Protection of Marine Equipment Power System for Single Phase to Ground Fault

A. Behniafar, M. Banejad, and A. Darabi

Abstract—**Marine electric equipment recently has been entered to the industry and commerce and before the shipboard power system could provide only the small loads. With appearing this equipment, existence equipped power systems with high reliability, has become inevitable. No earthing is the features of this system that makes the relays fails to recognize the single phase to ground fault (SPTGF). If another SPTGF occurs, makes two phase fault occurs, in this case relays will trip and emergency loads are disconnected. As you know, failure emergency loads could cause danger to health personnel. In this paper, the purpose is to using wavelet transform and intelligent tools, SPTGF be detected in shipboard power system.**

Index Terms—**Single phase to ground fault (SPTGF), wavelet transform, truth table, shipboard.**

I. Introduction

With the development of marine industry and tending to become electrical equipment, reliability of ship power system (As a marine equipment) is the topic that recently some papers have considered. When discussing the military ships, it is very important. Heretofore about this new power system is studied, but it is a very small number and the system still requires further analysis, innovation and essential change.

Shipboard power system is ungrounded system. Relays in ungrounded system are not able to detect single phase to grounded fault because fault current is less than current of relay`s trip[1].

For two reasons, shipboard power system is chosen ungrounded system. First, because ships are moving and cannot be used for common ground.Also hulk will not be a suitable ground for the system. and the second reason, there are loads on ships which are called emergency loads such as navigation devices , radar system , helm ,etc.because of existence of this loads ,discussion of the reliability of the shipboard power system is important. Ungrounded system is suitable for supplying these loads because at the time the SPTGF occurred, the system will remain continuously. Ungrounded system besides its advantage also has some disadvantages such that when the second SPTGF occurred, two phase fault occurs and cause the high fault current to flow and failure of emergency loads.

Therefore it is necessary that SPTGF in shipboard power system to be detected.

Methods to detect this type of fault is expressed such as using ohm metric system and also the three lamps lighting that both these methods have been very low accuracy and is not used in high frequency faults. To detect SPTGF many algorithms have been proposed. All these algorithms are composed of two sections: (1) obtaining Feature Extraction of occurrence and (2) Pattern Recognition.

In previous papers for the first section of algorithms such as vectors of the dominant harmonic [2], Fractal Techniques [3] and Wavelet transform in high-frequency noise model [4], is used. On the other hand, to recognize patterns, techniques such as certified systems [5], Kaman filter [6], neural network [7,8] and Fuzzy Inference system have been proposed.

Although, each of methods mentioned in above, have been successful to some extent but general method for detecting this type of fault is not offered yet. In most of methods mentioned, SPTGF is considered equivalent to high impedance fault (HIF) that the disadvantages of these methods has been and will not get accurate results[9-16]. Also SPTGF characteristics must be done in a compromise with other disturbances.

In this paper for obtaining Feature Extraction of occurrence discrete wavelet transform (DWT) is used and explanations about the intelligent methods to Pattern Recognition is presented. Also determination of faulted phase is considered by using truth table.

In the second part of this paper, the theory of discrete wavelet transform is described briefly. In the third part, to the overall simulation algorithm is discussed and in part IV of the simulation results are presented.

II. Discrete wavelet transform

DWT is one of the most powerful tool of analysis is the transient mode. By using of this transform transient signal data from time domain to time- frequency domain can be written. Theory of DWT and Fourier transform in comparison with at [17] is completely described. In this section, the theory of DWT and its definition is given a brief explanation.

The Fourier transform, the signal can be expanded as a trigonometric polynomial. While DWT, signal by using scaled wavelet coefficients that resulted of compression and broadening of the mother wavelet, be extended. This property will be allows the analysis of transient signals by wavelet transform locally and in the event them. The equation used in the DWT is as follows:

$$DWT\ (m,n) = \frac{1}{\sqrt{a_0^m}} \sum_k x(k) g(a_0^{-m} n - b_0 k) \quad (1)$$

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According to equation (1), original signal into two signals, called approximations and details.

Approximation, the low frequency signal component is included and will form part of the original signal. On the other hand, details include transient and harmonic components high frequency of signal. This process can be continuing by analyzing of approximation to the next level of detail and approximation. This practice is known to Multi Resolution Decomposition.

Fig. 1 shows that how to decompose the original signal into different frequency levels.

