ENHANCEMENT OF A FAULT ANALYSIS METHOD USING ARC RESISTANCE FORMULA

HOUMAN OMIDI

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Faculty of Electrical Engineering
Universiti Teknologi Malaysia

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Specially dedicated:

To my beloved family

My mother, father

And

Dearest sister
ACKNOWLEDGMENT

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ABSTRACT

Generally there are two different methods in calculation short-circuit currents in power system networks in terms of considering arc resistance in calculations, first method is based on considering the value of the arc resistance as a constant value (usually 0.5Ω) or neglecting this value. By introducing some formulae for the arc resistance like the Warrington formula which is one of the most well-known formulae second method could be applied. Second method is based on considering the value of the arc resistance in short-circuit calculation. To calculate the short-circuit current in power system networks our model should be accurate enough, to have an accurate model in these studies the value of the arc resistance should be considered. The problem here is the non-linear relationship between fault current and arc resistance. By using more accurate formula like Terzija has been proposed in one of the recent studies values of short-circuit current and arc resistance can be identified more accurate but still there are some problems relates to the high fault currents. In this study by using ETAP software for fault analysis, Microsoft visual studio 2010 (C++ programming) for the related iteration and one the most recent formula for the arc resistance, short-circuit studies based on symmetrical components has been investigated on two different IEEE networks; IEEE 30-bus and IEEE 34-bus test feeders. Results have been compared with fault analysis based on phase coordination in the same network and shows the efficiency of the arc resistance formula which has been used in this study in special range of fault currents in balanced and unbalanced networks.
ABSTRAK

Secara umumnya, terdapat dua kaedah yang berbeza dalam pengiraan litar pintas arus dalam rangkaian sistem kuasa dari segi mengingati rintangan arka dalam pengiraan, kaedah pertama adalah berdasarkan mempertimbangkan nilai rintangan arka sebagai nilai malar (biasanya 0.5Ω) atau mengabaikan nilai ini. Dengan memperkenalkan beberapa formula untuk rintangan arka seperti formula Warrington yang merupakan salah satu kaedah yang paling terkenal kedua formula boleh digunakan. Kaedah yang kedua ialah berdasarkan menimbangkan nilai rintangan arka dalam pengiraan litar pintas. Untuk mengira arus litar pintas dalam rangkaian sistem kuasa model kita harus cukup tepat, untuk mempunyai model yang tepat dalam kajian tesis nilai rintangan arka perlu dipertimbangkan. Masalah di sini adalah hubungan bukan linear antara arus kerosakan dan rintangan arka. Dengan menggunakan formula yang lebih tepat seperti Terzija telah dicadangkan dalam salah satu nilai kajian terkini litar pintas semasa dan arka rintangan boleh dikenal pasti yang lebih tepat tetapi masih terdapat beberapa masalah yang berkaitan dengan arus kerosakan yang tinggi. Dalam kajian ini dengan menggunakan perisian ETAP untuk analisis kesalahan, Microsoft visual studio 2010 (C++ pengaturcaraan +) bagi lelaran yang berkaitan dan 1-formula paling terkini untuk rintangan arka itu, litar pintas kajian berdasarkan komponen simetri telah telah disiasat pada 2 IEEE rangkaian yang berbeza IEEE 30-bas dan IEEE ujian pemakan 34-bas. Keputusan telah dibandingkan dengan analisis kesalahan berdasarkan penyelarasan fasa dalam rangkaian yang sama dan menunjukkan kecekapan formula rintangan arka yang telah digunakan dalam kajian ini dalam julat khas arus kerosakan dalam rangkaian yang seimbang dan tidak seimbang.
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CHAPTER 1

INTRODUCTION

1.1 Background

This chapter discusses about the objectives, scope, significant and a short background of this study and this dissertation. This study focuses on fault analysis methods in both balanced and unbalanced systems and enhancement of these methods by using arc resistance formula which has been got from one the recent studies [1] and test this formula in two different IEEE test networks and compare the obtained values with the values which obtained based on previous methods.

Short-Circuit current calculation in power system networks is necessary for different reasons like network planning, operation purposes and also for network designs and expansions. Design of switchgears and protection devices needs accurate calculation of short-circuit current which protection coordination is so sensitive to these calculations. By introduction of distribution generators (DG) and other renewable sources these studies become more important than ever. In order to calculate the accurate value of the short-circuit current we should have an accurate model of our system.
In fault calculation both maximum and minimum fault currents are calculated for the related network. To calculate the maximum short-circuit current we should assume that all generators are connected and the load is maximum load and also the fault is bolted which the fault impedance equals to zero.

