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Detection of short circuit with current transformer saturation by wavelet transform

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Abstract: *Along with the development of power systems, the need to provide reliable power is also increased. So that electricity consumers expect to see the least amount of interruptions in received electrical energy. One of the things that makes it difficult is detection of the errors of short circuit caused in the network in terms of current transformers saturation. With the saturation of current transformers, protective relays encounter numerous problems in dealing with current transformers. In this research, it was tried to provide useful and practical solutions to this. It has been suggested that current transformer saturation in terms of network error is detected using wavelet transform and then the protective relay zone is changed to deal with this. Differential and distance relays are selected for this and for each of them, an algorithm has been suggested to detect saturation current, and then to deal with it. In order to detect current transformers saturation, wavelet transform, which is a new method in digital signals processing, was used. Wavelet transform has high-speed performance and Due to its simple structure, it can also be implemented in protective relays. Simulation on a modeled power system was performed based on the actual network in EMTDC/PSCAD software and its outputs were analyzed by using MATLAB software. The results of simulation confirmed the efficiency and usefulness of the proposed algorithm.*

Keywords: *short circuit, current transformers saturation, wavelet transform*

INTRODUCTION

Today, due to advances in technology and also with the arrival of digital relays, the use of current and voltage transformers to protect and to measure the quantity of current, voltage and electric power is inevitable and using them in electrical enclosure and medium and strong electrical substation in order to achieve the above objectives is increasing. In the power industry, two parameters of voltage and current are required for two purposes of measurement and protection but since these amounts are so large numbers and accessing to them is not practical nor economically affordable, so we have to apply voltage current transformers to convert these values to smaller values that are a fraction of the real value. In fact, this equipment is a small sample of primary voltage and current with very low error and since all measurement instruments such as ammeter, voltmeter, varmeter, etc. as well as protective relays are made based on the secondary current and voltage of this equipment, the objectives of measurement and protection can be achieved by using these transformers. Due to high current in transmission networks as well as high voltage, the current is sampled from different parts of a network. For this, a tool called current transformer is required that does following doings:

- It transforms high currents to low 5A or 1A-current.
- It isolates high voltage networks from measurement and protection systems.

The current transformers (CTs) are used for the objectives of measurement and protection of network. These transformers are used at the beginning of input lines to electrical substation and also, at the input of power transformer and secondary input of transformer and also at the outputs of substation and other key points where it is necessary to control the current in. Each of these points are used and equipped with its own transformer both in terms of insulator and structure and in terms of power and accuracy. Current transformer is placed in series in circuit. Current transformer is composed of two primary and secondary windings that in substation, the current passes the primary winding and as a result of the current passage and according to it, little current (about A) is created in the secondary winding. The secondary winding of these transformers, with lesser current compared to the primary, is connected to low voltage equipment of substation and relays and pointers. Secondary winding has greater number of turns compared to the primary one which is often made of only one ingot or several turns of ingot (Lee, 2000). Current transformers must be firstly able to continuously endure the voltage and rated current without causing additional heat and insulation fault (Galli. et al,1999). Second, protection current transformers, in the mode of additional current as a result of defects occurring in the network, must do transformation carefully and with high accuracy. Measurement current transformers, in the mode of additional current related to short circuit on network, must limit the current inherently to not damage measurement devices.

Simulation short circuit detection with current transformer saturation.

In this part, two new algorithms are suggested to detect short circuit occurring in the network when current transformers are saturated due to the occurrence of short circuit. In distance relay, current transformer saturation results in non-issuance of cut command of short circuit. In the differential relay, current transformer saturation results in issuance of the improper cut per external errors by the relay. In this part, two algorithms were suggested to solve the problem, based on wavelet transform. For this, the network was modeled based on the actual network including transmission lines, generator and transformer and simulation was performed on it. The results of simulation confirm the efficiency of supposed algorithms.

The modelled network

The network modelled in the present study is based on the model used in the transmission network in Iran. In the model, the equivalent circuit is connected to a substation, including a transformer and a transmission line, through a transmission line with a length of 140 km. The models used for each of the elements are based on the actual model in the electricity network in Iran.

The model used for current transformers

On one hand, the task of current transformer is to reduce the current to some extent which is proper for measurement devices such as voltmeter, ammeter, power meter and protection devices such as relays, error stabilization devices, etc. and on the other hand, it separates the high-voltage current from the low-voltage current (Fernández, 2011).

