Available Transmission Capacity Considering N-1 Risks

Yurong Wang[1, a], Jie Yu[2, b *], Weiyi Wang[3, c], Bike Xue[4, d], Jian Geng[5, e] and Yonghui Liu[6, f]

[1, 2]School of Electrical Engineering Southeast University, Nanjing, Jiangsu Province, China

[3] Nanjing University of Science and Technology, Nanjing, Jiangsu Province, China

[4, 5] China Electric Power Research Institute, Nanjing, Jiangsu Province, China

[6] Power Exchange Center of State Grid Company of China, Nanjing, Jiangsu Province, China

[a]wangyurong@seu.edu.cn, [b]yujie@seu.edu.cn, [c]1085446657@qq.com, [d]xuebike@epri.sgcc.com.cn, [e]gengjian@epri.sgcc.com.cn, [f]yonghui-liu@sgcc.com.cn

Keywords: Available transmission capacity; Optimal Power Flow; Risk; Fault set; Electricity Market

Abstract. Power available transmission capacity (ATC) is one of the important topics of research in the electricity market. So this paper puts forward an available transmission capacity calculation method considering the risks in electricity market environment. Firstly, establishing a regional available transmission capacity model based on the optimal power flow, using the tracking central locus interior point method to calculate the optimal model, and selecting the contingency reasonably, solving the available transmission capacity under various fault. Secondly, introducing the concept of risk, and putting forward method of the available transmission capacity calculation risk, and then publish the corresponding size of available transmission capacity based on risk. Finally, IEEE-30 bus system was simulated for the proposed method, and the results show that the available transmission capacity considering risks can more reflect the uncertainty of system operation under power market.

Introduction

With the development of power industry and electricity market, grid available transmission capacity (Available Transfer Capability) researchers have increasingly become an important issue. North American Electric Reliability Council defines the available transmission capacity as: ATC is the surplus transmission capacity in the actual transmission network which can be further used for commercial activities, based on the existing agreement,[1] .It is obvious that the available transmission capacity is an index to measure the power transmission capacity and reflect the safety of system in the electricity market conditions[2,7].

Most existing algorithms are just calculated the power transfer limit in running section view from the physical point, while ignoring the role of the electricity market. Available transmission capacity calculation considering N-1 static constraint often publishes the minimum one[3], which is too conservative, and the resources of grid can not be rationally used.

Considering the probability of failure of the power system and the economic losses, this paper proposes a method of available transmission capacity calculation according to the risk. Available transmission capacity calculation released by this method considering the electricity market, also reflecting the uncertainty of power available transmission capacity under the market environment[8].

ATC Calculation of N-1 Static Security Constraints

Large uncertainties exist in the grid, one of which is the fault of system components. This paper only considers line failure and generator failure. Power system faults generally divided into the seriousness and general fault, according to the network operating status, the general failure does not affect the safe operation of the system, therefore, it is not necessary to analysis accurately for each contingency, and which will take too much time. Reasonable selection of contingency can greatly save computing time and also not affect the results. The paper will choose modal analysis method for contingency[4] [5], select those greater impact on system security failures, use the optimization model mentioned in this article and point algorithm tracking center tracks calculation to solute available transmission capacity, under the premise to ensure system security.

Generally available transmission capacity which considers N-1 static security constraints releases the minimum calculation results.

$$ATC = Min\left\{ATC_1, ATC_2, ..., ATC_p\right\} \tag{1}$$

p is the number of faults set. Probability of failure is usually very small when the corresponding ATC is the minimum, so this release way too conservative and power resources can't be fully utilized[9].