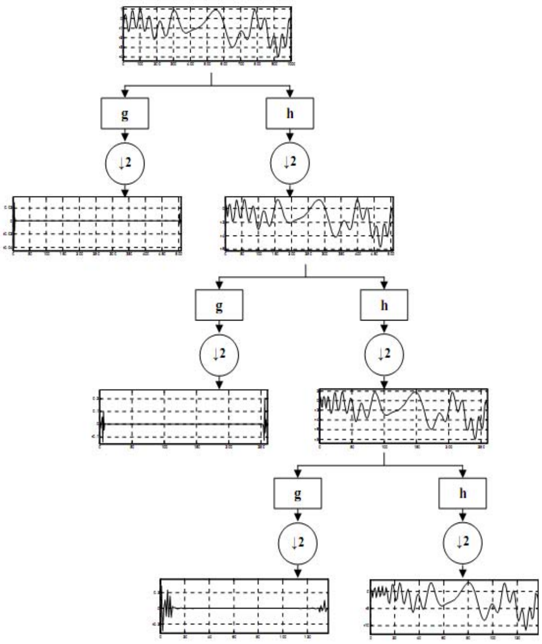

Fig. 1. Decomposes the original signal into different frequency

Frequency range of each details of DWT depends on original signal's sampling rate.

Because of the logarithmic structure of DWT, to each of frequency range of this transform, called level. The maximum number decomposition level of wavelet transform (j) is defined according to follow equation.

$$j = \log_2^N \qquad (2)$$

where N is the number of samples.

DWT can be done by chosen a0=2 and b0=1 in equation(2) and using multilevel filter with mother wavelet, as a low pass filter l(n), and its dual as a high pass filter h(n). Also with sampling the top down by factor 2 from low-pass filter output, wavelets will be scaled for the next level and thus, the simplification is done[18-22].

III. The Single Phase to Ground Fault Detection

To determine the different stages of the algorithm and performing related simulations, the power system as shown in fig. 2 is considered.

SPTGF detection algorithm consists of three basic steps are as follows:

A. Modeling system to obtain the characteristic three-phase voltage system in the event of SPTGF and other common network operations.

B. The use of DWT to obtain Feature Extraction of three - phase voltage and formation decision criteria for intelligent tools.

C. Intelligent or truth table method for pattern classification and SPTGF detection.

In all of the steps mentioned in above, the MATLAB software is used to obtain results.

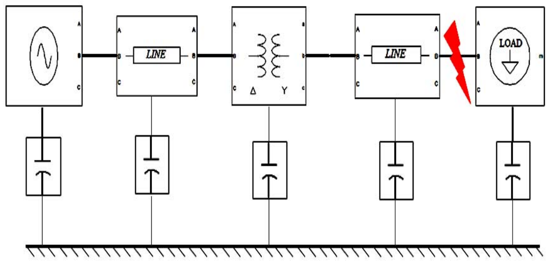

Fig. 2. Shipboard power system model

IV. Simulation

Below, according to steps listed in the part III simulation is done. It should be noted that in this simulation, the fault on phase C and in appropriate portions shown in the figure (2) is applied.

A. Modeling Sample Power System

Most of the elements used in the simulation, such as generators, transformers and load combination (RLC) in the MATLAB software is available.

In the shipboard power system, ground does not exist thus cannot be used of software's models. And shall used of broadcast model [23]. Software does not it possible, therefore each of elements model should according to their equations as block be simulated that would be very complicated and difficult. Or that by adding branches to the same element, approximate wide model be prepared that this recent method is easier and more convenient.

The [24] has been used to determine the wide model. Ship hull (ground system) by a capacitor series with resistance is the related elements. After determining the values for the parameters in the wide model, model will be ready for simulation.

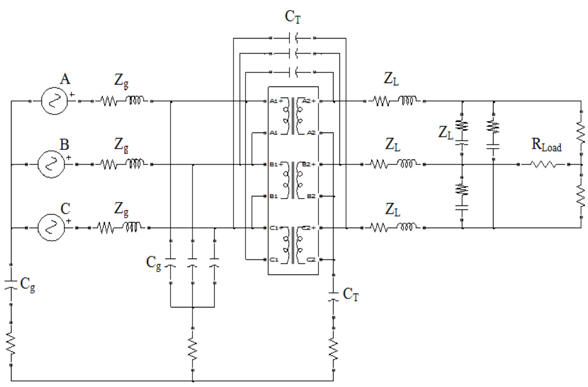

Fig. 3. Circuit diagram used in stimulant

During 0.025 s to 0.05 s Single phase to ground fault was applied on the phase C and near the bar and line voltages is measured before and after fault. The voltage waveform in Figure (4) and (5) is visible.

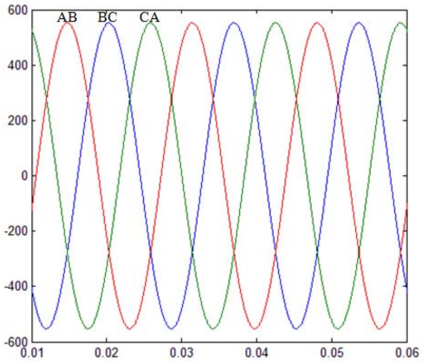

Fig. 4. Three-phase voltage before fault occurrence

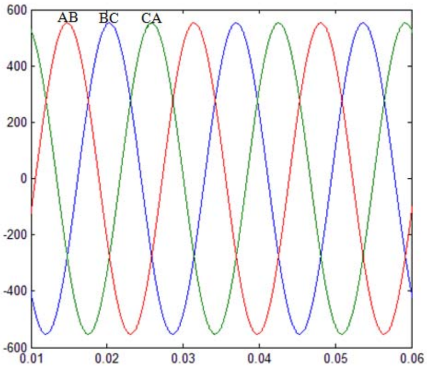

Fig. 5. Three-phase voltage during the fault occurred

It can be seen that the line voltages are unchanged (not changed much) and fault detection by using these figures would be almost impossible. Below, wavelet transform is used for fault detection.

