DETERMINATION OF REGIONAL TRANSMISSION CONNECTION CAPACITIES IN A DEREGULATED ENVIRONMENT

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Abstract

This paper discusses determination of transmission connection capacities based on distribution regions. In a deregulated environment in which generation and distribution parts of power system are deregulated, planning of transmission system investments is a cumbersome task. In addition, transmission system operators (TSO) have no direct control over plant investments. Instead, several mechanisms introduced to the electricity market considering the economical and reliable transmission expansion planning. In Turkish electricity market case, TSO is obliged to calculate regional allowable generation capacity for the next five and ten year period in order to encourage power plant investments to proper locations and to prevent possible inadequacy of transmission system in the future. In this study, regions are utilized according to distribution companies' geographic borders. The main purpose for capacity assessment work is the determination of available capacity for the connection of new generation to the transmission system. Besides, it indicates the weak points of transmission system that should be strengthened. The proposed method is applied to Turkish Transmission System for 2020 and 2025 summer peak loading condition scenarios.

1. Introduction

Power industry is undergoing a restructuring period throughout the world. The traditional vertically monopolistic structure has been deregulated and replaced by generation, transmission, distribution and retail companies with competitions introduced to generation and retail companies in order to reach higher efficiency in electricity production and utilization [1]. In a deregulated environment, transmission system operators have no direct control over plant investments. Instead, several mechanisms introduced to the electricity market considering economical and reliable transmission expansion planning. Mainly, generation investments are encouraged to locate predetermined geographic regions via transmission tariffs (such as [2, 3]); however, they may be regulated by special mechanism such as carbon criteria [4], environmental criteria or due to another concerns. In Turkish electricity market case, Transmission System Operator (TSO) is obliged to calculate regional allowable generation capacity [5, 6] for the next five and ten years period to encourage power plant investments to proper locations and to prevent possible inadequacy of transmission system in the future. Otherwise, with rapid annual growth of 5 % - 7 % electric consumption, the grid is confronted by a challenging planning problem for the years to come.

In this paper, a study on determination of regional transmission connection capacities in Turkey is presented. Meanwhile, weak points of transmission network that limits the capacity is identified and used as a guide for master planning studies of transmission system network. Transmission capacity assessments are performed through security constrained AC load flow calculations. The main prerequisites are a suitable network model considering planned transmission and generation investments that are already foreseen. That model allows determining the influences of the neighboring areas and estimated generation and load patterns to stimulate cross-regions exchanges [7]. Methodology during the work has three main parts; determination of appropriate regions, adding artificial units to a specific region, increasing region's generation using these artificial units while keeping total generation constant and observing grid overloads at N and N-1 conditions. Considering the worst case for a transmission grid, the proposed method is applied to Turkish Transmission System for summer peak loading conditions in 2020 and 2025.

This article is structured as follows: In section II, information is given about network data utilized in the study. The transmission connection assessment methodology is described in section III. The application and results are given in section IV. Finally, in section V, the summary of this study is given.

2. Information about Analyzed Network Data

The transmission grid is owned and operated by Turkish Electricity Transmission Company (TEIAS). There are two main voltage levels (400 kV and 154 kV) utilized in transmission system and their corresponding grid lengths are roughly 16500 and 33500 km, respectively.

The network data utilized throughout the study is based on existing transmission network topology. In addition, long term public and private transmission network investments (i.e., transmission substations, transmission lines and power plants etc.) are modelled in detail. Results of long term substation based load forecast study [8] and generation forecast study [9] are utilized as prerequisite works. Finally international trade foreseen by TSO is also considered.

3. Methodology

The method followed during the work has three main parts; determination of regions, modeling artificial generation capacity in the regions, determination of related region's additional

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generation capacity via security constrained AC load flow calculations.

In order to maintain safe and stable operation for a transmission system for all loading conditions, capacity calculations should consider extreme operation points for the grid. Considering summer peak condition is yearly peak condition for Turkish Electricity Network, and ratings of electrical equipment are at lowest condition, these scenarios are assumed to be sufficient for capacity calculations. Hence the study has been conducted for two different scenarios: Turkish Transmission System summer peak loading conditions for 2020 and 2025 years.