ATC Calculation Model Based on OPF

ATC Mathematical Model. ATC optimization model calculations include the objective function, equality and inequality constraints , specific model is as follow:

$$\begin{aligned}
& Max \sum_{i\in A, j\in B} (P_{ij}^{optm} - P_{ij}^{base}) \\
s.t.\quad & P_{Gi} - P_{Di} - V_i \sum_{j=1}^{n} V_j (G_{ij}\cos\theta_{ij} + B_{ij}\sin\theta_{ij}) = 0 \\
& Q_{Gi} - Q_{Di} - V_i \sum_{j=1}^{n} V_j (G_{ij}\sin\theta_{ij} - B_{ij}\cos\theta_{ij}) = 0 \\
& P_{Gi}^{base} \le P_{Gi} \le P_{Gi}^{\max} \quad i \in A \\
& Q_{Gi}^{base} \le Q_{Gi} \le Q_{Gi}^{\max} \quad i \in A \\
& P_{Di}^{base} \le P_{Di} \le P_{Di}^{\max} \quad i \in B \\
& V_i^{\min} \le V_i \le V_i^{\max} \quad i \in A \cup B \\
& \left|P_{ij}\right| \le P_{ij}^{\max} \quad i \in A, j \in B
\end{aligned} \tag{2}$$

Among the formula， P_{Gi} 、 Q_{Gi} denote generator active and reactive power output of the node i； P_{Di} 、 Q_{Di} expresses load active and reactive power demand of the node i; G_{ij} 、 B_{ij} symbol the real part and the imaginary part of the admittance matrix elements respectively; θ_{ij} is the phase angle difference of node i and node j; V shows the node voltage; P_{ij} indicates the power flow of the lineij; A is representative of the regional power transmission， B represents a power receiving area。 Superscript base is ground state case，superscript max is upper limit，min is lower limit。And the equation constraints of the above formula represent constraint equation for the power flow, while the inequality constraints are generator active, reactive power, active power load demand, the voltage limit and line capacity constraints respectively。The objective function is maximum of section tide limit transmission capacity. Then using the point algorithm tracking center tracks [6] to solve a new approximate solution of the optimization model (2).

Relations with the Risk of Available Transmission Capacity. This paper analysis the ATC impact of system failure based on probability and affect of system failure.

Firstly, using the model (2) and point algorithm tracking center tracks to calculate the values of fault set ATC: ATC1， ATC2, ... , ATCp, p is the number of faults set. Take the ATC which values k as the release value of the failure K. If the system has the fault M (ATC value m), the economic costs Ckm of the release value k for failure M are listed as follows:

$$C_m^k = \begin{cases} -(k-m)\cdot R_0 + (k-m)\cdot R_1 & k>m \\ (m-k)\cdot R_0 - (m-k)\cdot R_1 & k<m \end{cases}$$

$$m = 1, 2, ..., p, m \neq k \quad (3)$$

Where R0 is the price difference of purchase and sale of electricity, R1 is the compensation price. According to the definition of risk, risk of failure M under the release value k is:

$$Risk_m^k = C_m^k \times P_m$$

$$m = 1, 2, ..., p, m \neq k \quad (4)$$

Where Pm is the relative probability of failure M occured. According to equation (3), (4), the p-1 economic costs and risks of other p-1 faults which is corresponding to publishing value k can be obtained. And taking the maximum risk as the released value k, that is:

$$Risk^k = \max\left\{Risk_1^k, Risk_2^k, .., Risk_{p-1}^k\right\} \quad (5)$$

And so on, risks released by each available transmission capacity of fault set can be obtained. The steps of available transmission capacity calculating counting risks are as follows:

1) combining with the modal analysis method to choose a reasonable set of faults;
2) using the optimization model (2) and tracking center locus point method to calculate available transmission capacity of a fault set when a fault occurs, $\left\{ATC_1, ATC_2, ..., ATC_p\right\}$, p is the number of faults set;
3) calculating the corresponding relative probability of failure calculated based on the absolute probability of failure of each set;
4) based on the risk calculation method described in the article, using the formula (3) , (4) and (5) to calculate the each corresponding risk value fault released by available transmission capacity[10].

ATC Calculation Model Based on OPF

In this paper, IEEE-30 bus system was simulated. IEEE-30 bus system shown in Figure. 1, the system has 30 nodes, where are 6 power nodes, 20 load nodes (including generators - load node), and 41 lines. The system is divided into three areas, divided manner is shown in Fig. 1.

