Faults on Electrical System

A Research

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Abstract

In electrical system, there is a common and unexpected that once occurred of some other time on a system, the “Faults on Electrical System”, Fault, a connection or a situation on which causes unbalanced on particular three phase system, nowadays, by technology powered technique on either digital or analog types of protection that can prevent faults on the system. By clearing those as mention on this research, their occurrence, its location this entire situation can be equate with the corresponding formulas on balancing such unwanted harmonics on a system. With also the maintenance of a transient stability requirements of the synchronizing balance power to overcome the sufficient occurrence of a fault. All this matter is being discuss on this research.
Acknowledgement

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Chapter 1

1.1 Introduction

In Electrical system there is an interrupted system called Fault, a connection or a situation that causes an unbalance among the three phases. That can be broken down into three groups of balanced vectors. When all the factors have been tentatively selected and balanced, they should be checked by calculations for the limiting the fault condition. Such calculations can be made by hand but are very laborious if more than two generating stations are involved, and in such cases the use of the a-c calculating board is the only satisfactory means of solution. Foregoing discussion has treated transient stability when faults occur. However, a first consideration in system design is the prevention of faults. This includes such factors as clearances, ruggedness of structures, lightning-diverting cables and towers, and guards against birds and animals. With proper structural designs and fast clearing of ground and phase-to-phase faults, the possibility of three-phase faults on the higher voltage lines can be practically eliminated.

The researcher chooses the topic “Faults on Electrical System” to discuss the types fault systems on how to be cleared out into the system, another form that will satisfy on the electrical system.

1.2 Statement of the Problem

In general, transient instability results when the flow of synchronizing power between generating stations during and following a fault is insufficient to overcome the speed changes acquired by the generators during and following the disturbances quickly enough to prevent faults, system design are usually requires that transient stability shall be maintained if the most important interconnecting line of a network shall be tripped out due to one or more of the faults which may be experienced. Transient stability for three phase faults on the main lines of a transmission system is to be cleared. The Researcher picks the topic “Faults on Electrical System” to determine the importance of the faults and to eliminate them to the system.

1.3 Objective of the Study
In every study has its own purpose to rely on. Primarily, this study is aiming to the faults on electrical system. Secondly, this is aiming on the following:

1. To discuss Faults on Electrical System.
2. To discuss the clearing of faults using transient stability.
3. To discuss how the faults occur.
4. To elaborate the types of faults and its location.
5. To equate the formulas of the various types of faults.

1.4 Significance of the Study

Beyond these faults using transient stability, the researcher will know how to use this clearing way in a proper a manner. The researcher will not only discuss faults on electrical system but also will know how it is being eliminated. The importance of this study is to discuss the faults and how to be cleared, how it can affects the system. On the other hand, the researcher must know first the basic principle behind on this systems and its configuration. It also enables the researcher to widen his knowledge on the certain topic that will provide enough understanding. By understanding its principle the researcher will know how this matter be done.

1.5 Scope and Limitation

Fault on Electrical System is a very wide topic to discuss. This research focuses on the different kinds of faults on a system. That is being cleared on the system. That is why this topic tackles Faults, Transient Stability, and The types of faults. Namely, Single-Line to Ground Fault, Line to Line fault, Double Line to Ground, Three Line to Ground Fault, where this system is being discussed briefly based on its basic principle and configuration. It also includes a brief history on transient stability to refresh the mind of the researcher from the various matter of Electricity.

Chapter 2
Review on Related Literature
2.1 Transient System Stability

A power system may be said to have transient stability if the various generating stations will regain equilibrium following a periodic system disturbances. System disturbances which cause the greatest trouble are those due to line faults. A line fault, in addition to the changes in generator loadings which it causes before being cleared, will trip out a radial line causing a loss of load, or else it will trip one of the interconnecting lines of a network, thereby requiring a readjustment of phase angles all around and at the same time increasing the impedance between plants and impairing the flow of synchronizing power. Transient Stability studies are essentially a study of the momentary-speed changes of rotating equipment, which are functions of their inertias.

2.1.1 Factors Affecting Transient Stability

a. Generator $WR^2 X \text{rpm}^2$. The greater this quantity the lower the acceleration factor.
b. System Impedance, which must include the transient reactances of all generating units. This affects phase angles and the flow of synchronizing power.
c. Duration of the fault, chosen as the criterion for stability. Duration will be dependent upon the circuit-breaker speeds and the relay schemes used.
d. Generator loadings prior to the fault which will determine the internal voltages and the change in output.
e. System loading, which will determine the phase angles among the various internal voltages of the generators.