3.1. Identification of Regions

Turkish Distribution System is privatized and managed by 21 distribution companies. Fig. 1 shows geographic borders of the distribution companies. Regions of distribution companies are evaluated as areas subject to capacity calculations with only one exception, city of Istanbul. Since Istanbul has power consumption more than 15% of national consumption and its geographic property due to Bosporus, the city was divided into two distribution regions as Asia and Europe. In this study, city is accepted as one region. So the study is conducted for twenty regions instead of twenty-one. The reasons behind using distribution region are that the borders of regions are definite in terms of electrical connection, and practical for generation investment evaluations.

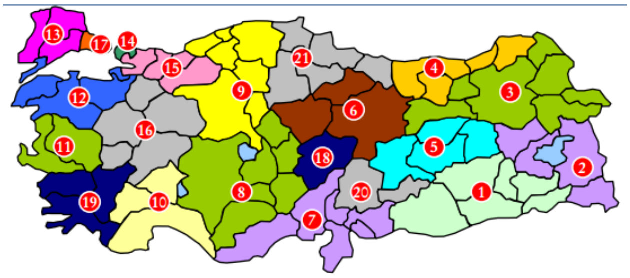

Fig. 1. Geographic Borders of the Distribution Companies

3.2. Assignment of Artificial Generation Units

In order to determine a region's generation capacity, it must be possible to change the generation in that specific region while keeping total generation of the system constant. The generation increase in a specific region is achieved through artificial units.

For any generation grid connection application, TSO is responsible for planning safe and sufficient connection scheme from grid side of view. Hence in this study it is assumed that any artificial generation to be connected to the grid model are safely planned and sufficient number of connections are to be realized to relief and balance regions' transmission. In this perspective, optimum selection of artificial generating units is to distribute artificial units throughout the region. With the utilization of this approach both the process automatization (automatic increase / decrease of generation during capacity calculations) and balanced distribution of generation can be achieved.

Additionally, it is clear that any plant that is planned to connect the grid should satisfy the regulations that are implied by grid code. Considering also the requirements stated in grid code artificial generating unit transformer requirements and reactive power capabilities are adjusted.

Finally in order to ease the process automatization codes are developed utilizing python libraries.

3.3. Determination of Capacities

In order to determine a region's generation capacity, the generation of the region is increased gradually while an equivalent decrease of generation is made for rest of the system to keep total supply – demand of the system constant. This generation shift is made step-wise and continued until a network constraint is violated.

For generation increase / decrease operations, there are mainly three ways in the literature [7]. These are;

- Proportional increase / decrease
- Increase / decrease according to previously observed behaviors of generators
- Increase / decrease according to a well-known merit order

In this study, proportional increase / decrease is used as it is the most common practice in capacity assessments. The increase / decrease steps are determined as 100 MW steps. Each 100 MW increase is divided between artificial units equally while the generation units in other regions shared 100 MW decrease.

At each iteration, AC load flow calculations are executed and security constraints are checked. These constraints are mainly loading conditions of zonal lines, loading conditions tie-lines and operational voltage limits.

If no violation is observed, the contingency analysis is performed for the lines in that region and security constraints are checked in each step. The process is terminated when at least one of the security constraints are violated (mostly the line of critical importance for the region is overloaded).

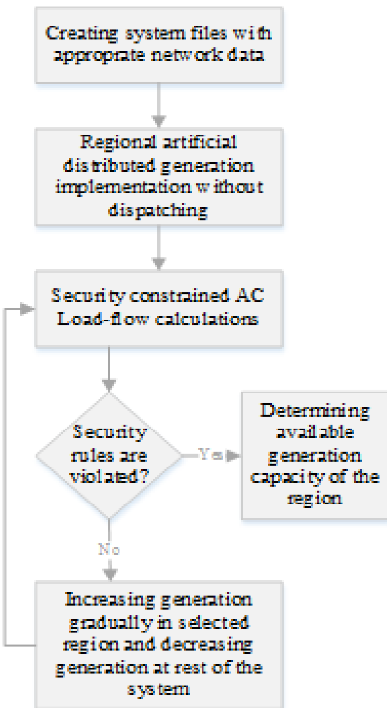

Fig. 2. Flow Chart of Solution Algorithm

4. Application and Results

The methodology as it is mentioned before was applied each region individually. The results of calculated capacities are presented in Fig. 3 and Fig. 4 for the 2020 and 2025 summer peak loading conditions scenarios, respectively. Darker yellow regions refer to the locations more prone to generation connection availability while uncolored regions state unavailability. Results of two regions are explained in detail as bellow.

