A New Fault Type Identification Technique Based on Fault Generated High Frequency Transient Voltage Signals

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Abstract: *Faults on EHV/UHV overhead lines are in majority single-phase-to-ground arcing faults and are mostly temporary. It is quite evident that accurate and fast isolation of the faulty phase will improve the stability of the grid, so providing the facility of single pole reclosing is necessary. Traditional phase selectors can suffer some deficiencies in their performance due to varying system and fault conditions. This paper presents a novel technique based on the fault generated high frequency transient signals. A wide variety of generated data from the simulation of a typical 400-kV power system using ATP-EMTP were used to test the performance of the technique. The obtained results indicate that the proposed algorithm presents excellent performance.*

Keywords**:** *Power System Protection, Fault Type Identification, Single Pole Autoreclosure.*

1. Introduction

Important lines, especially tie lines that connect important generating stations, often require single pole autoreclosing (SPAR) in order to maintain system stability for a given desired operating condition. This means that one or more generators will become unstable unless the system is restored to normal in a short time, often just a few cycles. Since 90% or more of all line faults are temporary in nature, this means that autoreclosing will usually be successful in restoring these essential circuits [1].

The conventional schemes for SPAR are more complex. Several techniques are used for selecting the faulted phase. However, like any other power frequency-based measurement methods, they suffer from limitations due to fault-path resistance, line loading and source parameters, remote –end infeed, etc. As a result, the accuracy attained in phase selection is rather limited [2].

An approach to transmission-line protection has been developed based on the detection of fault-generated high-frequency transient signals, and the research shows that the technique can be applied to attain prominent results. This development has led to a new concept in power system protection – The 'Transient Based Protection' (TBP) [3]. Several phase selection algorithms utilizing TBP approach have been reported recently in the literature [5-7].

Reference [5] describes the design of a phase selector using ANNs to essentially recognize the various patterns generated within the frequency spectra of the fault generated noise signals on the three phases, for the purposes of accurately deducing the faulted phase.

Reference [6] describes the design and implementation of a technique based on wavelet transform. The proposed algorithm employs sharp transitions generated on the faulted phase.

Reference [7] presents a new approach to real-time phase selection in power transmission systems using fuzzy-logic-based multi-criteria approach. Only the three line currents are utilized to detect the faulted phase.

In this paper a novel phase selection algorithm employing the fault generated high frequency noise on faulted EHV transmission lines is proposed.

It is essentially based on a specially designed stack tuner (tuned to a certain frequency bandwidth) which is connected to the coupling capacitor of the capacitor voltage transformer (CVT), thereby, overcome the bandwidth limitation of conventional transducers. *Discrete Fourier transform* (DFT) is utilized for processing the high frequency transient signals extracted from the stack tuner output. The paper concludes by presenting results based on the extensive simulation study.

2. Transient Based Protection Approach

In conventional power frequency based protection techniques, the high frequency generated transients are considered as interference noise and are filtered out [8]. Present protection techniques based on the detection of fault generated transients, such as, travelling wave based protection are limited by the bandwidth of the transducer and cannot separate and extract the high frequency information required from dominant power signals.

The TBP technique utilizes the HF generated transient signals which are a combination of the components generated by the very non-linear behavior of the fault arc and those due to travelling waves. These combined features give the TBP technique the immunity to the effect of fault inception angle, while algorithms based on travelling waves suffer from faults near voltage zero [4].

3. Model System

The model system used in the study is a double-end fed transmission line as illustrated in Fig. 1. The line is a 400 kV, 128 km vertical construction line. Z_A and Z_B are the equivalent source impedances. The line configuration is given in the Appendix. The system is simulated using the ATP-EMTP [9] where the line was simulated using the JMarti model, while the local-end source was simulated using a lumped impedance model. Within the simulation has also been embodied an emulation of the non-linear fault arc [10].

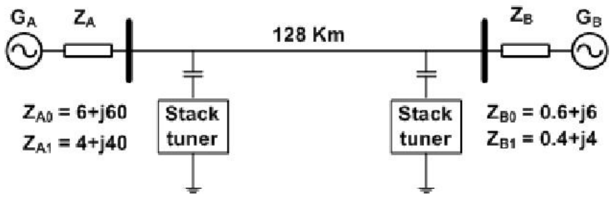

Fig. 1 400 KV transmission system

4. Measurement Technique

A fault on a power line produces wideband noise and/or travelling waves. Much of this noise is outside the bandwidth of the conventional instrument transformers. The authors in [4] has proposed a special technique that can be used for detecting the high frequency components of system voltage under fault conditions by means of a stack tuner circuit which is connected to a transmission line via the high voltage coupling capacitor of a typical CVT. Depending on line voltage and capacitor type, the capacitance values in use range from 0.001 to .05 microfarads.

