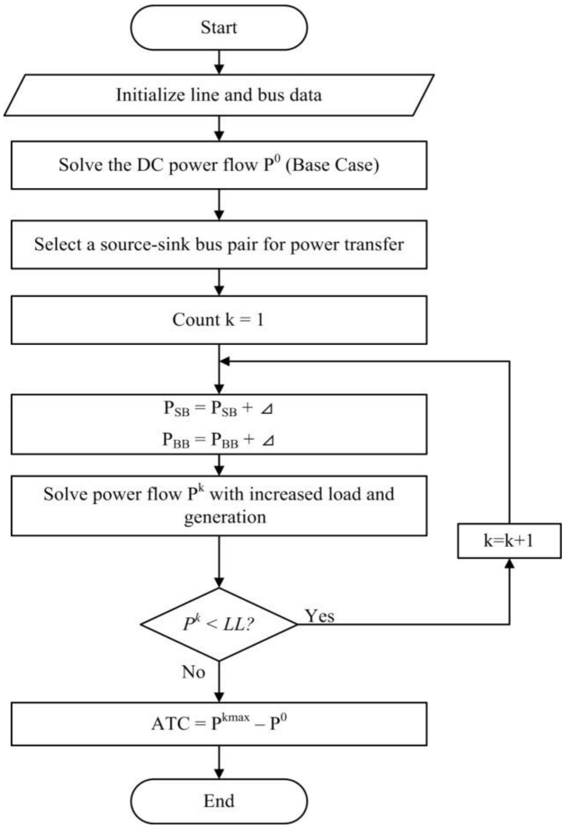

Figure 4: Steps of RPF methods

6. RESULTS AND TEST SYSTEM

In this study, we will look at the IEEE 5-bus experiment system. In this work, the bus and line data, as well as the maximum power flow limit, should be considered. The figure below shows the IEEE-5 bus system, which contains one slack bus, one generator bus, and three load buses. In MATLAB, the specified issue is solved. The data was collected using the IEEE-5 system [19]. We compute RPF among all the lines for different transactions, as well as the real line flows flowing through different lines, to comprehend the Sensitivity Analysis and ATC computation of the System. We can determine the ATC value for that transaction after computing the RPF [13]. We consider two transactions T1 (2-4) and T2 (2-3). The value of ATC is shown for these two transactions. Table 6.1 shown the value of ATC for normal condition and table 6.2 shown the value of ATC for line outage condition. The line 2-3 was out for this topology.

Table 1: ATC values for normal topology

Transaction	ATC (MW)
2-4(T1)	104
2-3(T2)	132

Table 2: ATC values for lineout topology

Transaction	ATC (MW)
2-4(T1)	60
2-3(T2)	66

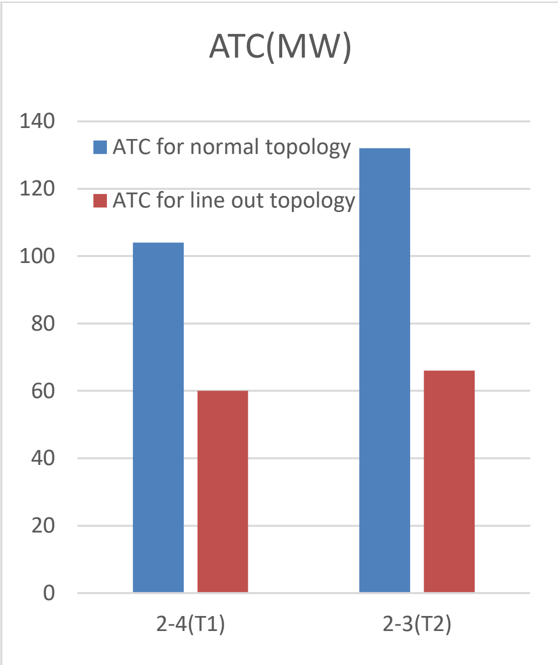

Figure 5: ATC for normal and line out topology

7. CONCLUSION

In this paper, we addressed the ATC calculation technique (Repeated Power Flow). ATC was estimated using several methods, including standard ATC calculation (without any contingency) and ATC calculation with line outage. The simulation was carried out using a 5-bus test system. The acquired results were attempted to explain as much as possible in each simulation. For the sake of simplicity, we disregarded two margins: Capacity Benefit Margin (CBM) and Transmission Reliability Margin (TRM). Furthermore, the voltage and stability limits were disregarded. Although just the temperature limitations of transmission lines were examined, the real ATC calculation procedure is fraught with technical difficulties. The optimal state of the power system must also be taken into account for ATC computation in the actual electricity market.

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