2.1.2 Utilization on Transient Stability

a. The use of high-resistance amortisseur windings in salient-pole machines. This is no great benefit if faults are cleared by modern high-speed breakers and relays.
b. The use of neutral grounding resistors at generating stations to reduce load changes during ground faults. The application of such resistors should be investigated for possible excessive over voltages.
- **Resistance Grounding** of high-tension transmission neutrals is not used extensively but has been proposed as an aid to the maintenance of transient stability.
- When such installations are being considered, it should be given a searching analysis, utilizing the method of symmetrical components.
- The best neutral grounding scheme is one which provides the required limitation of ground-fault currents and at the same time causes the minimum distortion of the system voltages when the ground fault occurs. This usually means that some ratio of zero-sequence impedance to positive and negative-sequence impedance is established as the criterion for grounding.

c. The use of neutral grounding reactors to reduce the drop in positive-phase sequence voltage during ground faults, thereby improving the flow of synchronizing power.

d. The use of special quick-response excitation systems has been considered but is no longer believed to be of appreciable benefit when high-speed relays and circuit breakers are used.

*When all the factors have been tentatively selected and balanced, they should be checked by calculations for the limiting fault condition. Such calculations can be made by hand but are very laborious if more than two generating stations are involved, and in such cases the use of the a-c calculating board is the only satisfactory means of solution. Alternating-current calculating-board studies will be found to have sufficient accuracy for all practical purposes.*

### 2.2 Sequence Network

A copy of original balanced system to which the fault point is connected and contains the same per-phase impedances as the physical balanced system arranged in the same way. The only difference being that the value of each impedances are a value unique to each sequence.
The Thevenin’s equivalent or open circuit voltages in the negative and zero sequence networks are zero because by definition the only voltages generated in the three-phase system are positive sequence (sequence a-b-c) voltages.

Where: 
F = Fault Point
N = Zero – potential bus

Eₐ = Thevenin’s equivalent voltage (per unit) or the pre-fault (F open) voltage of phase at point F.

Z₁ = Positive sequence impedance (per unit)
Z₂ = Negative sequence impedance (per unit)
Z₀ = Zero sequence impedance

Iₐ₁ = Positive sequence current component of phase a (per unit)
Iₐ₂ = Negative sequence current component of phase a (per unit)
Iₐ₀ = Zero sequence current component of phase a (per unit)

Vₐ₁ = Positive sequence voltage component of phase a (per unit)
Vₐ₂ = Negative sequence voltage component of phase a (per unit)
Vₐ₀ = Zero sequence voltage component of phase a (per unit)

### 2.3 Faults

As any connection or situation that causes an unbalance among the three phases. A system design usually requires that transient stability shall be maintained if the most important interconnecting line of a network shall be tripped out due to one or more of the types of fault which may be experienced.

**Faults Analysis**
a. Fault currents cause equipment damage due to both terminal and mechanical processes.

b. Goal of fault is to determine the magnitudes of the currents present during the fault.

**Ground Faults**

Is an undesirable condition in an electrical system, in which electrical current flows to the ground. A ground fault happens when the electrical current in a distribution or transmission network leaks outside of its intended flow path. Distribution and transmission networks are generally protected against faults in such a way that a faulty component or transmission line is automatically disconnected with the aid of an associated circuit breaker.

2.3.1 **Types of Faults**

**Main Types:**

a.) Metric faults: system remains balanced. These faults are relatively rare, but are the easiest to analyze.

b.) Unsymmetrical faults: system is no longer balanced. Very common, but more difficult to analyze.

c.) The most common type of fault on a three phase system by far is the single line-to-ground, followed by the line-to-line faults, double line-to-ground faults, and balanced three phase faults.

a. **Single-Line to Ground Fault**

This fault requires the zero-positive and negative-sequence networks for phase "a" be placed in series in addition to $3Z_0$ in order to compute the sequence currents for phase "a",
b. Line to Line Fault

Consider a fault between phase b and c through an impedance $Z_f$ figure. Connecting the sequence networks for phase "a" as found earlier (positive and negative-sequence networks in opposition).

c. Double Line to Ground Fault

Here phase b and c are shorted and connected to ground through a fault impedance $Z_f$. 

d. Three Phase Fault (Three Line to Ground Fault)

the three-phase fault is often the most severe type of fault.

2.3.2 Fault Point

A system or network is that point to which the unbalanced connection is attached in an otherwise balanced system.
Where: $Z_a$, $Z_b$, $Z_c$ = Phase impedances at the fault point.

$V_a$, $V_b$, $V_c$ = Line to Ground voltages at the fault point.

$I_a$, $I_b$, $I_c$ = Line Currents at the fault point.

2.4 Symmetrical Components

The key idea of symmetrical component analysis is to decompose the system into three sequence networks. The networks are then coupled only at the point of the unbalance, the fault. The three sequence networks are known as the positive sequence this is the one we’ve been using, negative sequence, and zero sequence.

