# The Brittleness Source Identification of Electric Power System based on Sources Reorganization

Yang Chen [1], Tingting Deng [2, *], Limei Yan [1], Jinlan Gao [1], Aihua Xu [1] and Jianjun Xu [1, a]

[1]School of Electrical Engineering & Information, Northeast Petroleum University, Daqing 163318, China

[2]School of information technology, Heilongjiang Bayi Agricultural University, Daqing 163318, China

[a]junjianxu@163.com

**Abstract.** Brittleness source of electric power system is the element of rising brittleness motivated. Brittleness source identification is the work of finding every brittle source. At first, build model of electric power system, based on direct current tide, all branch currents can be solved quickly. Break off every branch in turn. Use distributing factor method to obtain the other branch currents by breaking a branch current. If the other branch current exceeds the 20% rating current, then it breaks. This will lead to the refresh distribution, until all branch breaks, namely the brittleness being motivated, or until the other branch currents all satisfy the restriction condition. Thus all branches which lead brittleness to be motivated is the brittle source of electric power system. Through analyzing a three generatrixs system, obtain that (2), (3) and (4) is the brittle source.

**Keywords:** electric power system, sources reorganization, brittleness source identification, branch tide, distributing factor, brittleness excitation motivated.

## 1. Introduction

The brittleness is a property of a system [1]. The brittleness problem of the system has already caused the concern of many scholars: Wei etc. [1] analyzed the process that a system collapse process from the characteristics of the complicated system; Yan Limei etc. [2] studied initially the collapse process of the complicated systems; Jin Hongzhang etc. [3] carried on some brittleness analysis to the epidemic situation of SARS according to the glide t verify method ; Wei Qi etc. [4] carried on some brittleness analysis to the complicated systems with the brittleness functions; Xu Jianjun etc. [5] carried on some brittleness analysis to some systems according to fuzzy layers analysis method: and so on. According to the researches to the brittleness of systems [2-5], we find that only a part of sub-systems or components can cause the brittleness of a system, calling this sub- systems or components as the brittleness source of the system.

The brittleness source in a system once gets some influence of outside or internal and, that will bring a chain of collapses in the inner part of system, and at last, the whole system will collapse, that means motivated brittleness. Brittleness source of electric power system is the element of motivated brittleness, so the key that keeps the system brittleness from motivating is how to find out all brittleness sources within a system. Only the available brittleness source identification, then carries on the control and the management to it. we can control the probability of brittleness motivation effectively, and then at the beginning of brittleness motivation according to the path of the motivation, cut off the brittleness by valid measures, in order to control and stop motivation brittleness motivation, this is very important for the the safety of the system.

The method of the brittleness source recognization is to build up the system model, then simulate the brittleness fault motivation to each component, at last find out all brittleness sources.

From to now, there’s no research report about the brittleness source recognization .This paper, according to the method of direct current ride and distributing factor, carried on the brittleness analysis to a three generatrixs electric power system, and found out the brittleness sources of the system. Based on that I did some sum up some characteristics of brittleness sources in the electric power system, hoping that can be reference to discover the brittleness sources in the systems quickly and timely.

## 2. The Brittleness in the Electric Power System

A metal characteristic of motivated brittleness is the form of chain of collapses. According to the research to the great power-off phenomenon of the electric power system [6-8], we found that. The main reason of the great power-off phenomenon of the electric power system is the chained faults in the electric power system. The chained faults present that because of the interference or other reasons, a part of electric power transmission lines or a part of power supplies in the electric power system break circuit automatically, then other circuits or power supplies will bear the impact that it brings, and cause the chain break circuit of other circuits or power supplies. This will bring electric voltage collapses, frequency collapses or abruption to the system, at last the ineluctable great power-off trouble will happen in the whole electric power system. In fact, this kind of chained fault in the electric power system are the epidemic of brittleness in the system, and the broken circuits or the components that cause collapses are the brittleness sources of the electric power system. The phenomenon of the great power-off in electric power system is the result of motivated brittleness in electric power system. So, at present a kind of good measures to solve the problem of the great power-off in electric power system is carrying on the brittleness analysis of the electric power systems.

## 3. The Method of Brittleness Sources Reorganization in the Electric Power System

The components included in the electric power system are numerous, but not all the components can cause brittleness of the electric power systems. So we need to recognize to the brittleness sources in the electric power systems, finding out the brittleness sources that can cause motivated brittleness of the electric power systems, and watch them in emphasis to decrease the rate of the motivated brittleness in electric power systems.