Current transformers are placed in series I the network and its primary winding can be made of a single turn or multiple turns. The selected current transformer can provide required or permitted secondary current for protection devices in both normal mode of current and the mode of short circuit. So, the accuracy of protection devices completely depends on the accuracy of measurement transformers providing the input of relay and in the absence of sufficient accuracy in measurement transformers, the performance of relay will not be entirely correct even if the relays are very accurate (Sevov, et al, 2000).

Based on the definition of current transformers provided by IEEE, saturation point of CT with closed core (without air gap) is a point where the permeability of core is maximum. This point, in the stimulation curve plotted in log sheet, is a point where the tangent to the curve make a 45-degree angle with the horizontal axis (Phadke et al,1988). When CT has air gap in the core, a 45-degree angle becomes a 30-degree angle. As standard, knee point of a stimulation curve is a point where 10% increase in sinusoidal voltage applied to the secondary winding of CT with rated frequency leads to 50% increase in stimulation current (it should be noted that in this mode, all other windings are open circuit)(Meyer et al, 1993). In order to reduce and minimize the error of CT, magnetic curve should become almost a line with a constant slope. If a very small air gap or non-magnetic matter is placed in an iron core, the magnetic resistance of path will be equal to the sum of magnetic resistances of iron core and air gap. Due to the higher magnetic conductivity of iron than air, magnetic resistance of iron is less than the magnetic resistance of air gap. Therefore, nonlinear curve of iron will be converted to linear curve of iron and air(Villamagna et al, 2006).

The results of simulation of algorithm proposed for detection of CT saturation in distance protection.

Flowchart 1 shows the algorithm proposed for detection of short circuit in terms of current transformer saturation in distance relay using wavelet transform.

