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Power System Faults: A Hindrance to Sustainability and Reliability

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Abstract: Faults hinder the reliability and sustainability of power systems. Power system faults cannot be totally eliminated but can only be reduced or prevented from frequent occurrence. This paper focuses on the various types of power system faults such as symmetric and asymmetric faults, the effects on the power system reliability, accurate and fast location of the faults and how to minimize the effects on power systems.

Keywords: Faults, Sustainability, Dependability, Reliability, Generator acceleration, Symmetrical faults, Asymmetrical faults, Travelling wave.

1 Introduction.

Fault in a power network is any failure which interferes with the normal operation of the system. It can be very destructive to power systems. Failures in power system are inevitable due to some natural occurrences(Carpenter et al 2005, Wattanasakpubal and Bunyagul 2007, Zhu et al 2007).

Power system failures are caused by natural occurrence that normally results into power system faults which retard the continuity of power supply, dependability and reliability. System protection schemes are therefore implemented for the reliability and safety of power systems(Johns et al 1993, Eriksson et al 2005).

2. An overview of power system faults.

Since faults cannot be totally eliminated (due to unavoidable factors such as adverse weather conditions, insulation breakdown caused by aging, animal contact and human mistakes), the only way is to minimize its impacts(Zamora et al 1996).

Any abnormal flow of current in a power system's components is called a fault in the power system. Fault can also refer to a short circuit in a power system and can be divided into two broad classes: temporary and permanent faults(Saha et al 2009).

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2.1. Temporary Faults

These cause momentary disruption which is later cleared without protection operation intervention. The most common types of temporary faults are those faults from lightning strike. They are also known as transient faults because they do not cause damage to insulation permanently and always allow the circuit to be reclosed safely after a short period of time(Schweitzer 2010, Novosel et al1996, Jarventausta et al 1994)..

2.2 Permanent Faults

They cause sustained disruption to power systems that needed the involvement of protection engineer for rectification in order to put the system back to normal. The most common permanent fault types are associated with one or more of the following: wind, ice, loading thermal heating and sag(Wattanasakpbal and Bunyagul 2007)..

The faults affecting transmission system can either be symmetric or asymmetric in terms of phases. The most four common types are: Three Phase, Single Line to Ground, Double Line to Ground, Line to Line faults(Saha and Provoost 2009, Yuan et al 2011)..

Symmetric Fault or balanced faults: This affects each of the three phases equally. This is in contrast to an unsymmetrical fault, where the three phases are not affected equally. In practice, most faults in power systems are unbalanced (Saha et al 2000)..

An asymmetrical or unbalanced fault does not affect each of the three phases equally. Common types of asymmetric faults, and their causes are (Sachdev and Agarwal 2008):

- *Line-to Line* - a short circuit between lines, caused by ionization of air, or when lines come into physical contact, for example due to a broken insulator.
- *Line-to-Ground* - a short circuit between one line and ground, very often caused by physical contact, for example due to lightning or other storm damage.
- *double line-to-ground* - two lines come into contact with the ground (and each other), also commonly due to storm damage

2.3. Effects of Faults on Power Systems:

Current:

Since most fault result in short circuit, this makes the voltage at fault section to become zero thus making generator to have low impedance path to ground resulting in a large current. Therefore, there is the need for a protective system that can handle a very

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high current in a fault situation (Wiszniewski 1983, Girgis and Johns 1989, Xia et al 1994).

Generator Acceleration

The effect of fault on the power is to increase the reactive power and to decrease the real power. This happens because the high current causes an increase in voltage drop across the reactive elements in the generator lines and a decrease in voltage drop across the load impedance. The fact that the real power consumption of the network decreases is a problem because the real power mechanical input to the generator does not decrease (it comes from the turbine, from the steam, which is unaffected by the fault).The faulted condition must be removed quickly, otherwise the generator will speed up too much and lose synchronism with the rest of the network (Zimmerman and Costello 2004,Takagi et al 2002)..

Loss of a Component

- Proper action by the protection system to eliminate the faulted condition from the network results in loss of a component and therefore a weakening of the network. This can cause overloads, under voltages, and voltage instability.
- Thus, it is important to know the location of a fault or to locate it with possibly high accuracy. This allows us to save money and time spent on inspection and repair, as well as to provide a better service due to the possibility of faster restoration of power supply. Blackouts can be avoided this way if temporary faults are self-cleared and do not permanently affect the continuity of supply (Guzman et al 2007, Tziouvaras et al 2001,Novosel et al 2006).

