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# Numerical Differential Algorithms using Walsh Hadamard Transform and Rationalised Haar Transform for Power Transformer Protection

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*Abstract:* **Here we are using algorithm of walsh hadamard transform and Rationalised haar transform for numerical protection of power transformer. Fundamental, second and fifth harmonic components are extracted using numerical relay algorithms. These components are further used for harmonic restraint differential protection of power transformers. Different graphs are plotted and compared for walsh hadamard transform and rationalized haar transform based methods for Inrush, Over-excitation and internal fault conditions.**

*Keywords:* **Walsh hadamard transform, Rationalised haar transform, power transformer protection, and numerical differential relay.**

## 1. INTRODUCTION

Differential relay is used for protection of Power transformer. Fundamental second and fifth harmonic components of post fault current are compared. A differential protection scheme with harmonic restraint is used for protection of power transformer against internal faults and restraining the tripping operation during non fault conditions, such as magnetizing inrush currents and over-excitation currents.

Several algorithms have been proposed for numerical protection of power transformers. Here walsh hadamard transform and Rationalised haar transform based algorithm have been compared for numerical differential protection of power transformer.

## 2. 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. 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.

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
$F_9 = 0.180W_{w1} +0.435W_{w5}+0.65W_{w9} - 0.269W_{w13}$
$F_{10}=0.180W_{w2}-0.435W_{w6}+0.65W_{w10}+0.269W_{w14}$

## 3. RATIONALISED HAAR TRANSFORM

The algorithm for extracting the fundamental frequency component, second harmonic component and fifth harmonic component from the distorted after-fault relaying signal is here based on RHT. This algorithm has been developed with a sampling rate of 16 samples per cycle, i.e for the 50 Hz power frequency, sampling frequency is 800 Hz.

The RHT coefficients are calculated by the given formula:-

$C_{rh0}=(x_0+x_1+x_2+x_3+x_4+x_5+x_6+x_7+x_8+x_9+x_{10}+x_{11}+x_{12}+x_{13}+x_{14}+x_{15})$

$C_{rh1}=(x_0+x_1+x_2+x_3+x_4+x_5+x_6+x_7)-(x_8+x_9+x_{10}+x_{11}+x_{12}+x_{13}+x_{14}+x_{15})$

$C_{rh2}=(x_0+x_1+x_2+x_3)-(x_4+x_5+x_6+x_7)$

$C_{rh3}=(x_8+x_9+x_{10}+x_{11})-(x_{12}+x_{13}+x_{14}+x_{15})$

$C_{rh4}=(x_0+x_1)-(x_2+x_3)$

$C_{rh5}=(x_4+x_5)-(x_6+x_7)$

$C_{rh6}=(x_8+x_9)-(x_{10}+x_{11})$

$C_{rh7}=(x_{12}+x_{13})-(x_{14}+x_{15})$

$C_{rh8}=(x_0+x_1)$

$C_{rh9}=(x_2-x_3)$

$C_{rh10}=(x_4-x_5)$

$C_{rh11}=(x_6-x_7)$

$C_{rh12}=(x_8-x_9)$

$C_{rh13}=(x_{10}-x_{11})$

$C_{rh14}=(x_{12}-x_{13})$

$C_{rh15}=(x_{14}-x_{15})$

$A_1=0.0555Crh1-0.011C_{rh2}+0.011C_{rh3}-0.0276C_{rh4}+0.0184C_{rh5}+0.0276C_{rh6}-0.0184C_{rh7}-0.0169C_{rh8}-0.0096C_{rh9}+0.0033C_{rh10}+0.0143C_{rh11}+0.0169C_{rh12}+0.0096C_{rh13}-0.0033C_{rh14}-0.0143C_{rh15}$

$B_1=0.011C_{rh1}+0.0555C_{rh2}-0.0555C_{rh3}+0.0184C_{rh4}+0.0276C_{rh5}-0.0184C_{rh6}-0.0276C_{rh7}+0.0033C_{rh8}+0.00143C_{rh9}+0.0169C_{rh10}+0.0096C_{rh11}-0.0033C_{12}-0.0143C_{rh13}-0.0169C_{rh14}-0.0096C_{rh15}$