To calculate the minimum current we assume that the number of connected generators has the minimum value and the load is at a minimum, also the fault is not a bolted fault which means that the fault impedance is consists of tower footing resistance and the arc resistance. It means to calculate the minimum current the arc resistance should be taken into account. The point here is that the practical value which often use for the fault resistance introduces a large error into our final results of calculation because these values are far away from the actual values.

The networks in the power system that we are going to analyze may be radial or meshed, balanced or unbalanced and also may be single-phase, two-phase or three-phase which need different calculation methods.

For example distribution system which is one of the most complex systems to analyse is generally unbalanced, there are many different methods to analyze a distribution network which some of them are based on symmetrical components and others are not. The main advantage of the symmetrical component method is that the three sequence matrices are treated separately but the problem relates to this method is that this method does not enable the exact modeling of the four-wire distribution networks.

Arc resistance which is an important macroscopic parameter describes the complex nature of arcs. Arc discharge is occurred in everyday use of power system equipment [2].
Permanent faults in power system equipment like machines, transformers, cables and transmission line always involve an arc. Every time which a circuit breaker is opened when carrying a current an arc strikes between its separating contacts.

All arcs in nature possess a highly complex nonlinear nature which is influenced by a number of factors. This phenomenon can be considered as an element of an electrical power system which has a resistive nature, for example as a pure resistance. One of the important factors in describing the arc behavior and arc resistance is the length variation.

Warrington formula is one of the formulas which the fault arc resistance can be calculated by use of this formula. He (Warrington) derived a relationship by using the measured arc voltage gradient and arc current for arc voltage. Recent studies shows that his measurements and the results according to his measurements are not accurate [2], in this study one of these new studies which has been done by Terzija (2011) [1] has been used.

To calculate the fault current in power system networks accurately we need an accurate model of fault which must include the electrical arc existing at the fault point which is so important in fault current calculation. In this study the value of the arc resistance at the fault point must be known in advance. But the question is how to calculate the arc resistance and fault current at the fault location when these two values are related to each other.

In this study the goal is to introduce some of most applicable short-circuit analysis for balanced and unbalanced networks and enhance these methods by using the arc resistance formula to achieve more accurate values of short-circuit current and arc resistance.
1.2 Problem Statement

Statistically in more than 80% of all faults arcing faults occur [3] which makes the consideration of arc resistance in fault analysis essential. To calculate the arc resistance value the problem is that the fault current depends on arc resistance which itself a nonlinear function of fault current so, the question here is how to calculate the unknown arc resistance and fault current consequently and also accurately.

Previously in calculating the short-circuit the value of the arc resistance has been assumed to be constant (e.g. $0.5\,\Omega$) or has been neglected at the fault location. But the problem relates to these calculations is that the currents obtained by this are larger than those which would be obtained if the value of the arc resistance had been included in the calculation procedure. On the other hand, the actual value of the arc resistance which exists on the fault location would affect the real value of the fault current.

The arc resistance physically is determined by the arc current and the arc length which is proportional to the arc length and inversely proportional to the arc current. Compare to the existing methods of short-circuit calculation which the arc resistance has been totally neglected or assumed to have a constant value the method which is used in this study offers a more accurate short-circuit current calculation which can be useful in protection coordination and also power system design and planning. Because based on these studies the components of switchgears are designed, constructed, manufactured and installed and protective devices are so sensitive in changing of these values.

If the arc resistance is neglected the value of the impedance would be 25% smaller compare to the real value [1] which affects the fault current and can cause calculating wrong values of fault current. Therefore this method offers a more realistic approach and calculations of short-circuit currents and voltage profile is more accurate.
So one of the significant achievements of this study is that this method calculate short-circuit current and arc resistance consecutively which improves the accuracy of this computation.

One of the objectives of any short-circuit analysis is to calculate the fault current and the voltages. Short-circuit studies is needed for many power system studies such as transient stability and voltage sag analyses.

Distribution system in power system domain is one of the most complex systems. Analysis of distribution system becomes more important in recent days because of expansion of these networks and also the automation of its operation. To determine the rating of the protective devices in the distribution and design of the switchgears short-circuit analysis is an important tool. Distribution systems are generally unbalanced so, the analysis of short-circuit current in unbalanced networks becomes more important.

Symmetrical components method is one of the traditional fault analyses [4] which is implemented in the majority of software packages which are used today in industries. The reason lies on the computational efficiency and the simplicity of modeling power system elements such as generators and transformers but the existence of single-phase and two-phase lines in three-phase system made the application of symmetrical components complicated for fault analysis.