The purpose of the line tuner in conjunction with the coupling capacitor is to provide a low impedance path for a predefined HF component of interest and a high impedance path to the power frequency energy by forming a series resonant circuit.

An extensive series of studies have shown that a very narrow band centered on frequency of 30 kHz gives excellent results. The stack tuner has been incorporated into the simulation because of the close interaction that occurs between stack tuner circuits and the power system over the range of frequencies of interest.

5. Proposed Algorithm

Fig. 2 shows the output of the stack tuner connected to the coupling capacitor of the capacitor voltage transformer (CVT) for an 'a'-G maximum voltage fault at mid-point, it is evident that the faulted phase experiences a high degree of frequency distortion.

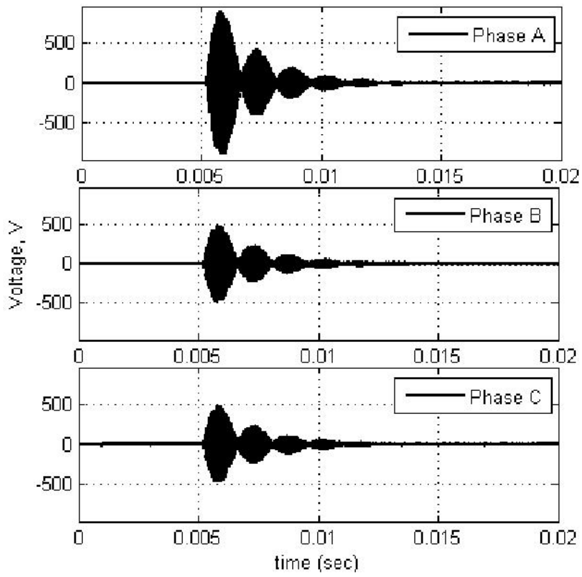

Fig. 2 Stack tuner output

As expected, distortion also appears on the healthy phases due to the mutual coupling effects between the faulted and healthy phases. Each stack tuner is arranged to have an impedance approximately equal to line surge impedance at the very narrow band centered on frequency of 30 kHz, and an overall high impedance to the power frequency component with respect to earth. Fig 3 demonstrates that the frequency spectra of the high frequency signals are very distinctly different for both sound and faulted phases. When comparing the outputs of the stack tuner for the three phases, it is clear that the magnitude of the peak transient for the faulty phase is larger than the other two healthy phases.

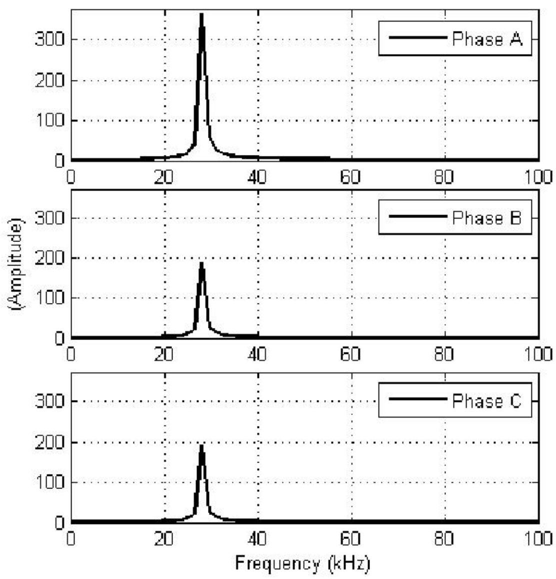

Fig. 3 Frequency spectrum of stack tuner output

The key idea of the proposed algorithm utilizes this feature in order to discriminate between the faulty and sound phases. The inputs to the phase selector are the three phase voltage signals from the stack tuners at a sampling rate of 200 kHz. Anti-aliasing filters are employed to attenuate any frequency components above the *Nyquist Frequency* i.e., above 100 kHz. The digitized voltage signals are processed by applying the *Fast Fourier Transform (*FFT) technique to a moving time-domain window of length 128 samples. The magnitude of the peak spectra for each phase – for one cycle - is estimated, and then the largest value of them is compared against a threshold setting (**ε**o) to diagnosis the system status first.