Therefore fundamental frequency is calculated as—

$F_1=\sqrt{}(A_1^2+B_1^2)/2$

Similarly 2nd harmonic is calculated as follows:

$A_2=0.0533C_{rh2}+0.0533C_{rh3}-0.022C_{rh4}+0.022C_{rh5}-0.022C_{rh6}+0.022C_{rh7}-0.0312C_{rh8}-0.0129C_{rh9}+0.0312C_{rh10}-0.0129C_{rh11}-0.0312C_{rh12}+0.0129C_{rh13}-0.0312C_{rh14}-0.0129C_{rh15}$

$B_2=0.022C_{rh2}+.022C_{rh3}+0.0533C_{rh4}-0.0533C_{rh5}+0.533C_{rh6}$
$0.0533C_{rh7}+0.0129C_{rh8}+0.0312C_{rh9}-0.0129C_{rh10}-0.0312C_{rh11}+0.0129C_{12}+0.0312C_{rh13}-0.0129C_{rh14}-0.0312C_{rh15}$

Therefore 2nd harmonic is calculated as:

$F_2=\sqrt{}(A_2^2+B_2^2)/2$

Likewise 5th harmonic is also calculated as:

$A_5=0.0074C_{rh1}-0.011C_{rh2}+0.011C_{rh3}-0.044C_{rh4}+0.0088C_{rh5}-0.044C_{rh6}-0.0088C_{rh7}-0.040C_{rh8}-0.014C_{rh9}+0.061C_{rh10}-0.072C_{rh11}+0.040C_{rh12}+0.014C_{rh13}-0.061C_{rh14}+0.072C_{rh15}$

$B_5=0.011C_{rh1}+0.0074C_{rh2}-0.0074C_{rh3}+0.0088C_{rh4}-0.044C_{rh5}-0.0088C_{rh6}-0.044C_{rh7}+0.061C_{rh8}-0.072C_{rh9}+0.040C_{rh10}+0.014C_{rh11}-0.061C_{12}-0.072C_{rh13}-0.040C_{rh14}-0.014C_{rh15}$

Therefore 5th harmonic is calculated as:

$F_5=\sqrt{}(A_5^2+B_5^2)/2$

## 4. 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 |

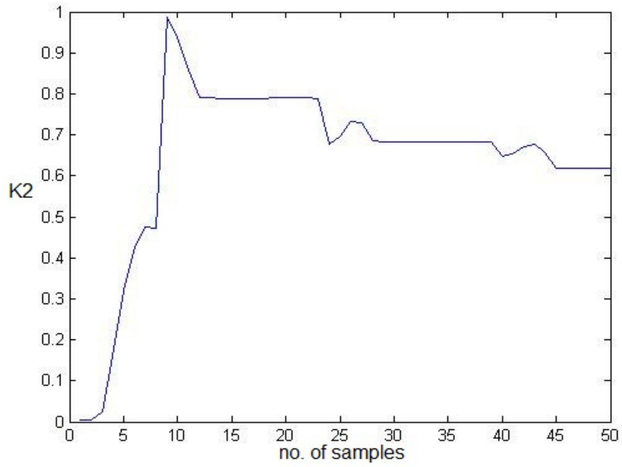
**Table2: Transmission line parameters**

