Improve Fault Analysis Program in Transmission Networks Using Improved Fault Model

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Abstract— **The value of fault current is always depends on the arc resistance which is itself a non-linear function of the fault current that is the fault current and arc resistance are mutually dependent, so the short circuit analysis cannot be performed directly. In transmission networks, the calculation of the fault current is a very important task and the accuracy of the short circuit analysis always depends on the fault modelling. In order to get the accurate reading of fault current, it is very important to know the value of the arc resistance at the fault location. From the existing approaches, the values of arc resistance is either known in advance or totally neglected from the consideration. By assuming the value of arc resistance or totally neglected it value, the value of fault current obtained become larger and not accurate compared with the value obtained when the arc resistance is included. The reading of fault current can be more accurate when the arc resistance is included in the calculation.**

Keywords—**Arc resistance, fault current calculation, short circuit analysis, fault modelling**

I. INTRODUCTION

The calculation of short circuit current (fault current) in transmission networks is a very important task. When a fault occurs in a power systems (transmission networks), at the fault point a high current fault arc will be occurred. In order to recovery quickly from the fault, it is very important to investigate the fault arc phenomena [1].

It is very important in short circuit analysis to consider the arc resistance because the arcing faults occur in over 80% of all faults [2], [3]. An arc fault is a high power discharge of electricity between two or more conductors [4]. The arc occurs in the gas-filled space between two conductive electrodes that often made of carbon [5].

When the value of arc resistance is assuming from the experience or from handbooks (e.g 1.5Ω) or simply neglecting it for calculation, the value of fault current obtained is larger compare to the current obtained from the calculation that including the arc resistance inside.

From the comparison, it is very obvious that the value of arc resistance determines the value of fault current [1]. This new method can help in the selection of the switchgear component selection and other security devices. The better protection co-ordination and the optimal operation of protective devices are very important to get the more accurate fault current reading [3].

In this paper the calculation for the accurate fault current by using iterative procedure is shown. By using this method, the value of calculated arc resistance at the fault point is including in the impedance matrix. The value of new fault current is calculated by using the updated impedance matrix.

II. THEORETICAL BACKGROUND

A. Fault Analysis

From the IEEE Std 100-1992, the meaning of fault is a physical condition that causes a device, a component, or an element to fail to perform in a required manner, for example, a short circuit, a broken wire, or an intermittent connection. There are two types of fault that are symmetrical and unsymmetrical fault with three types of fault that are single line to ground, line-to-line and double line to ground fault.

Fault can cause a large voltage drop on the system, disturbance to the system stability that can cause shut down, the protection system cannot functioning well and interruption to the service.

The objectives of the fault analysis are to determine the maximum and minimum three phase fault current, to investigate the operation of protection relay, to determine what the rated capacity of circuit breaker is and to determine the fault current distribution and bus bar voltage during the fault [6].

B. Symmetrical Fault

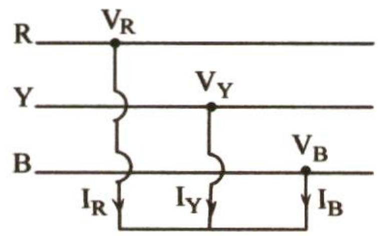

Figure 1: Symmetrical Fault

Figure 1 shows the symmetrical fault; the fault types of symmetrical fault are line-line-line and line-line-line to ground. Symmetrical fault can be defined as the simultaneous short circuit across all three phases [7].

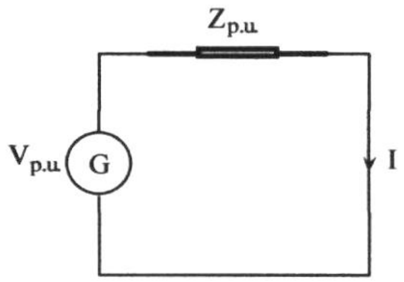

Figure 2: 3-Phase Fault Equivalent Circuit

Figure 2 above show the equivalent circuit of a three – phase fault. The three phase symmetrical fault current will allow determining the symmetrical breaking capacity of the circuit breaker and switchboard.