After that, if a fault condition is detected, each peak spectra is checked against another threshold setting (**ε**1) so as to discriminate the faulty and sound phases.

The proposed phase selector algorithm can be summarized as shown in Fig. 4.

Where Ya_max, Yb_max and Yc_max are the magnitudes of the peak spectra for each phase and Ymax is the largest value of them.

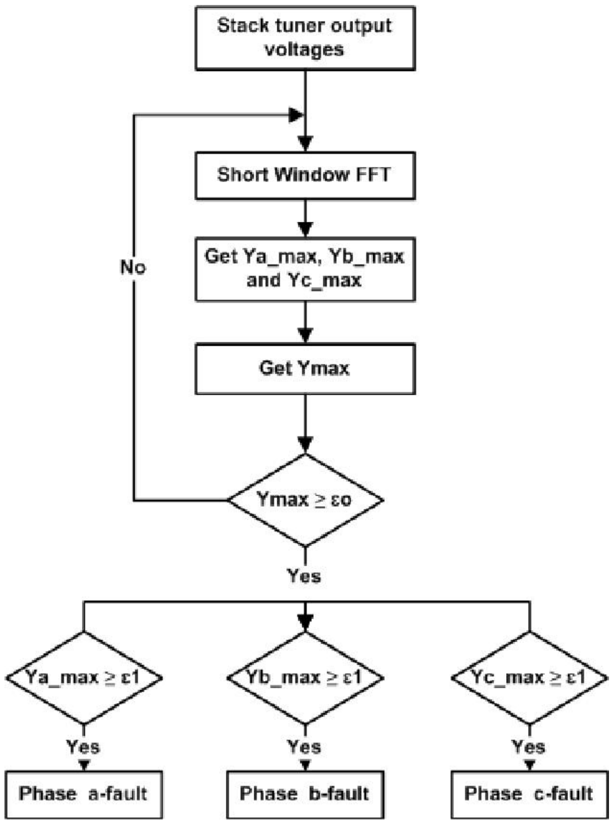

Fig. 4 The proposed algorithm

6. Performance Evaluation

6.1. Effect of fault location and fault inception angle

It is well known that the performance of travelling wave based phase selectors suffer for faults near voltage zero because these techniques utilize the magnitudes of generated travelling waves which are very much dependent on the fault inception angle. The proposed phase selector described here is immune to this problem, as it uses the high frequency generated noise created by nonlinear arcing faults which are – to large extent – independent of the fault inception angle.

Fig. 5 and Fig. 6 show the spectra of the stack tuner output for an a-G fault at 100 km from the end A at inception angles of 0^o and 90^o respectively. Although the amplitudes of the spectra are severely attenuated for 0^o inception faults, the relative relation between the faulty phase and healthy phases is still obviously distinctive.

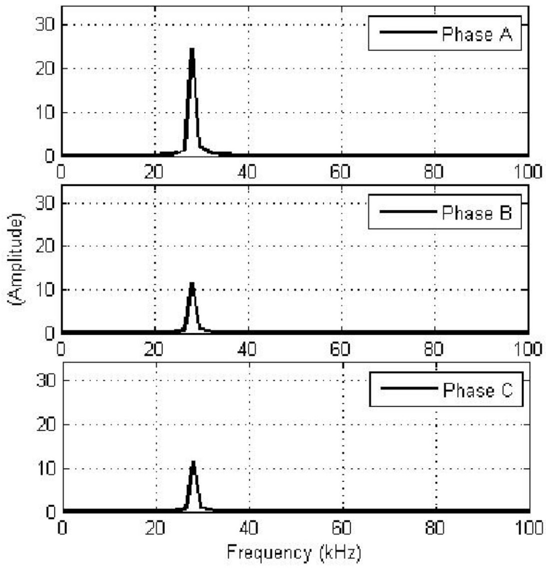

Fig. 5 Spectrum of the stack tuner output for an a-G voltage fault at 0^o at 100 km from end A

