Study on the Line Overload Harmonization and Optimization Control

Yangguang Wang¹, Xiaofang Guan², a, Lei Chen³, b, Jingzhong Wang⁴, Weimin Hu⁴, Shiyong Yang⁴

¹ State Grid Hunan Electric Power Company, Changsha 410007, China
² School of Electrical Engineering and Renewable Energy, Three Gorges University, Yichang 443002, China
³ Department of Electrical Engineering, Tsinghua University, Beijing 100084, China
⁴ State Grid Yichang Power Supply Company, Yichang 443002, China

a guanxf12@126.com, b chenlei08@mail.tsinghua.edu.cn

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Abstract. The line overload is discussed and the coordination and optimization model of preventive and emergency control is proposed in this paper. It combines with the sensitivity’s concept and reverse phase equivalent matching adjustment principle, takes into account the severity of the accident probability and consequences, and introduces the important factor of the corresponding accident; adjust automatically according to the influence degree of the accident to the power grid. Getting reasonable coordination optimization strategies to ensure the safety and economy of the system is effective and verified by this paper.

Introduction

With the development of the society, the structure of modern power network becomes large and complex, and some uncertainty factors also increase gradually, so accidental factors may damage the system safe and stable operation. So far, the traditional method of security analysis to ensure the system security and economy becomes more difficult. It tends to consider the probability of accident, and ignores the severity of the accident consequences. This only takes the effective preventive control for some common faults, but ignores the small probability events will lead to enormous losses, and that the risk can't be ignored, and taking emergency control’s cost after contingency is also very big. At present, although the research in coordinating preventive control with emergency control has been a lot, and the mathematical form has also been unified, the study of both still is remained independent. Each of the researches has advantages and a disadvantage, which is as the general theoretical research, also is not suitable for large complex system, the precision is also needed to be improved [1-4].

Therefore, the coordinated optimization method based risk theory of preventive and emergency control is proposed in this paper, considering the main influence factor’s probability and the severity of accident consequences, and making full use of complementarity of preventive and emergency control, to determine the appropriate control measures to reduce systemic risk, and ensure the safe and the economy of the system.

The Concept of Risk Theory

The risk theory is mainly used in financial field, and the application in electric power industry has also been more widely. The risk theory is defined as the product of probability of accidents (Pr) and the accident consequences (Sev) in power system. The risk’s value is the greater, and the security of the system is worse, which the accident should be solved firstly. The risk index formula is shown as follows [5-8]:

\[ Risk = Pr \times Sev \]  

(1)
(1) The Accident Probability
According to the history’s data statistics, the accident probability of the system obeys the poisson distribution, in \( t \) min, the accident probability of transmission lines is:

\[
\Pr(E_i) = 1 - e^{-\lambda_t}
\]

Type: \( \lambda_t \) is the incidence of accidents in a specific time period;

(2) The Line Overload Consequences
The consequences of overload are related to the line temperature, environment, system operation state and other factors. In this paper, the transmission power of lines is only considered. The consequences of overload are shown in the following type:

\[
\text{sev}(P_i) = \begin{cases} 
\omega \left( \frac{P_i - P_{s}}{P_{max} - P_{s}} \right) & P_i \geq P_{s} \\
0 & P_i < P_{s}
\end{cases}
\]

Type: \( \omega \) is the weight coefficient of the node, and shows the relative importance of the line in the system overload stability; \( P_{max} \) is the maximum transmission power rating of lines; \( P_s = 0.9 \times P_{max} \) is the setting overload alarm power threshold value of lines; \( P_{\beta} = \frac{P_{L}}{P_{max}} \) is the line transmission power; \( n_{\text{sev}} \) is the severity function’s factor, reflecting the situation of the line overload, the value usually takes 1.

The consequences of the accident have a cumulative effect, so is shown below:

\[
\text{Sev}(E_i, j) = \sum_{i=1}^{n} \text{sev}(E_i, j)
\]

Coordination Optimization between the Preventive and Emergency Control
The Model of Coordination and Optimization
System normally is in a safe state, but inevitably will undergo disturbance to be in an unsafely state or a state of emergency, so that it needs certain preventive and emergency measures. The coordination optimization model and the consequence are shown respectively in the following:

\[
F = C_p(x_r) + P_h(x_r, e) + \alpha \times \text{Cost}
\]

\[
\text{Cost} = f(\text{sev}) = \sum_{i=1}^{\text{sev}} \text{sev}(i)
\]

Where \( C_p \) is the cost of the preventive control, mainly for the adjustment of the generator; \( C_e \) is the cost of emergency control, mainly for the cutting machine and cutting load; Cost is the accident consequence, which has been converted to the corresponding power; \( s \) is distributive factor of generator’s output power; \( \alpha \) is the important factor of the corresponding accident, adjust automatically according to the influence degree of the accident to the power grid.