Where:

V_{pu} = Line voltage in p.u.

Z_{pu} = Phase impedance between the supply source and the fault location in p.u.

I = Current in p.u, $I_{pu} = \frac{V_{pu}}{Z_{pu}}$

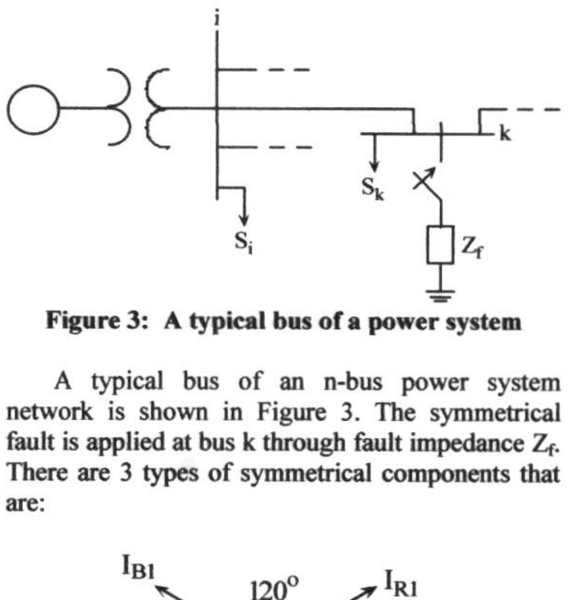

Figure 3: A typical bus of a power system

A typical bus of an n-bus power system network is shown in Figure 3. The symmetrical fault is applied at bus k through fault impedance Z_f. There are 3 types of symmetrical components that are:

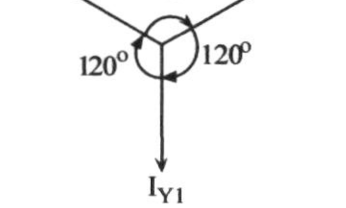

Figure 4: Positive Sequence

Figure 4 shows the positive sequence component. It consist same magnitude and 120° spaced to each other. These components have the same sequence as original that are R, Y and B. positive sequence is identical with the normal network.

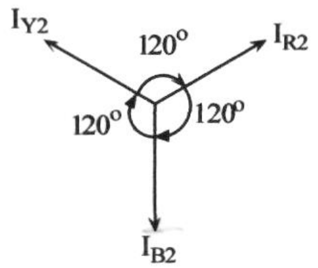

Figure 5: Negative Sequence

The negative sequence component is shown in figure 5. Same as the positive sequence but the phase sequence is opposite to the original phase. Almost similar to the positive sequence except there is no e.m.f source.

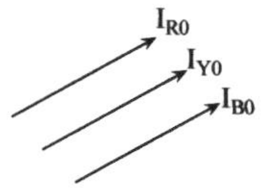

Figure 6: Zero Sequence

Figure 6 above shows the zero sequence components. Zero sequence consists of three-phase with same magnitude and zero phase difference between each other.

C. New Arc Resistance Formula

Based on experimental testing in high power test laboratory FGH-Mannheim (Germany) and exhaustive analysis and processing of real arc voltage/current signals at the University of Saarbrucken (Germany) and the University of Belgrade (Serbia and Montenegro), the calculation of new arc formula is derived [2][8]:

$$R = \frac{2\sqrt{2}U_a}{\pi I} \tag{1}$$

$$U_a = E_a L \tag{2}$$

By combining equation (1) and (2),

$$R = \frac{2\sqrt{2}}{\pi}\frac{E_a L}{I} \tag{3}$$

Where:

R is the arc resistance (Ω)

L is the arc length (m)

I is the arc current (A)

E_a is the arc voltage gradient in (V/m)

The voltage gradient of an arc that was calculated by dividing the arc voltage between the electrodes by the gap length, the equation can be written as following:

$$E = a + bI^{-n} \tag{4}$$

Where:
E is voltage gradient (kV/m)
a, b is constant
I is current (kA)
n is power