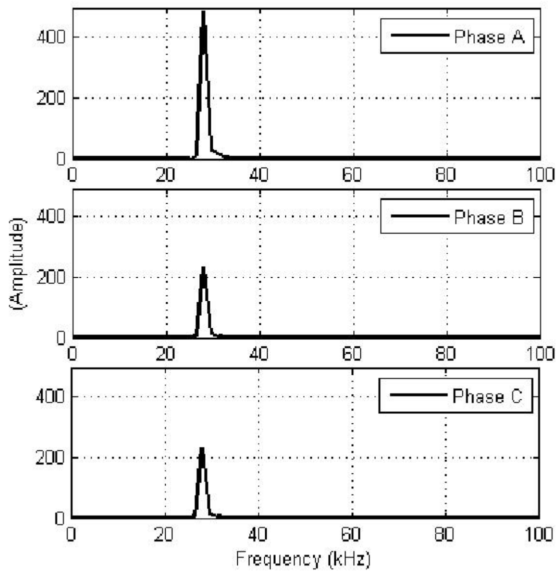

Fig. 6 Spectrum of the stack tuner output for an a-G voltage fault at 90^o at 100 km from end A

6.2. Effect of high resistance faults

Conventional phase selectors suffer some deficiencies in their performance when there is a high resistance involved in the fault. The proposed phase selector was tested against different high resistances included in the simulation. Fig. 7 shows the spectrum for an a-G fault near 0^o inception angle and at 100 km from end A, a fault resistance of 100**Ω**. It is clearly evident that the amplitude of the faulty phase is larger than those of the healthy phases.

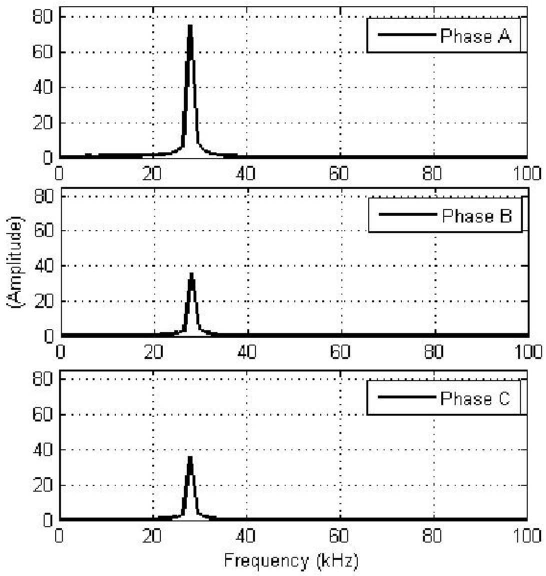

Fig. 7 Spectrum of the stack tuner output for an a-G voltage fault at 0° at 100 km from end A, a fault resistance of 100Ω

7. Conclusions

This paper presents a novel phase selection technique based on fault generated high frequency noise under arcing faults for EHV transmission lines. These high frequency signals are derived from the system by employing a specially designed stack tuner connected to a transmission line via the high voltage coupling capacitor of a typical CVT. FFT technique is used to decompose these transient signals. The phase selector proposed here employs the peak value of the spectrum of the three phase voltage signals to differentiate between the healthy and faulty phases. The results shown here demonstrate the robustness of the proposed algorithm against various system and fault conditions.

Appendix

The mean spacing between the conductors of the transmission line used in the study are shown in Fig. 8. The data for this line are:

(a) Phase conductors are 4 x 54/7/3.3 mm. with 0.305 m bundle spacing and of ACSR type.

(b) Earth wire is 54/7/3.3 mm.

(c) Earth resistivity is 100 Ωm.

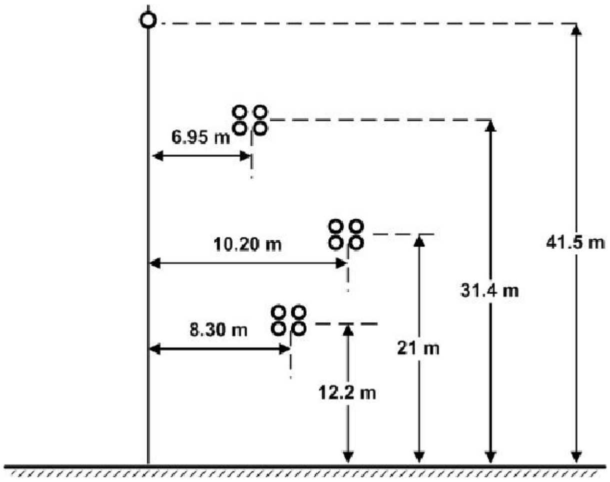

Fig. 8 Line configuration

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