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Numerical Differential Protection of Power Transformer using Walsh Hadamard Transform and Block Pulse Function Based Algorithm

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ABSTRACT: In this paper, application of Walsh Hadamard transform and Block pulse function have been described for numerical protection of power transformer. Numerical relay algorithms are developed to extract fundamental, second and fifth harmonic components. These components are further used for harmonic restraint differential protection of power transformers. In comparison with Walsh Hadamard transform, block pulse function based method is computationally simple and flexible to use with any sampling frequency. Different graphs are plotted and compared for Walsh Hadamard transform and block pulse function based methods for Inrush, Over-excitation and internal fault conditions. Simulated results indicate that the block pulse function algorithm can provide fast and reliable trip decisions.

Keywords: Walsh Hadamard transform, Block pulse function, power transformer protection, and numerical differbtial relay.

I. INTRODUCTION

For protection of power transformer, differential relay is commonly used [2]. This is based on comparison of the fundamental, second and fifth harmonic components of post fault current. A differential protection scheme with harmonic restraint is the usual way of protecting a power transformer against internal faults and restraining the tripping operation during non fault conditions, such as magnetizing inrush currents and over-excitation currents [2].

Several algorithms have been proposed for numerical protection of power transformers. Here result of walsh hadamard transform and block pulse function based algorithm have been compared for numerical differential protection of power transformer.

II. Walsh Hadamard Transform

The algorithm for extracting the fundamental frequency components from the complex post-fault relaying signals is based on Walsh-Hadamard Transform (WHT). The Walsh coefficients are obtained by using the Walsh-Hadamard transformation on the incoming data samples [3]. A fast algorithm known as Fast Walsh-Hadamard transform (FWHT) is available to compute the Walsh coefficients.

The FWHT is an algorithm to compute the WHT coefficients. FWHT reduces the computation to N $\log_2 N$ additions and subtraction [2].

Walsh coefficients are calculated as shown below

$$W_{w0}=1/16(x_0+x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8+x_9+x_{10}+x_{11}+x_{12}+x_{13}+x_{14}+x_{15})$$

$$W_{w1}= 1/16(x_0+x_1+x_2+x_3+x_4+x_5+x_6+x_7-x_8-x_9-x_{10}-x_{11}-x_{12}-x_{13}-x_{14}-x_{15})$$

$$W_{w2}=1/16(x_0+x_1+x_2+x_3-x_4-x_5-x_6-x_7-x_8-x_9-x_{10}-x_{11}+x_{12}+x_{13}+x_{14}+x_{15})$$

$W_{w3}=1/16(x_0+x_1+x_2+x_3-x_4-x_5-x_6-x_7+x_8+x_9+x_{10}+x_{11}-x_{12}-x_{13}-x_{14}-x_{15})$

$W_{w4} = 1/16(x_0+x_1-x_2-x_3-x_4-x_5+x_6+x_7+x_8+x_9-x_{10}-x_{11}-x_{12}-x_{13}+x_{14}+x_{15})$

$W_{w5}=1/16(x_0+x_1-x_2-x_3-x_4-x_5+x_6+x_7-x_8-x_9+x_{10}+x_{11}+x_{12}+x_{13}-x_{14}-x_{15})$

$W_{w6}=1/16(x_0+x_1-x_2-x_3+x_4+x_5-x_6-x_7-x_8-x_9+x_{10}+x_{11}-x_{12}-x_{13}+x_{14}+x_{15})$

$W_{w7}=1/16(x_0+x_1-x_2-x_3+x_4+x_5-x_6-x_7+x_8+x_9-x_{10}-x_{11}+x_{12}+x_{13}-x_{14}-x_{15})$

$W_{w8}=1/16(x_0-x_1-x_2+x_3+x_4-x_5-x_6+x_7+x_8-x_9-x_{10}+x_{11}+x_{12}-x_{13}-x_{14}+x_{15})$

$W_{w9}=1/16(x_0-x_1-x_2+x_3+x_4-x_5-x_6+x_7-x_8+x_9+x_{10}-x_{11}-x_{12}+x_{13}+x_{14}-x_{15})$