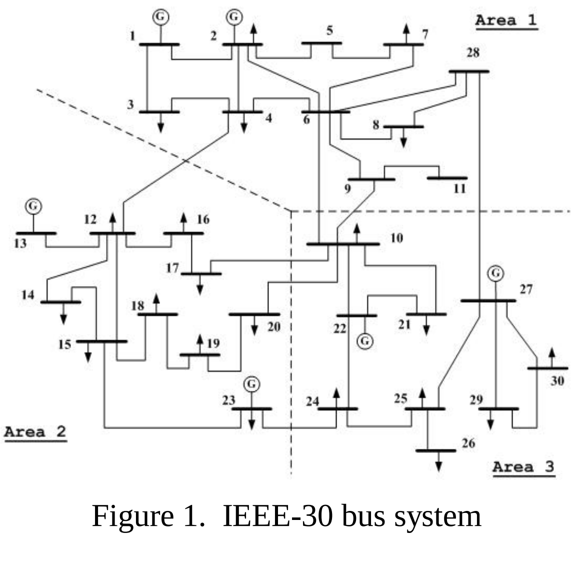

Figure 1. IEEE-30 bus system

ATC Calculation under Fault Conditions. This paper selects fault set includes 14 line faults and 6 generator faults. This paper calculates available transmission capacity under each generator failure. After determining the system state (including non-fault conditions), using the model (2) and point algorithm tracking center tracks to calculate the available transmission capacity under various fault conditions.

ATC under Various Fault Conditions Risk Analysis. ATC calculation results under fault sets will be obtained (including non-fault conditions), and the results illustrate that in electricity market environment, the release of available transmission capacity can not only consider physical factors, but also consider the impact of market factors on the decision. If the published values of ATC is too small, the capacity of power which can also be exploited will not be made full use of, because the failure probability under the condition of minimum ATC value is usually very low, which is not only a waste of resources, but also an economic loss; if the ATC released is too large, then more severe failure, the greater the damages. Thus, releasing a reasonable ATC value according to people's risk habit will make people do better decisions in market transactions.

It is better to tend to smaller risks, releasing 56.32MW is more reasonable, if not to avoid risks, it can take the expected value according to formula (3), where the release of available transmission capacity is 69.86MW, risk of 66.4057 million yuan.

Summary

This paper considered the issue of available transmission capacity release from the economic point of view, then a publishing method of available transmission capacity by using risk analysis method, it can be seen from the simulation results that available transmission capacity value released by the proposed method is fully reflected the market information, which has a certain reference value.

Acknowledgements

Project Contract No.: DZN17201500034

References

[1] Transmission Transfer Capability Task Force. Available Transfer Capability Definition and Determination. *North American Electric Reliability Council,* (New Jersey: 1996).

[2] Ilic M.D, Yoon Y.T and Zobian A: IEEE Trans on Power Systems, Vol.12 (1997), No.2, p.636.

[3] Haoming Liu, Weixing Li and Yixin Ni: Power System Technology, Vol.27 (2003) No. 9, p.1.

[4] Guoqing Li: *Based on the large interconnected power systems area continuous method of transmission capacity*. (MS..Tianjin University, China 1998).

[5] Xiong Pan and Guoyu Xu: China Electrical Engineering, Vol.24 (2004) No.12, p.87.

[6] Xifan Wang, Wanliang Fang and Zhengchun Du: *Modern Power System Analysis (*Science Press, China 2004).

[7] Guoqing Li and Cun Dong: Automation of Electric Power Systems, Vol. 25 (2001) No. 5, p.6.

[8] Yali Cui, Chaohong Bie and Xifan Wang: Automation of Electric Power Systems, Vol. 27 (2003)No.14, p.36.

[9] Haoming Liu, Yixin Ni,Junji Wu and Yun Zou: Relay, Vol. 31 (2003) No.10, p.45.

[10] G.Hamound: IEEE Transactions on Power Systems, Vol. 15 (2000) No.4, p.27.