From equation (4):

$$E_a = (1200 \div 1500)\ V/m \tag{5}$$

$$E_a = (950 + 5000) \div I\ (V/m) \tag{6}$$

Equation (5) and (6) into (4)

$$R_1 = (1080.4 \div 1350.5)\frac{L}{I} \tag{7}$$

$$R_2 = \left(\frac{855.3}{I} + \frac{4501.6}{I^2}\right)L \tag{8}$$

III. METHODOLOGY

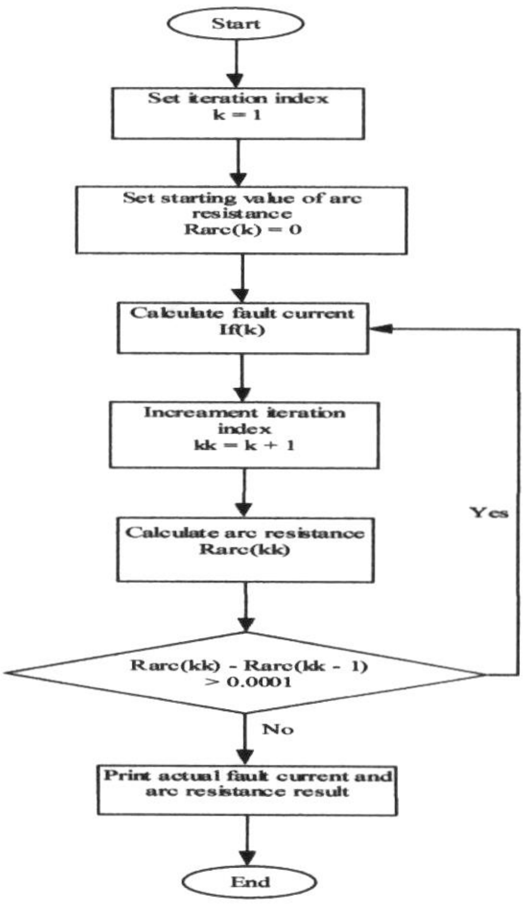

Figure 7: Flowchart for R_{arc} and new fault current calculation

Figure 7 above is the flowchart on how to calculate the value of arc resistance and new fault current:

1) Set the starting iteration index as k = 1 and starting value of arc resistance Rarc (k) = 0. Rarc (k) = 0 is used when to start comparing the value of arc resistance.
2) Calculate the fault current with the existing method. This fault current used to calculate the arc resistance.
3) Increment the iteration index kk = k + 1: 2, 3, 4....
4) Calculate the arc resistance using formula from equation (7) or (8). The arc current that calculated before is used in these formula.
5) Compare the value of new arc resistance with the old arc resistance. If the different is larger than 0.0001, go to step 2. The new fault current is calculated using the updated impedance matrix.
6) If the arc resistance different is equal or less than 0.0001 print the result. The result is in actual value.

IV. RESULTS AND DISCUSSION

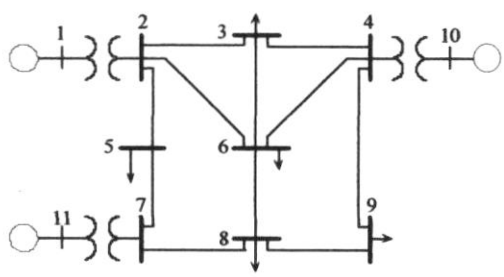

Figure 8: The 11-bus Power System Network

Generator Number	Ra p.u	X'd p.u
1	0	0.20
10	0	0.15
11	0	0.25

Table 1: The Transient Impedance of the Generators

Bus Number	Bus Number	R P.u	X p.u	½ B p.u
1	2	0.00	0.06	0.0000
2	3	0.08	0.30	0.0004
2	5	0.04	0.15	0.0002
2	6	0.12	0.45	0.0005
3	4	0.10	0.40	0.0005
3	6	0.04	0.40	0.0005
4	6	0.15	0.60	0.0008
4	9	0.18	0.70	0.0009
4	10	0.00	0.08	0.0000
5	7	0.05	0.43	0.0003
6	8	0.06	0.48	0.0000

7	8	0.06	0.35	0.0004
7	11	0.00	0.10	0.0000
8	9	0.0052	0.48	0.0000

Table 2: The Line and Transformer Data

Figure 8 above is the 11-bus power system network that was used to test the program. Table 1 and 2 shows the data of generators, line and transformer used in the network.