2.4.1 Positive Sequence

The positive sequence sets have three phase currents/voltages with equal magnitude, with phase b lagging phase a by 120°, and phase c lagging phase b by 120°. Three equal vectors whose phase sequence is the same as the original sequence of the unbalanced system of vectors, uses subscript 1.
Positive sequence sets have zero neutral current.

2.4.2 Negative Sequence

The negative sequence sets have three phase currents/voltages with equal magnitude, with phase b leading phase a by 120°, and phase c leading phase b by 120°. Negative sequence sets are similar to positive sequence, except the phase order is reversed. Three equal vectors whose phase sequence is opposite of the original sequence of the unbalanced system vectors, uses subscript 2.

\[
V_{b2} = aV_a,
V_{c2} = a^2V_a,
\]

Negative sequence sets have zero neutral current.

2.4.3 Zero Sequence

Zero sequence sets have three values with equal magnitude and angle. Zero sequence sets have neutral current. Three vectors which are equal and in phase, uses subscript 0.

\[
V_{a0} = V_{b0},
V_{c0} = V_{e0},
\]

Zero sequence vectors with zero phase shift.
3.1 Introduction

An interrupted electrical system called fault, foregoing discussion has treated transient stability when faults occur with proper structural designs and fast clearing of ground and phase-to-phase faults, the possibility of three phase faults on the higher voltage lines can be practically eliminated. When all the factors have been tentatively selected and balanced, they should be checked by calculations for the limiting the fault condition. Such calculations can be made by hand.

3.2 Unbalanced Fault Analysis Using Bus Impedance Matrix

We showed that the symmetrical components are independent, and for each component there is an impedance matrix $Z_{bus}$. Thus we can find $Z_{bus0}$, $Z_{bus1}$ and $Z_{bus2}$ in order to deal with each component separately. If the fault is at bus $k$, then we know that the $k^{th}$ diagonal element of the bus is the Thevenin impedance of the network viewed from that bus. This then allows us to find the sequence networks, which we connect according to the fault, and then go on to solve for the fault currents and voltages. The impedances obtained from the $Z_{bus}$ matrices are called $Z_{k0}$, $Z_{k1}$ and $Z_{k2}$.

3.2.1 Single-Line to Ground Fault Using $Z_{bus}$

The single line to ground fault on line "a" through impedance $Z$ to ground on bus $k$. This fault requires the zero- positive- and negative-sequence networks for phase "a" be placed in series in addition to $3Z$ in order to compute the sequence currents for phase "a", thus:

$$
I_{k0} = I_{k1} = I_{k2} = V_k / Z_{k0} + Z_{k1} + Z_{k2} + 3Z_f
$$

Where $Z_{k0}$, $Z_{k1}$, and $Z_{k2}$ are the diagonal elements in the $k$ axis of the corresponding impedance matrix, and $V_0$ is the pre-fault voltage at bus $k$. The fault phase current is:

$$
I_{kabc} = AI_{k012}
$$

3.2.2 Line-to-Line Fault Using $Z_{bus}$
Consider a fault between phases b and c through an impedance $Z_f$ at bus k as shown in the figure. Connecting the sequence networks for phase "a" as found earlier (positive- and negative-sequence networks in opposition,) the symmetrical components of the fault current are:

$I_{k0} = 0$

$I_{k1} = - I_{k2} = V_k / (Z_{k1} + Z_{k2} + Z_f)$

Where $Z_{k1}$ and $Z_{k2}$ are on the diagonal elements in the k-axis of the corresponding bus impedance matrix. The fault phase current is then obtained using the $A$ matrix as usual.

### 3.2.3 Double Line-to-Ground Fault Using $Z_{bus}$

Here phases b and c are shorted and connected to ground through a fault impedance $Z_f$. From before, the equations for the sequence currents of phase a at bus k are given by:

$$I_{k1} = \frac{V_k}{Z_{k1} + \frac{Z_{k2} (Z_{k0} + 3Z_f)}{Z_{k2} + Z_{k0} + 3Z_f}}$$

As usual, the $Z_{k0}$, $Z_{k1}$, and $Z_{k2}$ are the diagonal elements in the k axis of the corresponding impedance matrix, and $V_k$ is the pre-fault voltage at bus k. The phase currents are obtained using the $A$ matrix, and the fault current is $I_k = I_{KB} + I_{KC}$.