Fig. 3. Calculated Generation Capacities for 2020 Scenario

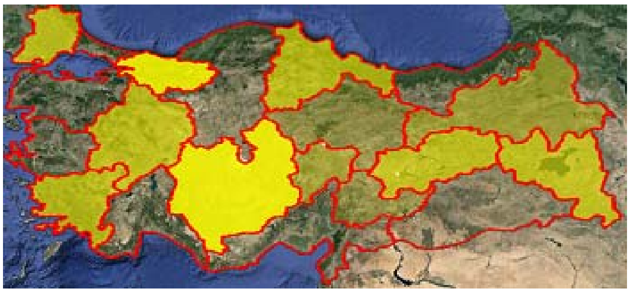

Fig. 4. Calculated Generation Capacities for 2025 Scenario

4.1. Case 1: Region Suitable for Plant Investment

In Case 1, results of a region suitable for generation investment, Trakya Distribution Company (DISCO), are given. Trakya DISCO comprises of *Tekirdağ*, *Edirne* and *Kırklareli* Provinces. In May 2015, the region had ~3500 MW installed capacity, mainly consisted of natural gas thermal power plants. Considering also the expected plants that have taken connection provision from TEİAŞ, the installed capacity is expected to reach ~11000 MW in ten years. The long term demand forecast of the region is assumed to be ~2700 MW in 2025, which is the 4 % of the national demand [10].

Analyses considering the existing and planned power plants are resulted as the region has 3000 MW additional connection capacity in both 2020 and 2025 summer peak loading condition scenarios. The new introduced capacity is mainly used in the transmission substations having high demands in Istanbul.

The limiting factors of the region's capacity are observed as the loading of some tie lines towards eastern region (such as *400 kV Gelibolu – Çorlu* Transmission Line) and contingency violations in some substations (such as *Silivri* Transmission Substation and *Çerkezköy* Transmission Substation). Line loading of the region after the additional capacity is visualized geographically in Fig. 5.

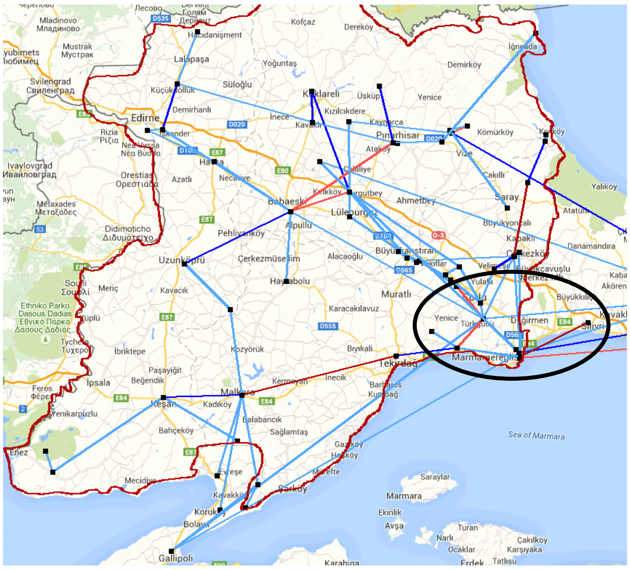

Fig. 5. Line Loadings of Trakya DISCO for 2020 Scenario

4.2. Case 2: Region Unsuitable for Plant Investment

In Case 2, results of a region unsuitable for generation investment, Uludağ Distribution Company (DISCO), are given. Uludağ DISCO comprises of *Bursa*, *Balıkesir, Çanakkale* and *Yalova* Provinces. In May 2015, the region had ~6600 MW installed capacity, mainly consisted of natural gas thermal power plants and imported coal thermal power plants. Considering also the expected plants that have taken connection provision from TEİAŞ, the installed capacity is expected to reach ~20600 MW in ten years, with mainly more imported coal fuelled plant investments. The long term demand forecast of the region is assumed to be ~5200 MW in 2025, which is the 8 % of the national demand [10].

