High Peak Current Limiting and Transient Detection Methods in Electrical Power System

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Abstract— The protection is very much important task in a power system to get uninterrupted power supply. In this paper we studied the different methods of current limiters, current diverters with different methods of transient detection. The method is primarily intended for use in systems where fast fault detection and fast fault clearing before the first peak of the fault current are required. An industrial system, in which high short-circuit power is desired but in which high short-circuit currents cannot be tolerated is an example of such a system. In this paper, the need for fast and reliable protection is discussed. Fault-current limiters are an essential building block in many systems as well as the need for fast and reliable fault detection. Here wavelet transform, S –Transform and phase-locked loop (PLL) are used to perform the discrimination. Here we compared the different types of current limiting methods and transient detection methods.

Key words: Fault Protection, S –Transform, Phase-Locked Loop (PLL), Wavelet Transform Power System, Transients

I. INTRODUCTION

Generally a power system should be protected from abnormal conditions such as faults, transients etc. In power system protection both the fault detection as well as fault discrimination has equal importance. In some type of system the discrimination of fault is very much essential one. In this paper, it has been demonstrated that a PLL can be used to determine whether a current transient is due to a fault in the system or due to a switching transient. High short-circuit power is often desired in an industrial system in order to connect and disconnect loads without causing disturbances to sensitive equipment or processes. With the high short-circuit power; a high fault current develops in case there are faults in the system. This high fault current has to be considered when designing the switchgear and other components that build up the power system. This is easily done in new installations but can be problematic when there is a need for higher short-circuit power in an existing system. In these cases, the installation of a fault current limiter could be an alternative to rebuilding the switchgear.

The installation of a fault current limiter can also provide the opportunity to make connections in the power system that otherwise would not be possible due to fault currents that exceed the rating of the switchgear. An alternative to rebuilding the switchgear. The installation of a fault current limiter can also provide the opportunity to make connections in the power system that otherwise would not be possible due to fault currents that exceed the rating of the switchgear. Power system protection is another important issue. It is essential for safe operation of the power system that faults are detected and cleared automatically in a fast and reliable manner so that the operation of the power system is not disturbed. A typical fault protection system is built from circuit breakers (CBs), protection relays, and primary transducers, such as voltage and current transformers and auxiliary equipment.

In this project, the need for fast and reliable protection is discussed. Fault-current limiters are an essential building block in many systems as well as the need for fast and reliable fault detection. It is demonstrated that a phase-locked loop (PLL) can be used for power system protection purposes as an alternative to other methods. An investigation on how to use a PLL for the purpose of discriminating between a fault and a switching transient has been performed. Furthermore, the combination of protection relays and PLLs is discussed. It is proposed that the protection relay will detect the current transient and that the PLL will determine whether the current transient is caused by a fault or a switching transient.

Switching transients can, under certain circumstances, give rise to high currents, which are much larger in magnitude than normal load currents. In existing relay protection, capacitor energization and transformer energization have been detected by analyzing the measured current to find certain characteristics of the two types of current transient. A current transient caused by a transformer energization typically contains a superimposed dc component and a superimposed second harmonic component. A current transient caused by a capacitor energization typically contains higher frequency harmonic components. The harmonic components in the measured current can be identified with Fourier-based methods, but that typically requires more time. So to minimize the fault discrimination time PLL logic has been applied.

II. POWER SYSTEM PROTECTION

Generally a power system should be protected from abnormal conditions such as faults, transients etc. In power system protection both the fault detection as well as fault discrimination has equal importance. In some type of system the discrimination of fault is very much essential one. The discrimination can be done by various types of techniques such as time domain analysis, wavelet transform, equivalent instantaneous inductance technique, absolute difference of active power technique for discrimination in various equipments as well as in whole power system. A typical fault protection system is built from circuit breakers (CBs), protection relays, and primary transducers, such as voltage and current transformers and auxiliary equipment.

Strong Power System: The system which has low impedance between source and load and cause very less disturbance to the source during the faults, called strong power system. Most of the industrial systems are strong power systems. In this paper, an alternative method to perform the discrimination is proposed. The harmonic components in the measured current can be identified with Fourier-based methods, but that typically requires more time. For fast fault detection purposes, other methods have to be investigated. The method that is proposed in this paper uses a PLL for that purpose.

They desire high short circuit power to connect and disconnect loads without causing disturbances to sensitive equipment or processes. With the high short-circuit power, a high fault current develops in case there are faults in the system. There are many methods and algorithms available to detect short-circuit current in a power system. One simple (but yet efficient) method is to estimate the current from measured current samples. If the magnitude of the estimated current is larger than a predetermined threshold it is assumed that a fault has occurred (magnitude relay). In general, if more information is available, the estimation will become more accurate. On the other hand, if faster fault detection is required, the estimation becomes less accurate since less information is available.