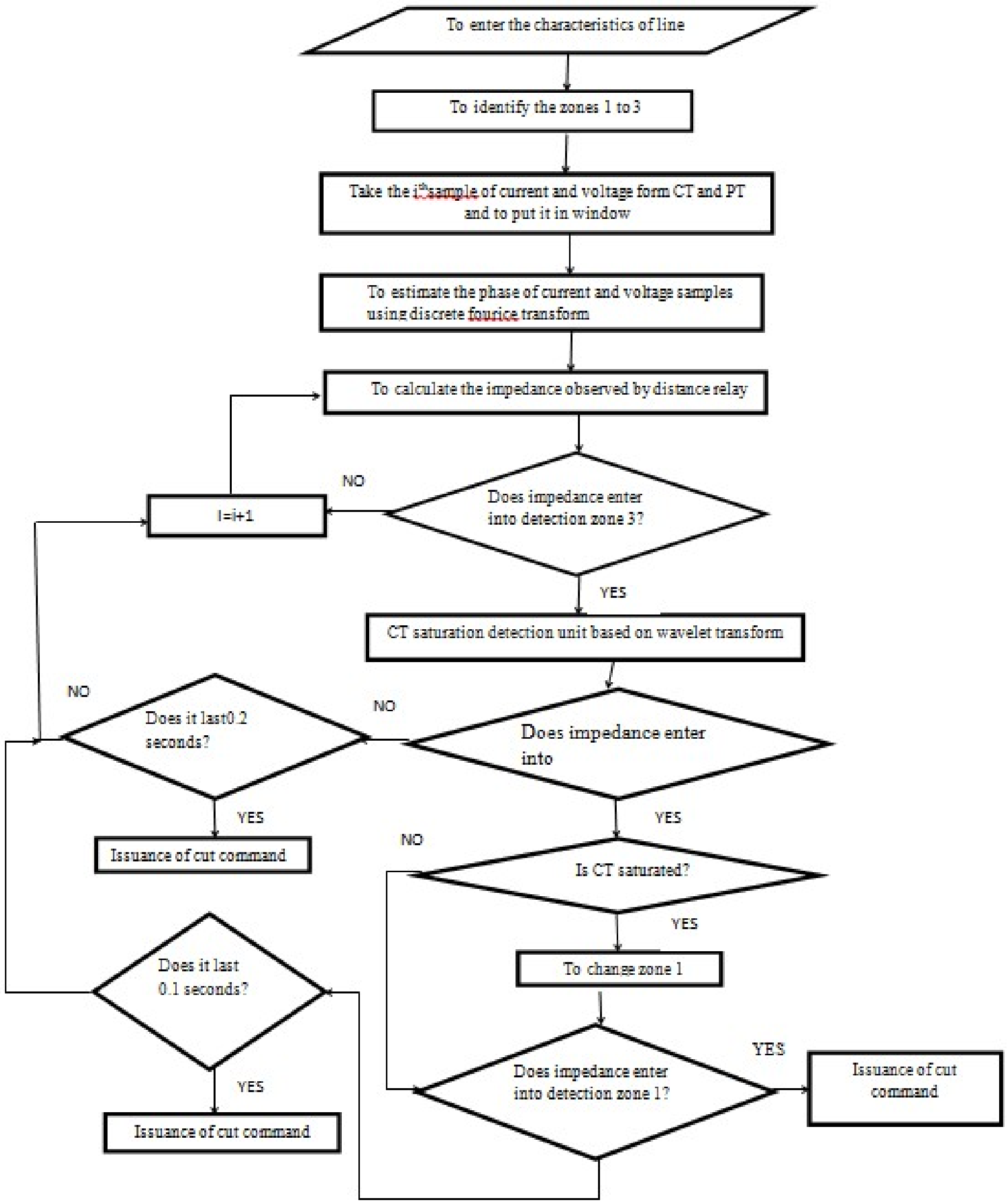

Figure1. The algorithm proposed for detection of short circuit in terms of current transformer saturation in distance relay

Two-phase and three-phase to ground faults in distance relay

In this part, two-phase and three-phase to ground faults are simulated. In this part, the wavelet transform was gotten from the observed current of each phase and waveform of wavelets were presented (Burrus et al, 1998). Then, the square of wavelet cD1 used for detection of current transformer saturation was zoomed for each phase. According to the results of two-phase fault, it is observed that after detection of current transformer saturation using wavelet transform, protection zone 1 is rotated clockwise to detect a short circuit. Also, after the occurrence of two-phase to ground short circuit, the seen impedances reduce significantly so that the relay detects its distance (Ziegler, 2005).

The results of simulation of algorithm proposed for detection of CT saturation in differential protection

In order to detect the current transformer saturation during the short circuit, wavelet transform was used. The steps of the doing are as follows:

1. The primary and secondary three-phase currents are obtained from the corresponding current transformers.
2. The obtained currents are analog and after passing through the required filters, they should be sampled using analog to digital convertor and specific sampling signal and then converted to digital signal. In this thesis, the signals were samples with frequency of 4 kHz, in advanced industrial relays, the signals are also sampled with the same frequency.
3. Before the main processing, the samples of the current of primary and secondary current transformers should be complied with each other both in terms of range and phase. In order to comply primary and secondary currents in terms of range, they are expressed in a per-unit form based on the base current where transformation ration of CT is considered in. the primary and secondary base currents are as follows:

$$I_{b1} = \frac{S_b}{\sqrt{3}V_{b1}} \times \frac{N_{CT1-p}}{N_{CT2-p}} \quad (1)$$

$$I_{b2} = \frac{S_b}{\sqrt{3}V_{b2}} \times \frac{N_{CT1-s}}{N_{CT2-s}} \quad (2)$$

Where I_b is base current, S_b is apparent power transformers, V_b is the voltage of transformer parties and NCT-P and NCT-S are transformation ratio of the primary and secondary CT. Per unit currents are obtained by dividing the sample currents by I_{b1} and I_{b2}. To compensate the difference between the primary and secondary phases of transformer, the transformation matrix (equation 3-5) is used that the phase is compensated by multiplying the matrix by the current samples. In matrix T, k is the transformer vector group.

$$T = \frac{2}{3} \times \begin{bmatrix} \cos\left({k\pi}/{6}\right) & \cos\left({(k+4)\pi}/{6}\right) & \cos\left({(k-4)\pi}/{6}\right) \\ \cos\left({(k-4)\pi}/{6}\right) & \cos\left({k\pi}/{6}\right) & \cos\left({(k+4)\pi}/{6}\right) \\ \cos\left({(k+4)\pi}/{6}\right) & \cos\left({(k-4)\pi}/{6}\right) & \cos\left({k\pi}/{6}\right) \end{bmatrix} \quad (3)$$

4. The compensated signals of the current sampled from the primary and secondary current transformers are entered into dual slope differential characteristic. In this characteristic, firstly, the restrain and operate currents are made based on the difference and the sum of primary and secondary currents. Then, according to the characteristic of differential relay,
it is decided that it enters to what zone (operating or restraining).
The steps of 1 to 4 are continued until the characteristic of differential current enters operating zone. When the characteristic of differential current enters operating zone, the algorithm is transmitted to step 6. When the characteristic of differential current enters operating zone, given the state of current

transformer saturation detected by the wavelet transform, the issuance or non-issuance order of cut command is issued.