$W_{w10}=1/16(x_0-x_1-x_2+x_3-x_4+x_5+x_6-x_7-x_8+x_9+x_{10}-x_{11}+x_{12}-x_{13}-x_{14}+x_{15})$

$W_{w11} = 1/16(x_0-x_1-x_2+x_3-x_4+x_5+x_6-x_7+x_8-x_9-x_{10}+x_{11}-x_{12}+x_{13}+x_{14}-x_{15})$

$W_{w12}=1/16(x_0-x_1+x_2-x_3-x_4+x_5-x_6+x_7+x_8-x_9+x_{10}-x_{11}-x_{12}+x_{13}-x_{14}+x_{15})$

$W_{w13}=1/16(x_0-x_1+x_2-x_3-x_4+x_5-x_6+x_7-x_8+x_9-x_{10}+x_{11}+x_{12}-x_{13}+x_{14}-x_{15})$

$W_{w14} = 1/16(x_0-x_1+x_2-x_3+x_4-x_5+x_6-x_7-x_8+x_9-x_{10}+x_{11}-x_{12}+x_{13}-x_{14}+x_{15})$

$W_{w15}=1/16(x_0-x_1+x_2-x_3+x_4-x_5+x_6-x_7+x_8-x_9+x_{10}-x_{11}+x_{12}-x_{13}+x_{14}-x_{15})$”

Fundamental fourier coefficient is calculated as

$F_1 = 0.9W_{w1} – 0.373W_{w5} -0.074W_{w9} –o.o179W_{w13}$

$F_2=0.9W_{w2}+0.373W_{w6}-0.074W_{w10}+0.179W_{w14}$

Second harmonic component

$F_3 = 0.9W_{w3} -0.373W_{w11}$

$F_4 = 0.9W_{w4} +0.373W_{w12}$

And fifth harmonic component

$F_9 = 0.180W_{w1} +0.435W_{w5}+0.65W_{w9} - 0.269W_{w13}$

$F_{10}=0.180W_{w2}-0.435W_{w6}+0.65W_{w10}+0.269W_{w14}$

III. Block Pulse Function

The BPF is a set of rectangular pulses, having magnitude unity, which comes one after the other as a block of pulses [4]. The algorithm is computationally simple and flexible to use with any sampling frequency. The fundamental frequency component is extracted by using this algorithm and operating conditions of relay is decided according to the value of this frequency component. The current samples acquired over a full cycle data window at the sampling rate of 12 samples per cycle. The Computations based on this algorithm require less memory space [2]. Taking the fundamental period as 1, current i(t) which is given by time function can be expressed in terms of Fourier coefficients as

$$i(t) = A_0 + \sqrt{2}\, A_1 \sin(2\pi t) + \sqrt{2}\, B_1 \cos(2\pi t) + \sqrt{2}\, A_2 \sin(4\pi t) + \sqrt{2}\, B_2 \cos(4\pi t) + \ldots\ldots + \sqrt{2}\, A_5 \sin(10\pi t) + \sqrt{2}\, B_5 \cos(10\pi t)$$

In terms of BPF coefficient a_n:

Fundamental component

$$A_1 = 0.0302\,(a_1 + a_6 - a_7 - a_{12}) + 0.0824\,(a_2 + a_5 - a_8 - a_{11}) + 0.1125\,(a_3 + a_4 - a_9 - a_{10})$$

$$B_1 = 0.1125\,(a_1 - a_6 - a_7 + a_{12}) + 0.0824\,(a_2 - a_5 - a_8 + a_{11}) + 0.0302\,(a_3 - a_4 - a_9 + a_{10})$$

Second Harmonic component

$$A_2 = 0.05626\,(a_1 + a_3 - a_4 - a_6 + a_7 + a_9 - a_{10} - a_{12} + 0.1125\,(a_2 - a_5 + a_8 - a_{11}))$$

$$B_2 = 0.09746\,(a_1 - a_3 - a_4 + a_6 + a_7 - a_9 - a_{10} + a_{12})$$

Fifth Harmonic component

$$A_5 = 0.0225\,(a_3 + a_4 - a_9 - a_{10}) + 0.06149\,(-a_2 - a_5 + a_8 + a_{11}) + 0.084\,(a_1 + a_6 - a_7 - a_{12})$$

$$B_5 = 0.0225\,(a_1 - a_6 - a_7 + a_{12}) + 0.06149\,(-a_2 + a_5 + a_8 - a_{11}) + 0.084\,(a_3 - a_4 - a_9 + a_{10})$$

IV. APPLICATION OF DIFFERENTIAL PROTECTION OF TRANSFORMERS

Here trip decision is based on the relative amplitude of fundamenral component compared to the second and fifth harmonic component in the differential current. Two indices are used to obtain the relative amplitude.