The method of brittleness sources recognition in the electric power system is to build up model of the electric power system, then simulate faults of all components. If the break of one component causes a break of another component of the electric power system, and it happens in the form of chain, and causes all circuits within the whole electric power systems to break, this means this component is a brittleness source. If the break of one component causes little change to others, then this component is not a brittleness source.

After building up the electric power system model, we will solve the tide of every circuit in the electric power system. There are many methods to solve tide in the electric power system, such as, Gauss method, Newton method, disassemble PQ method, direct current tide method, superior tide method etc. Once the brittleness source of the electric power system is motivated , it will calamitously calamitously influent the whole system, so we hope find out the brittleness sources of the electric power system, at the time when the electric power system is working. This will help us be aware of the serious result of the motivated brittleness in the initial stage of brittleness motivating source, after brittleness source is hit by something external and opens circuit to withdraw, we can adopt the fast valid measure immediately to avoid the extension of the brittleness. So it is requested a fast judgment to brittleness source generally. The direct current tide method applies in the state which don't request very high accuracy, and in the state requesting high accuracy the difference between the direct current tides solved in normal method is very small. Therefore within the scope of the allowed error range, the direct current tide method can solve the current of each branch quickly. After solving the initial tide of the whole system, it's time to solve the new tide state caused by the broken circuit, using the distributing factor method. If in the new tide state, some circuit in the system is overloading, then we get an overload quotient of 1.2 [9], and the circuit must be opened. Then this circuit must be opened. This causes the redistribution of the tide in the whole electric power system again, such back and forth, until all circuits open or all circuits are within the range of overload value. For finding out all brittleness sources in the system, we must do these things to every circuit, until finding out all brittleness sources within the system.

The steps of brittleness sources reorganization:

Step 1: Get the input the active power of every node: $P_i^{SP}$

Step 2: Get the tab ($l$) and the reactance value ($x_{ij} = x_l$) of every branch between the node $i$ and the node $j$;

Step 3: Choose one node as the reference node, and set the phase angle of the node is zero, $\theta_n = 0$

Step 4: Build up the node admittance matrix $B_0$, except the reference node [7], it's a matrix of $n-1 \times n-1$, the elements in it are:

$$\begin{cases} B_0(i,i) = \sum\limits_{\substack{j \in i \\ j \neq i}} 1/x_{ij} \\ B_0(i,j) = -1/x_{ij} \end{cases} \tag{1}$$

Step 5: Solve the roots, $X = B_0^{-1}$

Step 6: Solve the voltage phase matrix of each node, $\theta = XP^{SP}$

Step 7: Solve the branch tide [10], $P_{ij} = (\theta_i - \theta_j)/x_{ij}$

Step 8: Break the branch $l$ $(l = 1,2,\cdots,m)$ one in once, and solve $\eta_l = XM_l$, which $M_l$ is the related matrix

Step 9: Solve the self-impedance and mutual-impedance of other branch relative to branch $l$, $X_{k-l} = M_k^T \eta_l$ $X_{l-l} = M_l^T \eta_l$

Step 10: Solve the branch tide distributing fator between branch *k (k≠l)* and branch *l* [9],

$$D_{k-l} = \frac{X_{k-l}/x_k}{1 - X_{l-l}/x_l} \tag{2}$$

Step 11: Solve the tide of each branch after break [7], $P_k^l = P_k + D_{k-l}P_l$

Step 12: Assume that every branch is working within the range of rating, solve the tide enhancement of each branch. If it exceed the rating more than 20%, then open the branch, and do the step 8, else it's over.

## 4. Example

In the following, we'll take the three generatrixs system for example to solve the brittleness sources in the system. We know that the input power of every node in system, such as fig.1, which (1),(2),(3),(4) are branches; ①,②,③ are nodes. The reactance of every branch:

$x_{32} = x_1 = 0.2$, $x_{21} = x_2 = x_3 = 0.4$, $x_{31} = x_4 = 0.1$,

Which branch (2) and branch (3) are circle transmission lines.