### 3.3 Three Phase Fault Calculations

#### 3.3.1 Method I: kV Base Method:
Procedures:
- Draw the per phase diagram of the system
- Choose a common kV-Base ($V_c$) and express all impedances on the selected kV-Base.

$$Z_C = Z_A \left( \frac{V_C}{V_A} \right)^2$$

Where: $V_c$ = Common kV-Base

$V_a$ = Voltage Base of $Z_a$

$Z_c$ = New Impedance Base on $V_c$

- Calculate the total or equivalent impedance ($Z_T$) using circuit principles
- Calculate the fault current ($I_f$) using ohm's law.

$$I_f = \frac{V_F}{Z_T}$$

Where: $V_F$ = Voltage per phase at the fault.

- Evaluate the actual fault current using the relation

$$I_A = I_f \left( \frac{V_C}{V_A} \right)$$

$I_A$ = Actual fault Current

3.3.2 Method II: kVA-Base Method:

Procedures:
- Draw the per phase of the system
- Express all impedances in percentage of per unit values
- Choose a common kVA-Base and express all $Z_{pu}$ on the selected common kVA-Base

$$Z_{CPU} = Z_{APU} \left( \frac{\text{kVA}_C}{\text{kVA}_A} \right)$$

Where: $Z_{CPU}$ = New per unit impedance based on kVA$_C$

$kVA_c$ = Common kVA-Base

- Calculate the total per unit impedance of the system ($Z_{tpu}$) using circuit principles.
- Calculate the fault power (kVA$_F$) using the relation.

$$kVA_F = kVA_C / Z_{TPU}$$

- Evaluate the fault current ($I_f$) using the equation.

$$I_F = \frac{kVA_F}{\sqrt{3} \cdot V_F}$$

Where: $V_F$ = Line-to-Line voltage at the fault point in kV.

3.4 Location of Line Faults

Faults in electrical lines for the transmission and distribution of power, may be divided into two classes, closed circuit faults and open circuit faults. Close circuit fault
consist of “shorts” where the insulation between conductors becomes faulty and “grounds” where the faulty insulation permits the conductor to make more or less perfect contact with the earth. Open circuit faults or “opens” are produced by breaks in the conductors.

(a.) When the “shorts” is a low resistance union of the two conductors, such at M in figure line faults, the resistance should be measured between the ends AB; from this value and the resistance per foot of conductor, the distance to the fault can be computed. A measurement of resistance between the other ends A’B’ will confirm the first computation or will permit the elimination of the resistance in the fault, if this is not negligible.

(b.) the location of a “ground”, as at N in figure line faults, or of a high-resistance short is made by either of the two classical “loop” methods. Provided a good conductor remains. In Murray Loop test arrangement, which is suitable for low-resistance “grounds”. The faulty conductor and a good conductor are joined together at the far end, and a Wheatstone Bridge arrangement is set up at the near ends with two arms a and b comprised in resistance boxes which can be varied at will; the two segments of line x and (y + L) constitute the other two arms the battery current flows through the ground; the Galvanometer is across the near ends of the conductors. At balance,

\[
\frac{a}{b} = \frac{x}{(y + L)} \quad \text{or} \quad \frac{a + b}{b} = \frac{x + y + L}{y + L} \quad \text{(ohms)}
\]

The sum \(x + y + L\) may be measured or known. If the conductors are uniform and a like, and \(x\) and \(l\) are expressed as lengths, say in feet.
If the "ground" is of high resistance, very little current will flow through the bridge with the arrangement of Murray Loop test; in that case, battery and Galvanometer should be interchanged, and the Galvanometer used should have a high resistance. If ratio arms a and b consist of a slide wire (Preferably with Extension Coils). The sum \((a + b)\) is constant, and the computation of \(x\) is facilitated. Observations should be taken with direct and reversed currents, especially in work with underground cables.

In the Varley Loop, fixed ratio coils, equal in value, are employed, and the bridge is balanced by adding a resistance \(r\) to the near leg of the faulty conductor,

\[
\frac{a}{b} = \frac{r + x}{y + L} \quad \text{or} \quad \frac{a + b}{b} = \frac{x + y + L + r}{y + L} \quad \text{(ohms)}
\]

if \(a = b\)

\[
x = y + L - r \quad \text{or} \quad x = (0.5)(x + y + L - r) \quad \text{(ohms)}
\]

The total line resistance \((x + y + l)\) is conveniently determined by shifting the battery connection \(P\) to \(Q\) and making new balance, \(r'\). if \(a = b\) equation then becomes \(x = (0.5)(r' - r)\). When \(a\) and \(b\) interchanged and the average values of \(r\) and \(r'\) substituted in the foregoing equations.

c.) "opens", such as \(O\) in figure of line faults, are located by measuring the electrostatic capacitance to ground (or to a Good Conductor) of the faulty conductor and of an identical good conductor; the position of the fault is determined from the ratio of the capacitances.
References:


1001 Solve Problems, Romeo A. Rojas Jr.