$K2 = ((A2)^2 + (B2)^2)^{1/2} / ((A1)^2 + (B1)^2)^{1/2}$

$K5 = ((A5)^2 + (B5)^2)^{1/2} / ((A1)^2 + (B1)^2)^{1/2}$

Predefined value for K2 is 0.15 and for k5 is 0.05 for restraining relay action.

Testing of the schemes:

A 132kv/11kv three phase wye-wye transformer system has been simulated during present work. Table 3.1 gives the value of transformer parameters in present simulation and table 3.2 gives the value of transmission line parameters.

Table1: Transformer Parameters

Transformer nominal power and frequency	10 MVA 50Hz
Transformer Winding parameters	R=0.002 pu L=0.08 pu
Transformer core loss rsistance	500 pu

Table2: Transmission line parameters

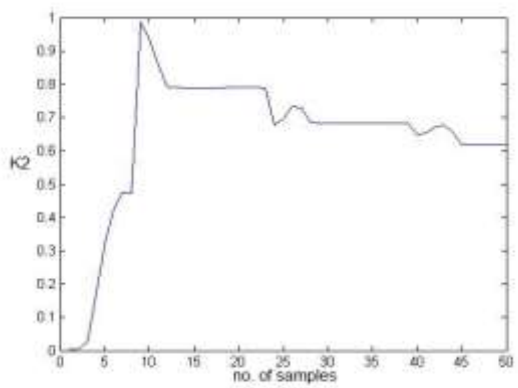
Length	300 km
Frequency used for RLC specification	50 Hz
Positive and zero sequence resistances(ohms/km)	0.01273 and 0.3864
Positive and zero sequence inductance(H/km)	0.9337e-3 and 4.1264e-3
Positive and zero sequence capacitance(F/km)	12.74e-9 and 7.751 e-9

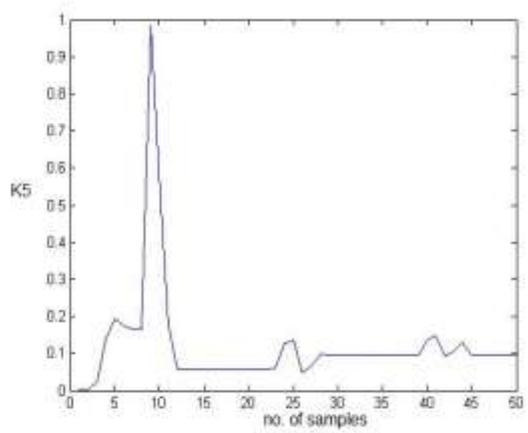
V. RESULTS

The plots below provide values of phase A, similar results have been obtained for other phases as well