From the test, the value of arc resistance and new fault current were calculated and compared with the value of fault current that calculated from existing method. The results as followed:

Bus Node	Fault Current (I_f) (kA)	New Fault Current (I_{fnew}) (kA)	Arc Resistance (Ω)
1	6.404	5.050	3.018
2	5.720	3.449	4.420
3	3.716	1.337	11.397
4	5.587	2.714	5.615
5	3.719	0.253	60.192
6	3.661	1.784	8.544
7	4.351	2.367	6.438
8	2.915	0.941	16.189
9	1.908	0	∞
10	7.368	5.787	2.634
11	5.029	3.891	3.917

Table 3: The Result of Fault current, New fault Current and Arc Resistance

From Table 3, the value of fault current can be compared. The value of fault current from the existing method is bigger than the new fault current. The value of new fault current determined is more accurate.

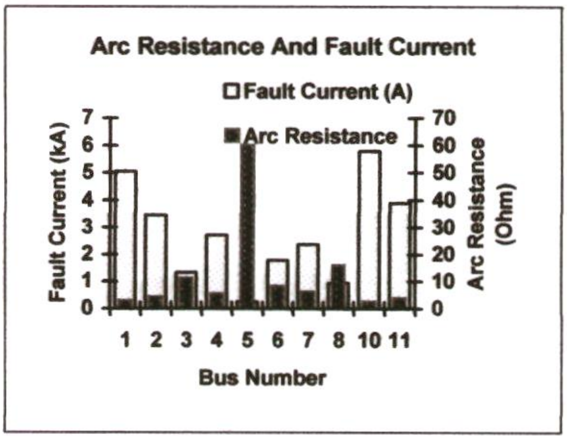

Fig 9: Arc Resistance and Fault Current in Different Nodes

Fig 9 shows the readings for arc resistance and new fault current. The bigger the value of arc resistance, the lower the value of fault current and vice versa.

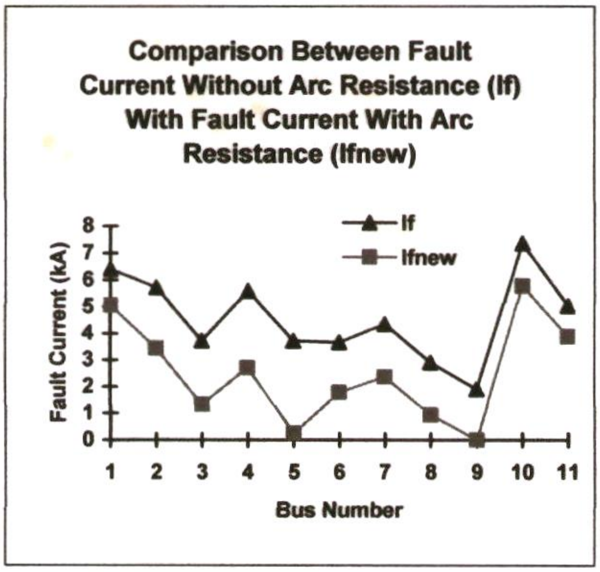

Fig 10: Comparison between Fault Current without Arc Resistance with New Fault Current

V. CONCLUSION

In this paper the new method for fault analysis in transmission network by including the value of arc resistance is presented. The method is tested using the 11-bus power system network on symmetrical fault.

From the new method, the value of fault current is more accurate compare to the existing method that totally neglected the arc resistance value or solved by assuming a suitable constant of arc resistance value.

The new method offers the more realistic approach and accurate calculation of fault current.

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