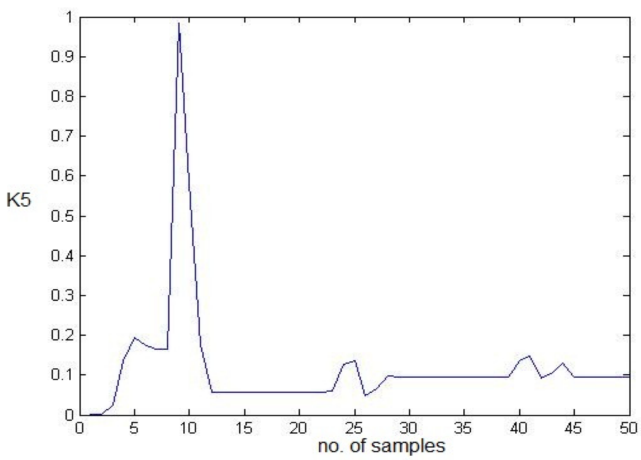
| Length | 300 km |
|---|---|
| Frequency used for RLC specification | 50 Hz |
| Positive and zero sequence resistances(ohms/km) | 0.01273 and 0.3864 |
| Positive and zero sequence inductance(H/km) | 0.9337e-3 and 4.1264e-3 |
| Positive and zero sequence capacitance(F/km) | 12.74e-9 and 7.751 e-9 |

## 5. RESULTS

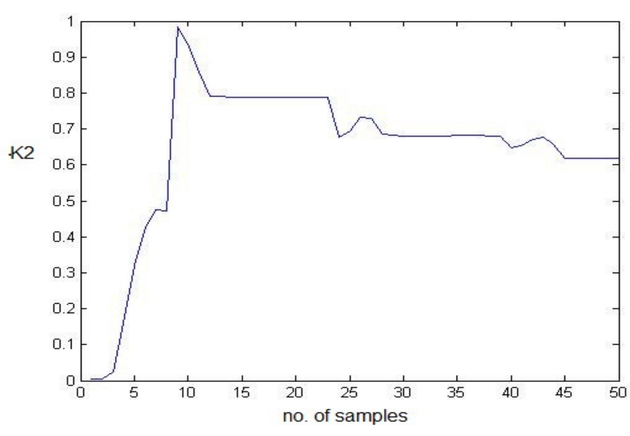
The plots below provide values of phase A, similar results have been obtained for other phases as well

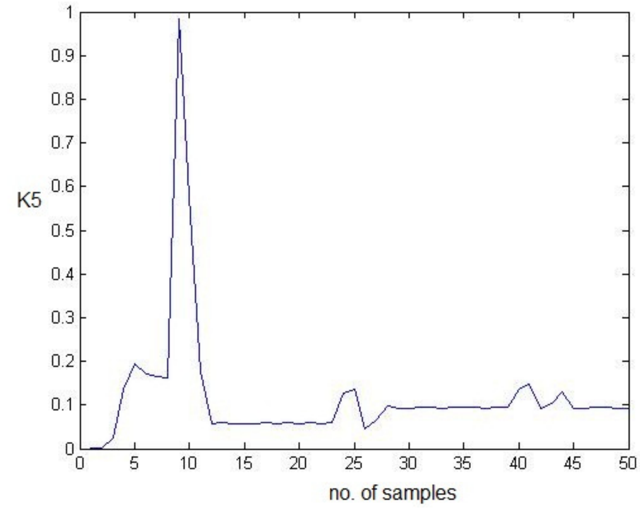
***Inrush condition: Result from FWHT***