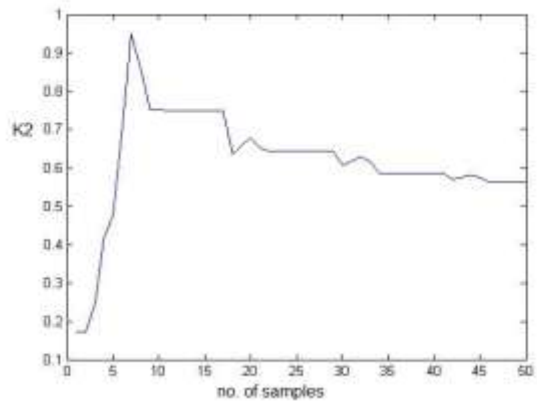
Inrush condition

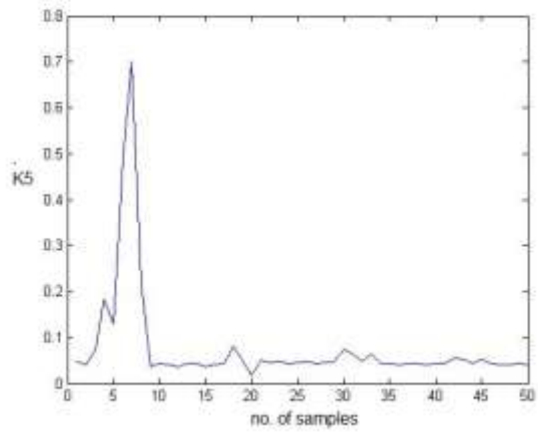
Result from FWHT





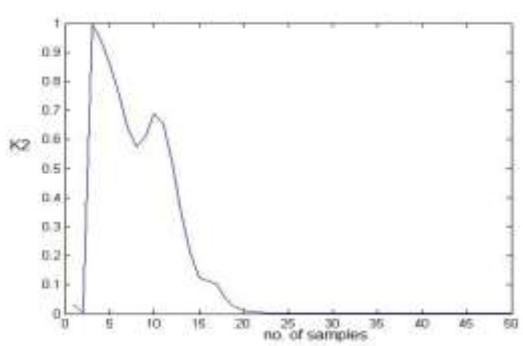
Result from BPF

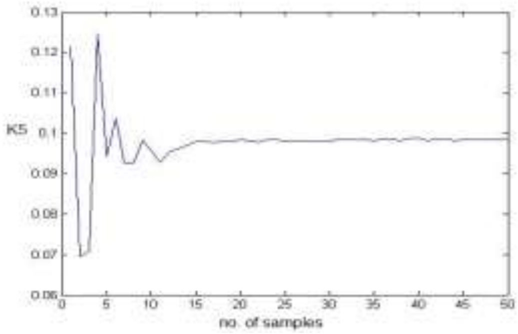




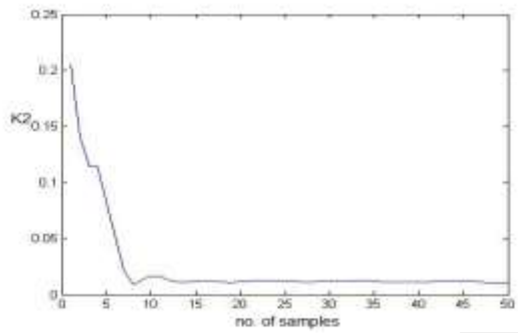
Over-excitation condition

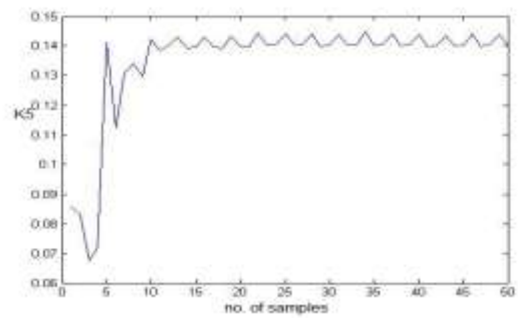
Result from FWHT





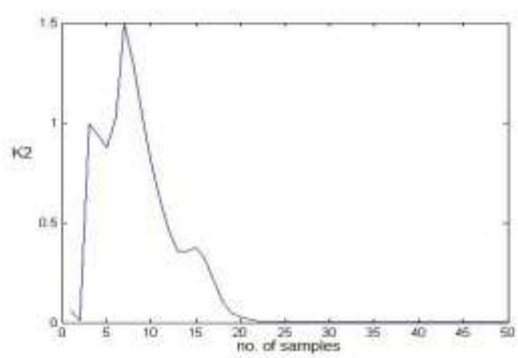
Result from BPF

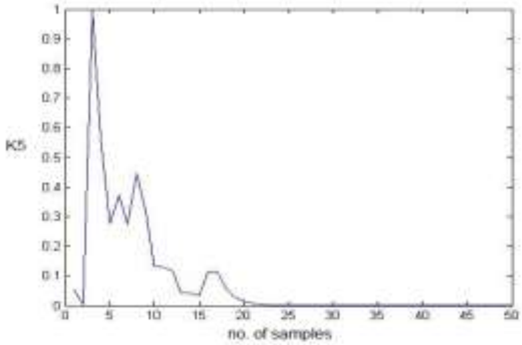




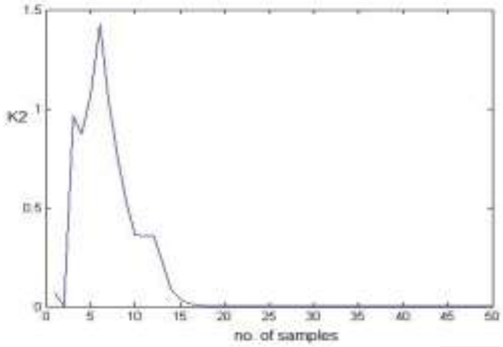
Internal fault condition

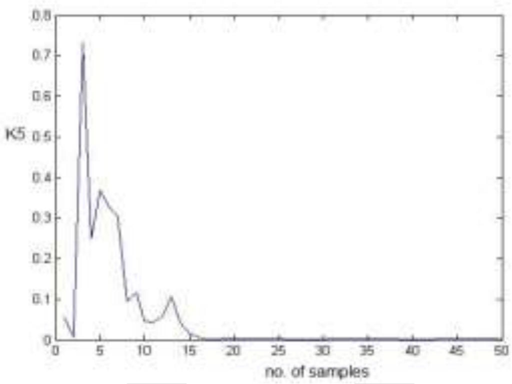
Result from FWHT





Result from BPF





VI. CONCLUSION

The simulation results from MATLAB sim power system reveal that differential current is high in case of internal fault condition, inrush condition and over-excitation condition.