The other issue which will be discussed in this study is analyzing the different methods of short-circuit calculation for both balanced and unbalanced networks. There are different methods to solve an unbalanced network, in this study some of the methods which are used to solve balance and unbalanced networks will be discussed and these methods are also has been compared to each other and advantages and disadvantages of each method has been discussed.
1.3 Objectives

The aim of this study is to investigate the applicable methods of short-circuit analysis in both balanced and unbalanced power system networks and compare these methods to each other.

In analyzing the short-circuit methods the effects of considering the arc resistance in calculating the fault current is also investigated which need to analyse the iterative method to calculate the accurate value of the arc resistance.

In this study the effects of considering arc resistance in two different IEEE test networks has been investigated and has been compared to the previous methods which do not consider this value into their calculations.

So the objectives could be specified as:

i. To analyze the importance and effects of considering the arc resistance in calculation of short-circuit current in balanced and unbalanced networks.

ii. To analyze the iterative method of finding the short-circuit current and the value of the arc resistance consequently which is based on an arc resistance formula.

iii. To evaluate the fault analysis methods which are used to calculate short-circuit currents in both balanced and unbalanced networks.

iv. To test a fault analysis method in balanced and unbalanced networks using ETAP software on two IEEE test networks.

v. To compare the method of considering arc resistance in fault analysis and methods which do not consider this value in both balanced and unbalanced networks.
According to the objectives which has been shown above two simulations has been done in this study in one balanced and one unbalanced networks in two different cases:

i. Case a: Considering the value of the arc resistance.
ii. Case b: Ignoring the value of the arc resistance.

1.4 Scope

The scope of this study is based on distribution networks due to existence of unbalanced loads in this network but the results can be extended to any other balanced or unbalanced networks.

To show the efficiency of this method result of short-circuit current simulation with and without considering arc resistance has been analysed.

As it considered before, our calculation according to the iterative method has been done on two different IEEE networks:

i. IEEE 34 Distribution Network
ii. IEEE 30 Bus Power System Test Case

Which the case a represent the unbalanced network and case b has been used as the balanced network.

1.5 Significance
By calculating the accurate value of the arc resistance according to the formula which is based on one of the recent studies [1] the accurate value of the current and impedance can be obtained.

This process will help us to improve the efficiency of the protection system which is so sensitive to the changes of these values. Also using these new and accurate values of current and impedance in procedure of sizing switchgears and components like CBs and bus bars is so useful.

Another application which can be considered using these new values is based on use of artificial intelligence of distribution system protection. For example this method will increase the learning ability and efficiency of neural networks.

On the other hand studying different fault analysis methods will help us to choose between these methods the appropriate model for our case. Traditional fault analysis is based on the symmetrical components which for any unbalanced fault the three sequence networks should be modified and they should connected together appropriately to model the fault conditions.

Several new methods have been proposed base on the Symmetrical component method. If the system contains the elements of unbalanced parameters which include mutual couplings between the sequence networks, in this case the symmetrical components will lose its advantages.

One of the recent methods which has been discussed in this study is named by Hybrid Compensation Method which capable of handling features of distribution system with different configurations.
The hybrid compensation method is basically a distribution power flow which has been developed by the Pacific Gas and Electric Company to solve short-circuit analysis in unbalanced system. Since this method does not work based on forming traditional admittance matrices this method achieves high speed and robust convergence with low needed memory.

1.6 Organization of Project

To obtain the appropriate results, this study has been divided into 5 main chapters. In the first chapter the background information, objectives, scope and significance of study has been discussed. Basically this chapter has been focused on preparing general information about the related topic and clarifies the objectives and scope of the study.

In the second chapter, improvements of two different methods relate to the calculation of arc resistance and short-circuit calculation has been discussed through the time.

Third chapter is consists of the theoretical materials which is needed as basic knowledge to understand the more complicated parts which has been discussed in the next chapter, in terms of fault analysis and specially recent methods of short-circuit analysis. Symmetrical components and basic fault analysis in balanced networks are some of these parts. Some of recent methods like the hybrid compensation method has been discussed in this chapter.

In the next chapter the methodology of this study is discussed which includes two major parts. The first part relates to the arc formula that has been used and second part relates to a fault analysis for unbalanced networks. The fault analysis which has
been discussed in this chapter contains the basic concepts of calculating short-circuit analysis in unbalanced networks.

Last chapter relates to the results of utilizing arc resistance formula and using ETAP software and iterative method consequently and analyzing these results. The arc resistance formula has been discussed in both balanced network and unbalanced networks. To test the methodology of this study below networks are used.

i. IEEE 34 Distribution Network
ii. IEEE 30 Bus Power System Test Case
REFERENCES