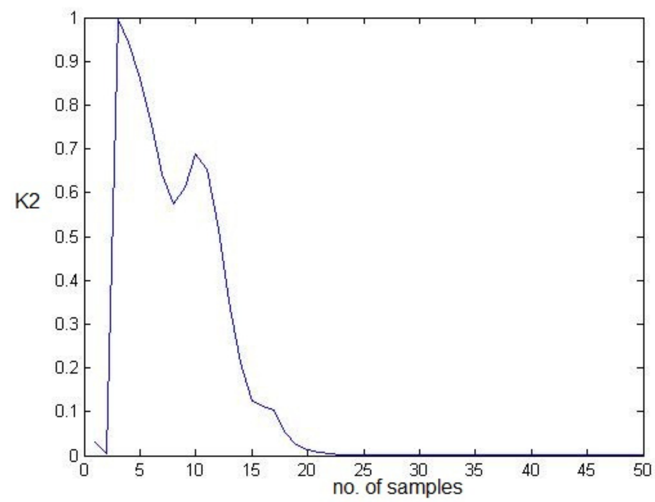



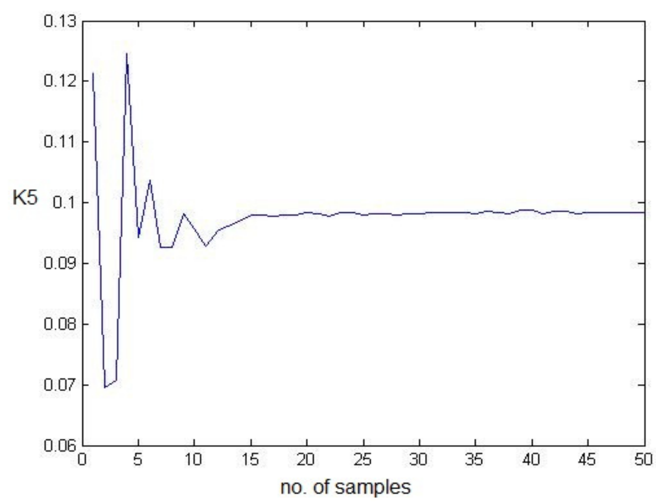

***Result from FRHT***



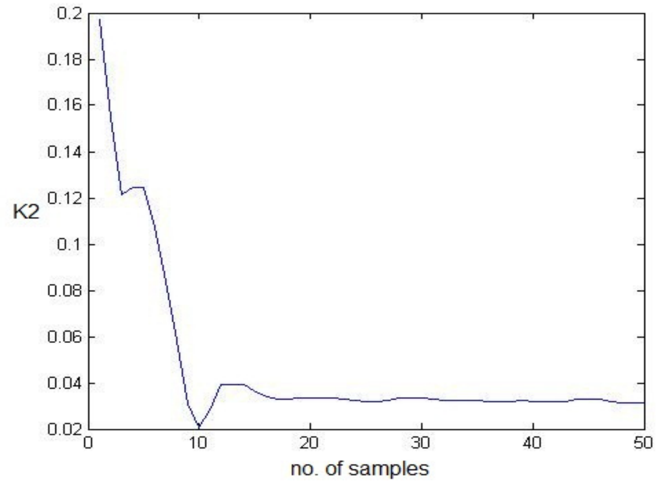



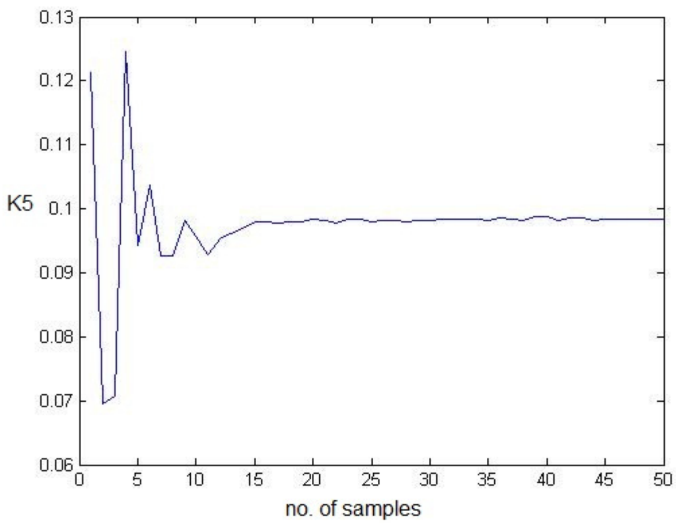

***Over-excitation condition: Result from FWHT***



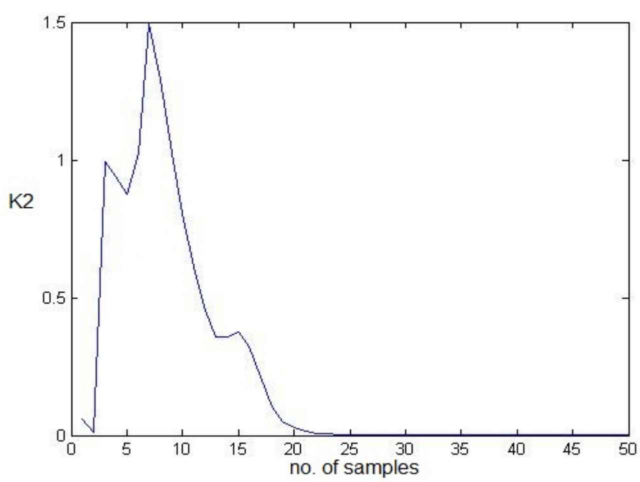



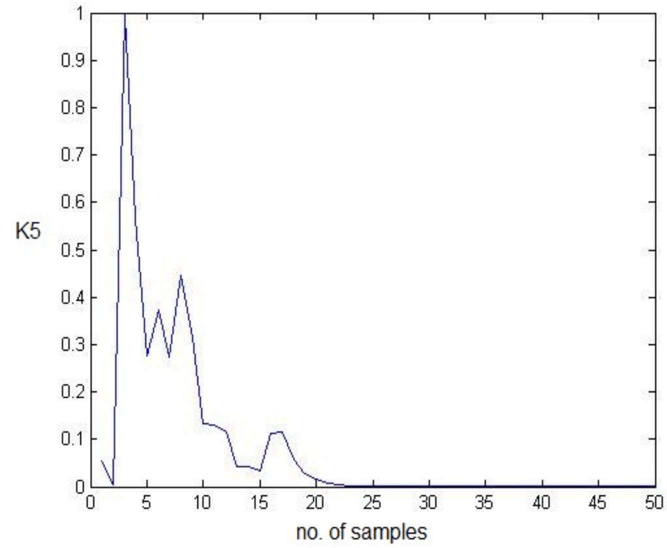