As soon as possible to eliminate the overload, the generators whose sensitivity is negative (\( S^- \)) should add output power (\( \Delta P_i^- \)), the ones whose sensitivity is active (\( S^+ \)) should reduce output power (\( \Delta P_i^+ \)), and the others whose sensitivity is zero (\( S^0 \)) should be used for balance the active power (\( \Delta P_i^0 \)). Calculating the objective function \( F \) must eliminate all overloads and ensure the power balance, meet capacity limit and the stability requirements of the system.
The Process of Coordinate Optimization

The general process of coordinate optimization between preventive and emergency control is shown as follows:

1) Select effective ones in the expected accidents, and calculate the probability of accidents; 2) Calculate the line overload \( \Delta P \), the consequences \( \text{Sev}_i \) and risk value \( \text{Risk}_i \); 3) Calculate transfer distribution factor of the generator’s output power \( S \), the ability of eliminating branches’ overload \( CL \), judge whether there is the optimum value of prevention control, in according to the principle of reverse equivalent matching adjustment. When the both sensitivity is equal, the generator whose \( CL \) is greater is preferred;

4) The coordination optimization process of preventive and emergency control: Preventive control is to change the operation mode of the system, if operation modes have n. In each mode, the accident consequence is calculated, and emergency control ways are m. and seek the minimum emergency control costs, to eliminate all fault, in order to make the system safe and stable operation;

5) Seek harmonization of minimum control cost, by the particle swarm optimization algorithm, namely the minimization of objective function, and the optimization is over.

Instance simulation analysis

The simulation is based on IEEE30 node system by the above process. The system parameters and the range on the generator power all adopt per unit. The power reference value is 100 MW. That E1, E2, E3 cut rate respectively shows 0.45, 0.15 and 0.75. The result is shown as the table 2.

<table>
<thead>
<tr>
<th>The number</th>
<th>Pr*10^-4</th>
<th>Sev</th>
<th>Risk*10^-3</th>
<th>CP</th>
<th>C_p</th>
<th>C_e</th>
<th>F_min</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>0.0143</td>
<td>7.362</td>
<td>0.0105</td>
<td>0.2594</td>
<td>0</td>
<td>0.1297</td>
<td>0.0231</td>
</tr>
<tr>
<td>E2</td>
<td>0.2140</td>
<td>7.495</td>
<td>0.1604</td>
<td>0.2638</td>
<td>0.044</td>
<td>0.088</td>
<td>0.2202</td>
</tr>
<tr>
<td>E3</td>
<td>0.3282</td>
<td>6.344</td>
<td>0.2082</td>
<td>0.2317</td>
<td>0.2317</td>
<td>0</td>
<td>0.2317</td>
</tr>
</tbody>
</table>

By analyzing table 2, the probability of accident E1 is the smallest, and the consequence is more serious, but the risk value is small. If the E1 happen, it just need take emergency control, and the control cost is minimum; And the probability of E3 is the largest, the consequence is still serious, and the risk is bigger, so if the accident once happens, the preventive control is needed timely carried out to prevent it from happening, the result is the best; The probability of E2 is also bigger, consequence is serious, and the risk is bigger. That it will need to take bigger cost of emergency control. The cost of only adopting preventive control is also bigger, so the E2 needs coordination between the two. The results are shown as fig.1, and prove the correctness of the above analysis, to make sure the economy and safety of the system.

Conclusions

This paper mainly analyzes the line overload, makes full use of the complementary characteristics of preventive and emergency control, considering the accident probability and the severity of the consequences, namely the uncertainty and severity. The example simulation analysis shows that the optimization model propose in this paper and analysis strategy is effective and practical, to ensure the safety of the power system, and makes the system to achieve the optimal economic target.
Fig. 1 The curve of the coordinated optimization control cost of overload

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