This short detection time is needed for the fault-current limiters as mentioned in the previous section. Some methods that have been suggested for use in transmission systems have the potential of being fast. These methods could be based on traveling waves, neural networks, wavelet transforms, and fault-generated noise.

III. DIFFERENT METHODS OF CURRENT LIMITERS AND FAULT-CURRENT DIVERTERS:

Regarding the short-circuit power of a supply network is that whereas there are obvious advantages with a stronger network (less voltage dips, more and larger loads can be connected, less switching transients), there are also obvious disadvantages (high-fault currents in case of short-circuit faults in the system).

- Fault-Current:

A fault is an unintentional short circuit, or partial short-circuit, in an electric circuit. A variety of factors such as lightning, downed power lines, or crossed power lines cause faults. During a fault, excessive current it's called a fault current which is flows through the electrical system often resulting in a failure of one section of that system by causing a tripped circuit breaker or a blown fuse. Damaging currents to house - hold devices. Currently, two broad categories of FCL technologies present high-temperature superconducting and solid-state.

A. Current Limiters Type:

A fault current limiter (FCL) limits the amount of current flowing through the system and allows for the continual, uninterrupted operation of the electrical system, similar to the way surge protectors limit

One way of solving this contradiction is to use a fault-current limiter. During normal operating conditions a fault-current limiter is a device that allows a strong network but when a fault occurs, introduces enough impedance in the circuit so that the fault current is limited. The current limiting functionality can be achieved in several ways (e.g., current limiting reactors; fuses; triggered fuse; superconductive fault–current limiters; and fuses and power-electronic-based current limiters.

The purpose of a fault-current limiter is to limit the fault current so that its prospective peak value never is reached.

1) Current Limiting Reactors:

Current-limiting reactor's function is to increase the impedance in a possible short-circuit loop. The short-circuit current driven by the voltage source in the faulty circuit is reduced by the reactance of the coil. During normal operation, any increase in reactance results in an increase of the voltage drop in the network. In general, this does not represent a particular problem for the grid operation since the voltage drop at the reactor is geometrically subtracted from the supply voltage, and is therefore a function of the power factor.

2) Fuses

Fuses are simple, reliable and they are usually used in low voltage and in middle voltage distribution grids. The main disadvantages are the single-use and the manually replacement of the fuses.

3) Circuit Breakers:

Circuit-breakers are commonly used, reliable protective devices. The circuit breakers for high current interrupting capabilities are expensive and have huge dimensions. They require periodical maintenance and have limited number of operation cycles.

B. Fault Current Limiters

At last three decades, for making fault current limiters new materials with proper parameters are used. Therefore FCL is classified as

1) Non-superconducting FCL

It has the non-lineal characteristics of ferromagnetic materials to realize a high inductance. In normal case, the core is saturated by a bias current; the coil inductance is negligible. Suppose, if the fault occurs, then magnetic core is taken out of saturation, the coil attain a high inductance and limits the fault current. The designs differ in the core shape, core bias arrangement and magnetic design.

2) Superconducting FCL

In the normal operation the current is flowing through the superconducting element RSC dissipates low energy. If the current rises above the critical current value the resistance RSC increases rapidly. The dissipated losses heats the superconductor above the critical temperature T_c and the superconductor RSC changes its state – from superconducting into the resistive state, some resistance is generated and fault current is reduced.

The main advantage of this type SFCL is the use of DC instead AC for the superconductor and avoiding of AC losses. The major disadvantage of this device is its size is high due to this device will become quite expansive.

The FCLs can be installed in three main places in distribution substations, incoming feeder position.

3) Fault-Current Diverters:

Fault-current diverters can be used as an alternative to fault current limiters. A current diverter consists of a switch that is in open position under normal operating conditions. When a fault is detected, the switch closes and short circuits the phases of the power system to earth at a predetermined location. The fault current must be limited before the first peak of the fault current. Taking into account that some of the fault-current limiters described before contain mechanical systems that require a certain time to operate, it can be concluded that fault detection is an essential prerequisite for a system containing a fault-current limiter. This predetermined location is preferably chosen as close to the source as possible. The voltage drop across the arc becomes practically zero, making the arc extinguish.

One common feature of the described fault–current limiters and current diverters is that they must be able to operate within a few milliseconds after fault inception. The fault current will still flow from the source through the current diverter to earth and will continue to do so until the main circuit breaker (CB) clears the fault current. The benefit of a fault-current diverter is that the load that is connected to the system does not see the full short-circuit current once the switch has been closed.

IV. Different Methods of Detection of Fault from Switching Transient

In order to improve electric power quality, sources of disturbances must be known and controlled. Therefore, different disturbances must be detected, localized with respect to time and then classified consequently a sensor basen on line real time evaluation device is necessary. To monitor electrical power quality disturbance, short time discrete Fourier transform (STFT) is most often used.