B. Discrete Wavelet Transform (DWT)

During applying the DWT, Selected mother wavelet and appropriate level depend to the sampling frequency, transient phenomena and applied for studied. By examining results of different simulations, using of fourth level wavelet db4 is suitable for fault detection.

Approximation and detail different levels of DWT for line voltages of SPTGF conditions are shown in the Fig. 6, 7 and 8.

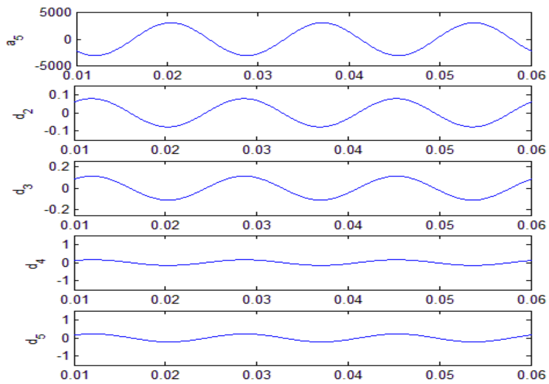

Fig. 6. Approximation and details of different levels in SPTGF condition for the line voltage AB

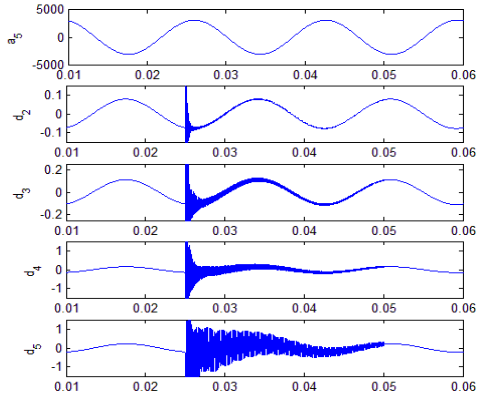

Fig. 7. Approximation and details of different levels in SPTGF condition for the line voltage BC

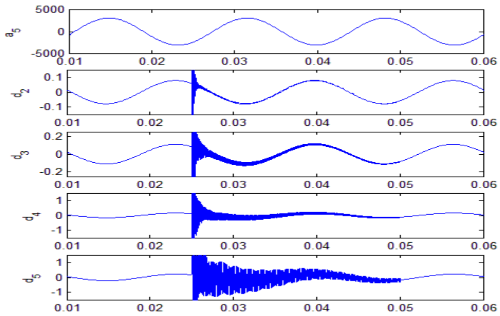

Fig. 8. Approximation and details of different levels in SPTGF condition for the line voltage CA

a_5 is fifth level approximation waveform of line voltage and d_2 to d_5 indicate second to fifth of voltage level.

As known in the figures, occurrence of fault caused an oscillatory wave with small amplitude in relatively long period in d_2 *to* d_5.

Although the exact size of peak and duration of survival depends on occurrence of fault conditions but however, energy of details in the period of fault in comparison with their energy in period of occurrence of normal operation of system is very different. The same criteria can be used to detect occurrence of SPTGF in the shipboard power system.

C. Pattern Recognition

At this step, it is needed to intelligent tools that has been used, be taught in a way that identify and classify the patterns. Thus, when occurred patterns, they will be easily detectable. In this paper, the truth table is used as an intelligent tool.

As is indicated in figures, a detail of line voltage AB is not changed and there is no disturbance. This is because that error on phase C is applied and only line voltage including phase C will be changed. Using this property, truth table like TABLE I can be arranged and based on faulted phase be identified.

TABLE I: TRUTH TABLE FOR THE FAULTED PHASE [1]

Phase AB	Phase BC	Phase CA		Fault on A	Fault on B	Fault on C
0	0	0		U	U	U
0	0	1		U	U	U
0	1	0		U	U	U
0	1	1		U	U	1
1	0	0		U	U	U
1	0	1		1	U	U
1	1	0		U	1	U
1	1	1		U	U	U

In TABLE I, symbol U represent no fault and number 1 represent fault.

V. CONCLUSION

In this paper by using of a case system with wavelet transform was used to detect occurrence of SPTGF in shipboard power system.

Simulations performed in various events prove high accuracy of proposed algorithm in the detection fault. On the other hand, proposed algorithm in conditions of normal events in power system such as switching load, switching capacitor banks, two phase fault and etc, works correctly because be different characteristics of each event is mentioned. This case high reliability of the proposed algorithm defined.

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