***Result from FRHT***



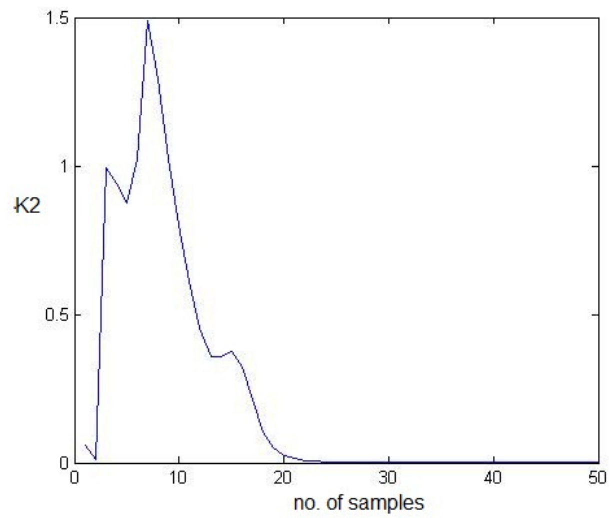



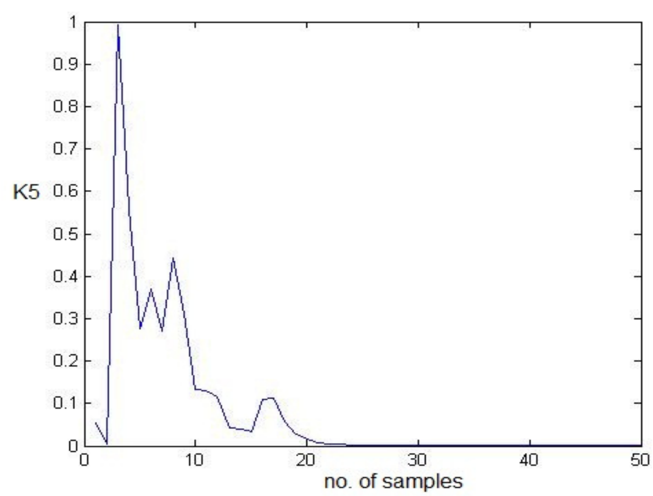

***Internal fault condition: Result from FWHT***




***Result from FRHT***



## 6. CONCLUSION

The simulation result from MATLAB sim power system reveals 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.

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