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A STUDY OF AVERAGE TRANSMISSION CONGESTION DISTRIBUTION FACTORS FOR ATC IMPROVEMENT

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ABSTRACT
Available transfer capacity (ATC) is a key factor in power transactions and commercial activity in deregulated power networks. ATC for power systems refers to the transfer capacity left in the physical transmission network for more commercial activity beyond what has already been committed. Because of power system deregulation, a competitive electricity market is emerging that supports alternative energy sources such as wind, small hydro, solar, and so on. Wind energy is the fastest growing renewable energy source since it is clean and abundant in nature. The addition of wind power may increase the ATC value of the agreements. A repeated alternating current power flow (RACPF) technique to ATC computation has been developed. Rarely has study been conducted on the ATC model and its computation in the presence of WTs linked to the power grid. An efficient ATC calculation approach for WPG-containing power systems should be developed. Much study has been conducted on the ATC model and computation in order to alleviate congestion.

KEYWORDS: Average Transmission, Congestion Distribution Factors, ATC Improvement, power flow, WPG-containing power systems

INTRODUCTION

In this study, a new average TCDF value, denoted as (ATCDF), is presented to determine the best position for WPG integration in a zone. The zones are first established using TCDF values by causing a line outage, and then the ATCDF values are determined. ATC is improved by the suggested improvement. An optimization approach was not employed to locate an appropriate position for WPG integration in order to decrease computation time and system complexity. To the best of our knowledge, no study on the ideal position of WPG for ATC augmentation has been disclosed.

CALCULATION OF ATC

In an open-access electricity market, there are two kinds of transactions: bilateral transactions and multilateral transactions. A bilateral transaction occurs when there is just one seller and one buyer, while a multilateral transaction involves more than one seller and buyer. ATC may be estimated using a variety of methodologies, including the DC power flow approach, the sensitivity-based approach, the FACT device integration approach, the optimal power-based approach, and so on. In the literature, two primary power transfer distribution factor approaches are utilized for ATC calculation: the DCPTDF method and the ACPTDF method.

1. ATC Calculation Using DCPTDF

The DCPTDF technique is utilized in the situation of DC load flow, although it does not provide superior results than the ACPTDF method owing to the calculation assumptions. The power transfer distribution factor is determined using DC load flow.

2. ATC Calculation Using ACPTDF

When there is a transaction between seller bus-c and buyer bus-d, the ACPTDF is employed. If the active power change in the transmission line between buses a and b is provided by MW. The greater the value of, the lower the ATC value of that system line. This indicates that the line is reaching its predetermined boundary. This greater ACPTDF number also implies that if power flow increases further, the line will become crowded. For the basic scenario, ACPTDF is computed using Newton Raphson load flow for the bilateral transaction between the supplier and buyer.

Zones/Clusters Concept Using the Average TCDF Values

The active power change () in line-k, which connects bus-m and bus-n, is denoted by TCDF, which is caused by a unit change in active power injection at bus-m (). The TCDF values are calculated using the Newton Raphson load flow jacobian matrix. [10] employs two methods: DC load flow and AC load flow. For every crowded circumstance, TCDF values are used to identify a group of buses that have a comparable impact. These TCDF values are used to build the zones, with the most sensitive zone (zone 1) generated utilizing the highest and unequal TCDF values. Small and comparable TCDF values are used to generate the less sensitive zones (zones 2 and higher order). As a result, every transaction or problem in zone 1 has the greatest influence on line power flow. Power changes in zones 2, 3, and above will have minimal effect on line flow. For each congested line, TCDF values are generated and zones are formed based on their values. It has been discovered that the TCDF values vary for various crowded lines, resulting in separate zones for each congested line. As a result, the cumulative impact of crowded lines is shown by superimposing these zones.

The important observations are as follows:

- The size and sign of the TCDF value of buses on a busy line are the same.
- Some buses have positive TCDF values, while others have negative TCDF values.
- Power injection to a positive TCDF value bus reduces the ATC value, while power injection to a negative TCDF value bus raises the ATC value.
- In order to optimize ATC, the power supply must be connected to the bus with the largest negative TCDF value.