Analyses considering the existing and planned power plants are resulted as the region has no additional connection capacity in both 2020 and 2025 summer peak loading condition scenarios. The unavailability of capacity is mainly due to the existing investment in region and congestion of transmission network in Dardanelles.

The limiting factors of the region's capacity are observed as the loading of some tie lines towards northwest region (such as *400 kV Sütlüce - Lapseki* Transmission Line) and contingency violations in some substations (such as *Demirtaş* Transmission Substation). Line loading of the region in base case is visualized geographically in Fig. 6.

Fig. 6. Line Loadings of Uludağ DISCO for 2025 Scenario

5. Conclusions

Deregulation in generation and distribution grids changed transmission planning philosophy entirely. The uncertainty of power plant investments, especially for the networks with rapid annual growth of 5 % - 7 % electric consumption, is confronted by a challenging planning problem. As a consequence of that, a regional capacity limitation mechanism is introduced to the Turkish Electricity System in order for the economic and reliably transmission expansion planning. TSO is obliged to calculate regional allowable generation capacity for the next five and ten years period in order to encourage power plant investments to proper locations and to prevent possible inadequacy of transmission system in the future.

In this paper, a method is proposed and applied for determining regional generation transmission connection capacities for Turkish Transmission Grid. The method followed during the work has three main parts; determination of regions, modeling artificial units in regions, increasing this region's generation by artificial units while keeping total generation constant and observing line overloads at base case (N) and contingency (N-1) conditions.

The results show that some regions are more prone to additional generation connection while some regions are unavailable due to the risk of transmission congestions. The results also become a guide for transmission network planning studies as it gives the bottlenecks of the network.

6. References

[1] Yixin Ni, Jin Zhong and Haoming Liu, "Deregulation of power systems in Asia: special consideration in developing countries," in *Power Engineering Society General Meeting, 2005*, 2005.

[2] F. J. Rubio-Oderiz and I. J. Perez-Arriaga, "Marginal pricing of transmission services: a comparative analysis of network cost allocation methods," *Power Systems, IEEE Transactions on,* vol. 15, no. 1, pp. 448,454, 2000.

[3] C. V. Konstantinidis, G. Strbac, D. Pudjianto, S. Gammons, R. Druce and R. Moreno, "European transmission tariff harmonization: A modeling analysis," in *European Energy Market (EEM), 2012 9th International Conference on the*, 2012.

[4] D. Shawhan, J. Taber, R. Zimmerman, J. Yan, C. Marquet, W. Schulze, R. Schuler, R. Thomas, D. Tylavsky, Di Shi, Nan Li, W. Jewell, T. Hardy and H. Zhouxing, "A Detailed Power System Planning Model: Estimating the Long-Run Impact of Carbon-Reducing Policies," in *System Sciences (HICSS), 2015 48th Hawaii International Conference on*, 2015.

[5] EPDK, "Elektrik Piyasası Lisans Yönetmeliği," 28 01 2014. [Online]. Available: http://www.epdk.gov.tr/index.php/elektrik-piyasasi/mevzuat?id=1414. [Accessed 03 07 2014].

[6] EPDK, "Elektrik Piyasası Bağlantı ve Sistem Kullanım Yönetmeliği," 28 01 2014. [Online]. Available: *http://www.epdk.gov.tr/index.php/elektrik-piyasasi/mevzuat?id=1436*. [Accessed 03 07 2014].

[7] European Transmission System Operators, "Procedures for Cross-Border Transmission Capacity Assessments," 2001.

[8] TÜBİTAK MAM Energy Institute, "National, Regional and Substation Based Long Term Load Forecast Study on Turkish Electricity System 2015 - 2024 Period," Ankara, 2015.

[9] TÜBİTAK MAM Energy Institute, "Generation Forecast Study on Turkish Electricity System 2016 - 2025 Period," Ankara, 2015.

[10] TEİAŞ, "Üretim Tesisleri Bölgesel Bağlantı Kapasite Raporu," Ankara, 2015. [Online] Available: *http://www.teias.gov.tr/YayinRapor/APK/projeksiyon/KapasiteRaporu.pdf* [Accessed 10 08 2014].