A. *Wavelet transform*

The wavelet transform is used as a method for analyzing electromagnetic transients associated with power system faults and switching. This method provides information related to the frequency composition of a waveform like the Fourier transform, but it is more appropriate than the familiar Fourier methods for the non-periodic, wide-band signals associated with electromagnetic transients. It appears that the frequency domain data produced by the wavelet transform may be useful for analyzing the sources of transients through manual or automated feature detection schemes. Wavelets are a powerful statistical tool which can be used for a wide range of applications, in Signal processing, Data compression, Smoothing and image demising, Fingerprint verification Speech recognition, Computer graphics and multi-fractal analysis.

The drawbacks of this method is that for fine analysis, it becomes computationally intensive, its discrimination, the discrete wavelet transform (comp. efficient), is less efficient and natural, it take some energy to invest in wavelets to become able to choose the proper ones for a specific purpose, and to implement it correctly.

B. *S –Transform*

The S–transform, on the other hand, is an extension to the ideas of wavelet transform, and is based on a moving and scalable localizing Gaussian window and has characteristics superior to either of the transforms. The S–transform is fully convertible from the time domain to two dimensional frequency translation domain and to then familiar Fourier frequency domain. The amplitude frequency–time spectrum and the phase–frequency–time spectrum are both useful in defining local spectral characteristics. The superior properties of the S–transform are due to the fact that the modulating sinusoids are fixed with respect to the time axis while the localizing scalable Gaussion window dilates and translates. The phase correction of the wavelet transform in the form of S—transform can provide significant improvement in the detection and localization of power quality disturbance transients.

Advantage of the S–transform over wavelet transform is better detecting, localizing, and classifying the power quality problems.

The disadvantage of the S-transform is the same assignment of the standard deviation for all signal components at all frequencies. That is, always defined as a reciprocal of the frequency. Some signals would benefit from different value of the standard deviation for the window function.

C. *A Probabilistic Approach*

Probabilistic approach is used to classification of transients in power systems using two probability-based methods, namely the method of maximum-likelihood (ML) and the probabilistic neural networks (PNN). The two methods are shown to share roots in the fundamental rule of classification, the Bayes rule. It is shown that direct application of the Bayes rule, however, requires knowledge of statistical properties of the features that are often unavailable. The two classification methods considered attempt to estimate such statistical properties. It presents the mathematical foundations of the Bayes rule, the method of maximum likelihood and the probabilistic neural networks; it also presents their implementation used for classification of three types of transients in a power system, namely three-phase faults, breaker operations and capacitor switching's. It also presents a discussion on training complexity of a two methods as well as their classification accuracy. The features used for the purpose of classification are obtained using wavelet and multifractal analyses of transients.

D. *PLL*

PLL is a feedback loop which locks two waveforms with same frequency but shifted in phase. The fundamental use of this loop is in comparing frequencies of two waveforms and then adjusting the frequency of the waveform in the loop to equal the input waveform frequency. The heart of the PLL is a phase comparator which along with a voltage controlled oscillator (VCO), a filter and an amplifier forms the loop. If the two frequencies are different the output of the phase comparator varies and changes the input to the VCO to make its output frequency equal to the input waveform frequency. The locking of the two frequencies is a nonlinear process but linear approximation can be used to analyze PLL dynamics.

1) *Basics of a PLL*

The PLL has been an important device in electronics and power system applications. A PLL is a circuit that is used to synchronize an input signal with a reference signal (an output signal that is generated by the PLL) with respect to phase and frequency. The function of the PLL can be explained from the block diagram of a simple PLL, as shown in Fig. 1.

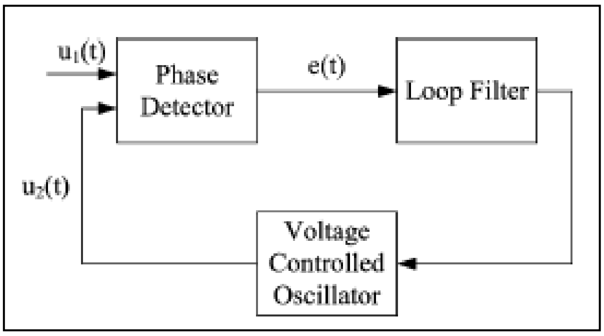

Fig.1: Block diagram of a PLL

The input signal $u_1(t)$ is compared with the reference signal $u_2(t)$ in the phase detector (PD). The output of the phase detector is zero as long as the input signal and the output signal is equal in phase and frequency.

If the phase or frequency of the input signals changes, the output of the phase detector will deviate from zero. The error signal is passed through a low-pass filter (LF) and then to a voltage-controlled oscillator (VCO), which generates a reference signal (the output signal). If the error signal deviates from zero, the VCO will adjust the frequency of the reference signal so that the phase error becomes zero and the two signals are in phase.