Because certain buses in a zone have positive TCDF values for one crowded condition and negative TCDF values for the second congested condition, it is difficult to locate the ideal site of WPG for ATC enhancement. It is conceivable that given a single line outage circumstance, N lines become congested, resulting in numerous congestions. In this situation, zones may be constructed based on TCDF values for each congested line. In this study, the ATCDF is presented to identify the ideal bus placement for WPG integration. The ATCDF value is calculated using the absolute average value of TCDF. The greatest ATCDF value will provide the best WPG site for ATC improvement.

It is apparent that integrating WPG will increase the ATC value if properly positioned. The ATCDF value will provide the ideal bus position where the incorporation of WPG will increase the ATC value more than other bus locations.

Different purposes recommend various bus sites for WPG hook-up. The appropriate bus selection for ATC augmentation in the limited lines is the major goal of this study. For ATC computation, the ACPTDF technique was examined. Because the ACPTDF approach is simple, rapid, non-iterative, and takes less time to compute, it is used in this study. The following procedures must be taken in order to calculate ATC, i.e.

- Select the base case and do a Newton Raphson load flow calculation.
- Outage of the line for TCDF computation and zone construction.
- ATCDF calculation for various buses in the zones.
- Choosing the best site based on the highest ATCDF values for the highest ATC value in the limiting line.
- Wind power integration on transmission lines is determined by the ATCDF value.
- ATC is calculated using the ACPTDF technique with WPG integration.
- A comparison of the ATC value outcomes obtained by incorporating the WPG at several buses.
- When compared to other sites with the same data input, the optimum position provides the highest value of ATC augmentation.

ATC Calculation Considering WPG at Different Buses in Zone 2

The incorporation of renewable energy sources, notably wind power, has transformed the dynamics of global power grids. Understanding and successfully controlling the impact of wind power output on grid operations is critical as demand for clean and sustainable energy develops. The availability of transfer capability (ATC) is crucial to guaranteeing the dependable and efficient movement of electricity across various sections of the grid. This in-depth investigation looks into the complexities of ATC computation, concentrating on Zone 2, where wind power production is a crucial influence. We get insight into how contemporary power systems adapt to the difficulties of renewable energy integration by exploring the challenges, approaches, and considerations involved in this process.

Wind Power Generation and Its Impact: Because of its vast availability and minimal environmental effect, wind power has developed as a key renewable energy source. Its fluctuating and unpredictable character, however, offers significant issues for grid operators. Wind production, unlike traditional energy sources, is dependent on meteorological conditions, making it fundamentally less predictable. Furthermore, since wind farms are often situated in distant or offshore places, considerable investments in transmission infrastructure are required to link them to population centers. Understanding the impact of wind power on grid operations is critical to ensuring a stable and dependable electricity supply.

Available Transfer Capability (ATC) in Power Systems: The greatest amount of power that may be transmitted between various sections of a power system while adhering to reliability limitations is represented by ATC. It considers the transmission network's capabilities, such as heat limitations, voltage stability restrictions, and other operational constraints. ATC calculations are critical in market operations because they notify market players about available capacity for purchasing or selling electricity. Grid operators guarantee that electricity flows are regulated within safe and reliable limits by precisely estimating ATC.

Zone 2 and Its Significance: Zone 2 indicates a discrete region or area inside the wider grid in the context of power system operation. It may include numerous linked substations, generators, and loads that share similar transmission infrastructure. The computation of ATC is influenced by the particular features of Zone 2, such as its generation mix, demand patterns, and grid topology. We will concentrate on Zone 2 in this presentation owing to its importance in wind power production. Understanding how wind power affects ATC inside this zone is critical for improving grid operations and encouraging renewable energy integration.