3 Accurate and Fast Location of Power System Faults.

Since faults cannot totally be eliminated due to unavoidable natural factors such as adverse weather conditions, insulation breakdown are caused by aging, animal contact and human mistakes, The location of accurate distance to fault has been of great advantage and cost benefit in power system fault analysis and repair. There may be need for emergence measures such as making use of protection system like relay, circuit breaker to guard against the possible effect of a second or third fault in the same locality. The need for this is always quite expensive but the economic importance of this in power system is for quick isolation of the faulted section, undertake repairs and return a network to normal operational status in the shortest possible time. This has been of greater importance in reliability of power system and save the customer from consistence blackouts.

3.1 Fault Location

This is a process of locating the fault with the highest accuracy possible. Fault locators are in general the supplementary protection equipment, which apply the fault location algorithms for estimating a distance to the fault. When locating faults on a line consisting of more than one section (multi-terminal line), initially a faulted section has to be identified and then a fault on this section has to be located. Accurate pin-pointing of faults is required by operators and utility staff in order to expedite service restoration and, thus, to reduce outage time, operating costs, and customer complaints.

3.2 Modern Travelling Wave Technique.

The principle is based on the reflection and transmission of the generated travelling waves along the faulty power networks. It can be used on single – ended line in such a way that the recorder is spread along the distribution networks. The fault generated travelling wave and the travelling time of the waveform are the parameters often used to determine the location of the fault.

Modern travelling wave system (MTWS) makes use of double ended method for location of fault. The most advantage of this method is that it does not require any operator intervention to determine the fault location. The system makes use of the arc at the fault site and the resulting step change in the voltage as a result of fault on the line to generate a travelling wave that is propagating along the line in both directions to the line ends. The system has to be placed at the line ends accurately to tag arrival time of the step change in voltage generated travelling wave by using GPS as a reference. These time tags are sent to a central location where they can be used to calculate distance to fault using the line length and the velocity of propagation.

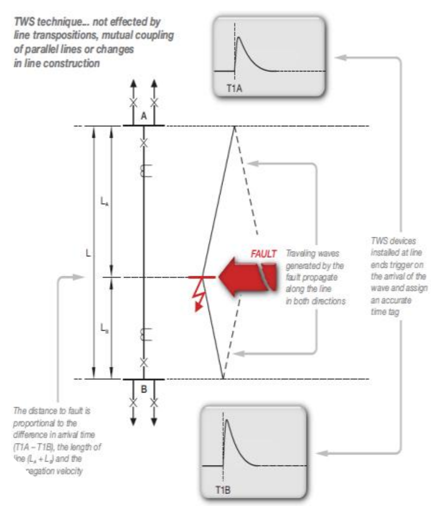

Figure 1- Double Line Travelling Wave Technique

This concept can be illustrated better in this Figure 2

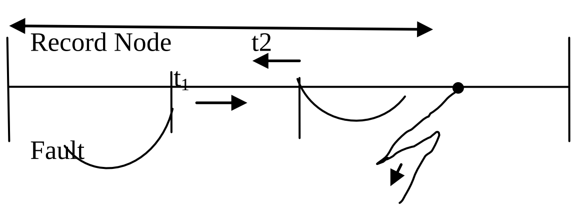

Figure 2 - Fault Location Using Travelling Wave Method

The fault location (d_f) can be calculated using this expression:

$$d_f = \frac{v(t_2 - t_1)}{2} \quad \ldots\ldots\ldots\ldots\ldots.. (1)$$

Where v = the velocity of the travelling wave, t_1 = time when waveform started to travel, t_2 = time when waveform arrived at the record node.

Benefit of accurate fault location.

Constant accurate fault location gives operation engineers the confidence to send repair teams to the right location at first time therefore, reduces time wastage in tracing faults. It also helps in giving sufficient details in establishing the trends of temporary or transient faults such as polluted or damaged insulators, encroaching tree growth or bird activity at the same location which can trigger a line inspection and possible remedial action being taken before a permanent fault develops.

Minimization of Power System Faults

- Effective Power System Protection: this can be achieved by protecting the electrical power system from faults through the isolation of faulted parts from the rest of the electrical network. The aim of protection scheme is to keep the power system stable and reliable by isolating only the component that are under fault, while leaving as much of the network as possible still in operation.

- Communication: This plays important role in the power system protection, in the sense that it aids in the transfer of crucial data in a save mode within a short period of time. The data is needed in a real sense to achieve high speed control and protection in a few seconds to convey power system state to substation –based control equipments to prepare them from future occurrence of faults.

Conclusion,

The concepts of power system faults as a hinderance to sustainability and reliability has been presented in this paper. The two broad classes of faults were clearly discussed. Modern travelling wave technique of accurate fault location as well as the various benefits of accurate fault location and minimization of power system faults were also discussed.

In order to have a sustainable and reliable power system, there is the need for a consistent accurate and fast location of faults and effective power system protection schemes to aid the reliability performance of the system..

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