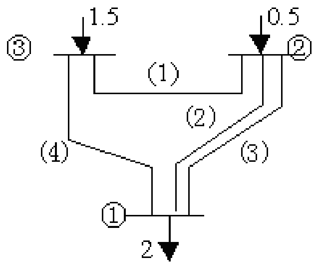


Fig1. three lines diagram of electric power system

Choose node ③ as reference node, its voltage phase angle is zero.So,

$$B_0 = \begin{bmatrix} 15 & -5 \\ -5 & 10 \end{bmatrix}, \quad X = B_0^{-1} = \frac{1}{25}\begin{bmatrix} 2 & 1 \\ 1 & 3 \end{bmatrix}$$

$$P^{SP} = \begin{bmatrix} -2 \\ 0.5 \end{bmatrix}, \quad \theta = XP^{SP} = \begin{bmatrix} -0.14 \\ -0.02 \end{bmatrix}$$

The tide of every branch:

$$P_{12} = \frac{\theta_1 - \theta_2}{x_{12}} = -0.6, \quad P_{13} = \frac{\theta_1 - \theta_3}{x_{13}} = -1.4, \quad P_{23} = \frac{\theta_2 - \theta_3}{x_{23}} = -0.1$$

(Because the branch between node① and node ②is circle transmission lines, so the tide of every line is -0.3), so the tide of every branch is showed in fig.2.

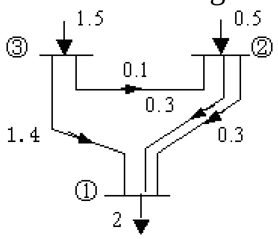


Fig2. tide of three lines of electric power system

In the following, we'll break branch (1), (2), (3), (4), one in once, and study how one branch's break influent other branches.

**4.1 Break branch (2) or branch (3)**

Because it's the same to break branch (2) and branch (3), so we just solve one case. For example, we break branch (2), so

$$\eta_2 = XM_2 = \begin{bmatrix} -0.04 \\ 0.08 \end{bmatrix}$$

The self-impedance and mutual impedance between branch (1), (3), (4) and branch (2):

$$X_{1-2} = M_1^T \eta_2 = -0.08, \quad X_{2-2} = M_2^T \eta_2 = 0.12,$$

$$X_{3-2} = M_3^T \eta_2 = 0.12, \quad X_{4-2} = M_4^T \eta_2 = -0.04$$

When branch (2) breaks, the tide distributing factor of branch (1), (3), (4):

$$D_{1-2} = \frac{X_{1-2}/x_1}{1 - X_{2-2}/x_2} = -\frac{4}{7}, \quad D_{3-2} = \frac{X_{3-2}/x_3}{1 - X_{2-2}/x_2} = \frac{3}{7},$$

$$D_{4-2} = \frac{X_{4-2}/x_4}{1 - X_{2-2}/x_2} = \frac{4}{7}$$

The tide after break:

$$P_1^2 = P_1 + D_{1-2}P_2 = -0.07143, \quad P_3^2 = P_3 + D_{3-2}P_2 = -0.42857,$$

$$P_4^2 = P_4 + D_{4-2}P_2 = 1.57143$$

The tide enhancement of every branch:

$$\Delta P_1^2 = -0.6143 < 0, \quad \Delta P_3^2 = 0.42857, \quad \Delta P_4^2 = 0.12245$$

Because branch (3) exceeds the rating 20% and breaks, so the new tide distribution in branch (1), (4):

$$D_{1-3} = \frac{X_{1-3}/x_1}{1 - X_{3-3}/x_3} = -1, \quad D_{4-3} = \frac{X_{4-3}/x_4}{1 - X_{3-3}/x_3} = 1$$

The tide after break:

$$P_1^3 = P_1 + D_{1-3}P_3 = -0.35714, \quad P_4^3 = P_4 + D_{4-3}P_3 = 2$$

The tide enhancement of every branch:

$\Delta P_1^3 = 3.9999$, $\Delta P_4^3 = 0.27273$

In the solving above, because the break of branch (2), branch (3) breaks, and then branch (1), (4) break. So branch (1) is a brittleness source. In the same, branch (3) is also a brittleness source. Therefore, if a branch has circle lines, their characteristics are the same, if one of them is a brittleness source, then the other is also a brittleness source, if one of them is not a brittleness source, then the other is not a brittleness source, too. From the result of solving, we know that the branch whose open-circuit current is bigger is easier to motivate the brittleness.