When the input signal is in phase with the reference signal, the PLL is in its locked state; hence the name phase locked.

Recent research related to PLLs has been from several research fields: general descriptions of PLLs, distributed generation applications, active power-line conditioner applications, servo controllers, as well as protection and control.

2) Description of a PLL that is Suitable for the Discrimination between a Fault and Switching Transient a

The PLL design which has been proposed for fault discrimination is drawn in the below figure. A vector implementation, as shown in Fig. 3, of a PLL is described in this paragraph. Compared to the block diagram of Fig. 2, the error signal e(t) corresponds to the output of the PD, whereas the proportional-integral (PI) regulator and the integrator corresponds to the loop filter and the voltage-controlled oscillator (VCO).

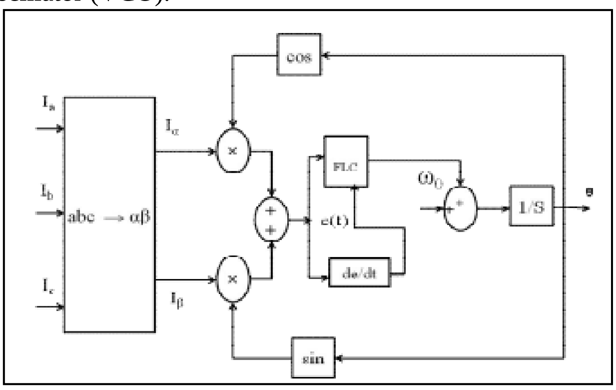

Fig.2: PLL implementation

Once the error is zero, the input signals are in phase with the reference frame.

If it is assumed that the system is in steady state and that the power system is completely balanced, the phase currents can be written as

$$I_a = I.\sin(\omega t)$$
$$I_b = I.\sin\left(\omega t - 2 * \frac{\pi}{3}\right)$$
$$I_b = I.\sin\left(\omega t + 2 * \frac{\pi}{3}\right) \quad (1)$$

Then, the Clarke's components I_α and I_β equate to

$$I_\alpha = \frac{(2.I_a - (I_b + I_c))}{3} = I.\sin(\omega t)$$
$$I_\beta = \frac{(I_b - I_c)}{\sqrt{3}} = -I\cos(\omega t) \quad (2)$$

Now, with reference to Fig. 2, the error signal is given by

$$e(t) = I_\alpha.\cos(\theta) + I_\beta.\sin(\theta) = I.\sin(\omega t - \theta) \quad (3)$$

Depending on the characteristics of the transient, the deviation will have different magnitude and frequency Thus, the error is zero exactly when the output angle of the PLL is in phase with the current of phase a. When a transient occurs in the system, the error signal will deviate from zero. Since a fault is typically an ac fundamental power frequency character, the deviation will be different than for a switching transient that contains non fundamental power frequency components. The behavior of the error signal of the PLL will also depend on the tuning of the PLL.

3) Tuning of the PLL

PLLs have been used for many years in HVDC transmission in order to synchronize the firing of the thyristors to the phase angle of the connected ac system. The PLL will be tuned to the power system frequency. It is thus a well-known procedure and it is advisable to use parameters from such an installation as a starting point for the tuning.

4) Fault Detection and Discrimination Using a PLL

To detect a fault and discriminate the fault from a switching transient the method that is used. Two algorithms are executed in parallel. The first algorithm is based on the estimation of the magnitude of the current. If the estimated magnitude is higher than a preselected threshold, a flag is set. The second algorithm is as previously mentioned, monitoring the error signal of a PLL. If this error signal exceeds a preselected threshold, a second flag is set. If both flags are set, it is determined that a fault has occurred.

V. Conclusion

In this paper, we see the different methods of fault current limiters. Also we see the different methods of transient detection. For current limiting we see the different devices like current limiting reactor, fuses, circuit breakers and fault current limiters. In this paper, we have seen different transient methods, wavelet transform, S-transform, Probabilistic approach and PLL. It has been demonstrated that a PLL can be used to determine whether a current transient is due to a fault in the system or due to a switching transient. The method is primarily intended for use in systems where fast fault detection and fast fault clearing before the first peak of the fault current are required. For all of these events, a large difference was observed in the error signal of the PLL when a fault or a switching transient was applied. This difference can be used to discriminate faults from switching transients. A phase-locked loop (PLL) is used to perform the discrimination. Here we studied the different techniques for discriminate switching transient. Wavelet transform, s-transform & probabilistic approach have been quite successful but are not adequate for the present time varying network configurations because it required more information to get accurate result. As compared to wavelet transform and S- transform, PLL is better method of transient detection. Hence Combination of PLL with FCL gives the fast detection of transient with good current limiting characteristic.

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