Challenges in ATC Calculation Considering Wind Power Generation

1. Variability and Uncertainty of Wind Power: The inherent fluctuation and uncertainty associated with wind output is the fundamental problem in ATC computation in the presence of wind power. Wind speed and direction fluctuations may cause fast variations in power production, making it difficult to precisely anticipate available generating capacity.

2. Forecasting Accuracy: Wind power forecasting accuracy is critical for ATC computation. Wind generation patterns are predicted by grid operators using weather predictions and sophisticated forecasting algorithms. Uncertainties in weather forecasts, on the other hand, might cause inaccuracies in projections, reducing the dependability of ATC computations.

3. Transmission Network Constraints: To meet the increasing power flows from wind farms, the transmission network in Zone 2 may have limited capacity. It is critical for accurate ATC determination to identify and mitigate possible congestion locations in the transmission network.

4. Coordinated Operation of Wind Farms: Coordination of several wind farms operating inside Zone 2 is critical for maximizing wind power and reducing grid congestion. Effective communication and control systems are required to alter generation levels depending on real-time grid circumstances.

5. Impact on Voltage Stability: Wind power output fluctuations may have an impact on voltage stability, particularly in places with considerable wind penetration. Maintaining grid dependability requires keeping voltage levels within acceptable norms.

ATC Calculation Considering Wind Power Generation

1. Power Flow Analysis: A crucial technique for ATC computation is power flow analysis. It entails solving a set of equations that characterize the network's power flows, voltages, and phase angles. Grid operators may examine the influence on power flows and voltage profiles by adding wind production as variable generating sources.

2. Dynamic Simulation: Dynamic simulation simulates the power system's transient behavior in response to changes in generation and demand. This method is especially useful for capturing the dynamic interactions between wind energy and the rest of the grid. It aids in assessing the stability and dependability implications of incorporating wind power.

3. Probabilistic Methods: ATC is evaluated using probabilistic approaches because to the uncertainty involved with wind generating. Based on probability distributions, these algorithms analyze a variety of probable situations for wind power generation. Grid operators may make educated judgments on ATC by calculating the possibility of various outcomes.

4. Optimization Techniques: Optimization models are used to determine the best allocation of generating resources while taking wind power into account as a variable input. These models seek to optimize transfer capabilities while remaining within grid limits. They may take into consideration things like transmission restrictions, voltage stability, and system security.

Considerations for ATC Calculation with Wind Power Generation

1. Wind Forecasting and Data Quality: Wind forecasting accuracy and wind speed data are critical inputs for ATC computation. To make educated decisions, grid operators must have access to high-quality meteorological data and powerful forecasting algorithms.

2. Real-Time Monitoring and Control: For dynamic ATC computation, continuous monitoring of wind power, grid conditions, and transmission flows is required. Grid operators can react quickly to changes in wind production and grid conditions thanks to real-time control systems.

3. Coordinated Operation with Wind Farms: Coordination with wind farm operators is critical for maximizing wind power and reducing congestion. To guarantee seamless functioning, communication protocols and control mechanisms should be devised.

4. Grid Modernization and Flexibility: Investing in grid modernization projects such as improved sensors, automation, and flexible AC transmission systems (FACTS) improves the grid's capacity to accept variable generating sources such as wind power and provides better control over the grid.

CONCLUSION

Electrical power consumption is rising on a daily basis, and renewable energy output is expanding to fulfil this need. The transmission line's capacity to carry electricity is limited. During the transaction, system analysis is required. ATC computes the system's available power transfer capacity. It is also beneficial in risk analysis. This study demonstrates the best position for a WPG using recommended ATCDF values for ATC augmentation. ACPTDF techniques are used to compute ATC. The maximum line loading is used as a limiting condition in problem formulation. A novel method to the optimum positioning of the WPG has been proposed. When ATC and WPG are compared at various bus stops, the ideally situated WPG according to ATCDF values improves ATC more than others. The findings also reveal the second best WPG position for highest ATC improvement. The ATCDF value may be used to determine the best position for multiple WPG integration or for installing WPG in various sensitive zones.

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