Fault conditions can be distinguished from non fault conditions within a cycle in both algorithms. In non fault conditions either K2 or K5 are above their respective threshold values, restraining trip action of protective relay. In internal fault condition, none of the indices are above the threshold value and tripping action takes place. Block pulse function requires less number of samples per cycle in comparison to walsh hadamard transform. It gives satisfactory result at sampling rate of 12 samples per cycle where as in case of walsh hadamard transform it is 16 samples per cycle.

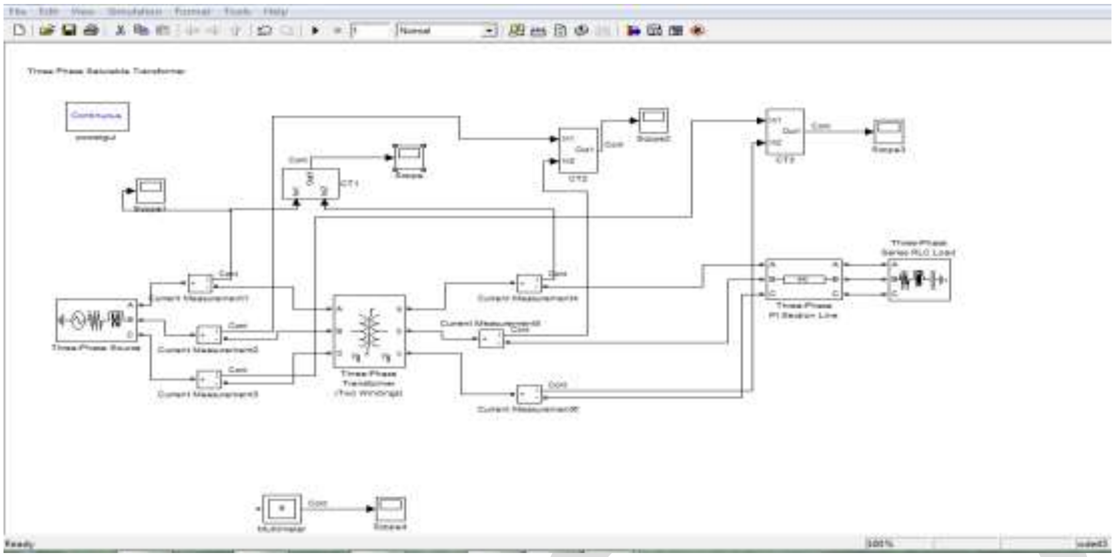


Fig: Matlab simulation diagram of Transformer

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