**4.2 Break branch (1)**

When branch (1) break, the tide distributing factor in branch (2), (3), (4):

$$D_{2-1} = \frac{X_{2-1}/x_2}{1-X_{1-1}/x_1} = 0.25,\quad D_{3-1} = \frac{X_{3-1}/x_3}{1-X_{1-1}/x_1} = 0.25,$$

$$D_{4-1} = \frac{X_{4-1}/x_4}{1-X_{1-1}/x_1} = 0.25$$

The tide after break:

$$P_2^1 = P_2 + D_{2-1}P_1 = 0.325,\quad P_3^1 = P_3 + D_{3-1}P_1 = 0.325,$$

$$P_4^1 = P_4 + D_{4-1}P_1 = 1.425$$

The enhancement of every branch:

$$\Delta P_2^1 = 0.08333,\ \Delta P_3^1 = 0.08333,\ \Delta P_4^1 = 0.01786$$

Now, we know that the break of branch (1) does not cause motivated brittleness, so branch (1) is not a brittleness source. This also certificate not all components in the system are brittleness sources.

**4.3 Break branch (4)**

When branch (4) break, the tide distributing factor in branch (1), (2), (3):

$$D_{1-4} = \frac{X_{1-4}/x_1}{1-X_{4-4}/x_4} = 1,\quad D_{2-4} = \frac{X_{2-4}/x_2}{1-X_{4-4}/x_4} = 0.5,$$

$$D_{3-4} = \frac{X_{3-4}/x_3}{1-X_{4-4}/x_4} = 0.5$$

The tide after break:

$$P_1^4 = P_1 + D_{1-4}P_4 = 1.5,\quad P_2^4 = P_2 + D_{2-4}P_4 = 1,$$

$$P_3^4 = P_3 + D_{3-4}P_4 = 1$$

The enhancement of every branch:

$$\Delta P_1^4 = 14,\ \Delta P_2^4 = 2.33,\ \Delta P_3^4 = 2.33$$

Now, we know that the break of branch (4) causes the break of branch (1), (2), (3), so branch (4) is a brittleness source.

From the solving above, the brittleness sources of the system are branch (2), (3), (4). It's necessary to know that the three buses in the system are also components of the system, so we also can analyze whether they are brittleness sources. The method is the same, now we don't do it.

## 5. Conclusions

Only the brittleness sources of the systems can motivate brittleness. Therefore the brittleness source recognization is also a valid measure to prevent the motivated brittleness. According to the method of direct current tide and distributing factor, this paper gives the steps to find out the brittleness sources quickly, and through the compute the three-node system, find out the brittleness sources. Through the process of solving, we know: high tide value is the characteristic of brittleness sources in the electric power system. Watch the brittleness sources, we can reduce the risk of the motivated brittleness of system.

## Acknowledgment

This work is supported by the Foster Fund of Northeast Petroleum University (XN2014110).


## References


[1] Wei Qi, Jin Hongzhang, Guo Jian. The Research of Complex Systems Breakdown Based on Brittleness [J]. Journal of Harbin Engineering University.2013,24(2): p.161~165

[2] Yan Limei, Jin Hongzhang, Fu Guangjie, etc. Initial Study on Brittleness Mechanism of Complex Systems [J] .Journal of Daqing Petroleum Institute, 2010, 28(5): p.56~60

[3] Jin Hongzhang, Guo Jian, Wei Qi, etc. some brittleness analysis to the epidemic situation of SARS Based on $t$ -Test [J]. Journal of Harbin Engineering University, 2013, 24(6): p.640-645

[4] Zhang Boming, Chen Shousun. Advanced Electric power Analyse[M].Publishing of Tsinghua University, 2006

[5] Xu Jianjun, Yan Limei, Liu Xiaobin. the Application of Fuzzy Analytic Hierarchy Process to Analyze the Brittleness for Transformer [J]. Transactions of China Electrotechnical Society, 2012, Vol.20(2): p.94~98

[6] I.Dobson, J.Chen et.al Examing criticality of blackouts in power system models with cascading events[C]. Hawaii International Conference on System Sciences. Hawaii. January, 2012.

[7] B.A. Carreras, D.E. Newman al. Initial evidence for self-organized criticality in electric power system blackouts [A]. Proceeding of Hawaii international conference on system sciences [C], Hawaii, 2014.

[8] Carreras B A,Newman D E. Evidence for self-organized criticality in electric power system blackouts [C]. Hawaii International Conference on System Science, Hawaii, 2011

[9] Geng Yi. Industry and Enterprise Power Supply [M]. Publishing of Metallurgy Industry,2011.