Internal and external errors of transformer

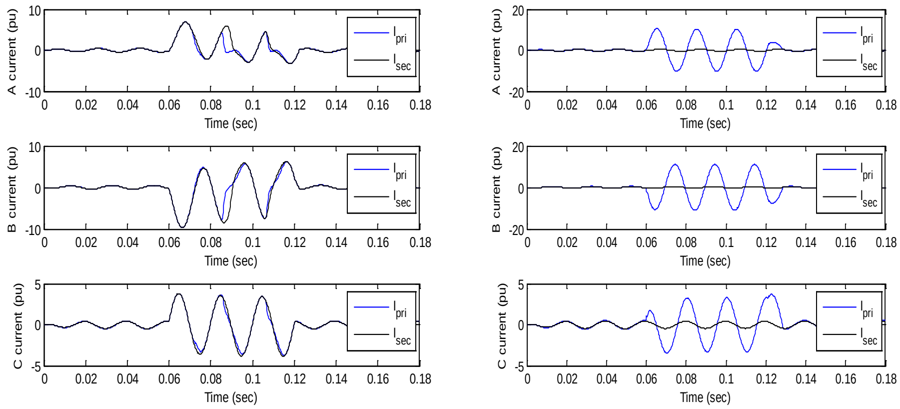

Figure2. Primary and secondary currents of protection current transforms after compensation during internal error (right) and external error (left) of transformer

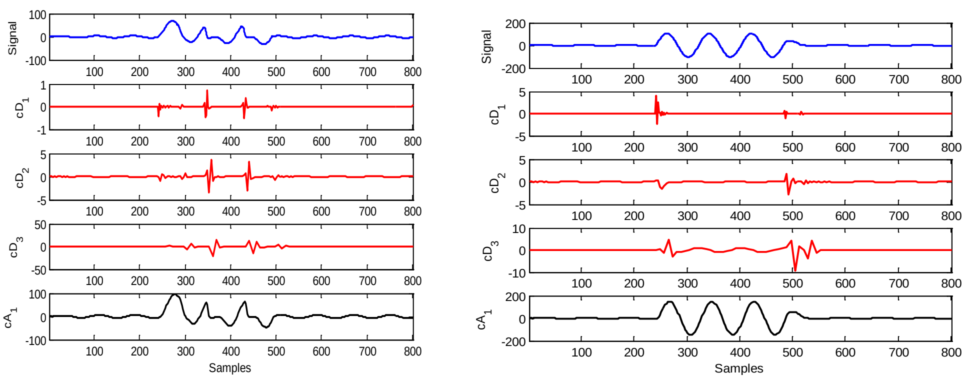

Figure3. The wavelet transforms of differential current of phase A during internal error (right) and external error (left) of transformer

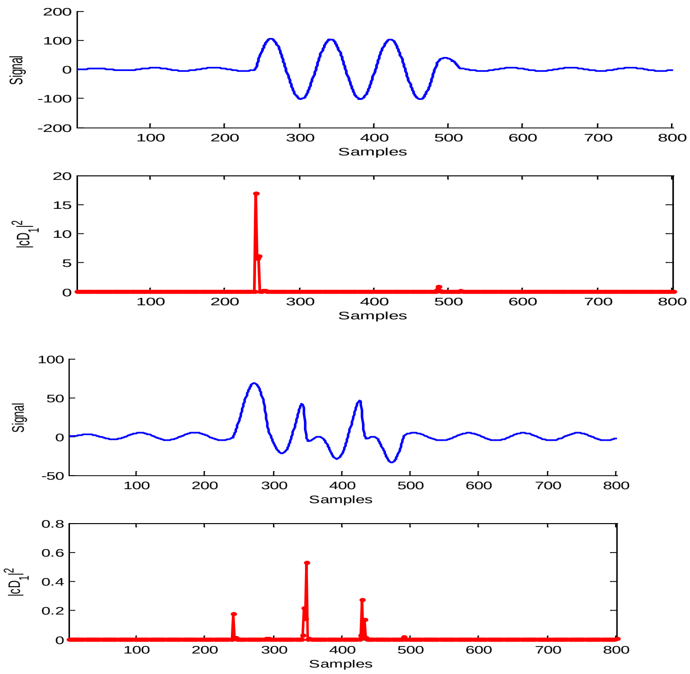

Figure4. The wavelet cD1 square of current of phase A during internal error (above) and external error (below) of transformer

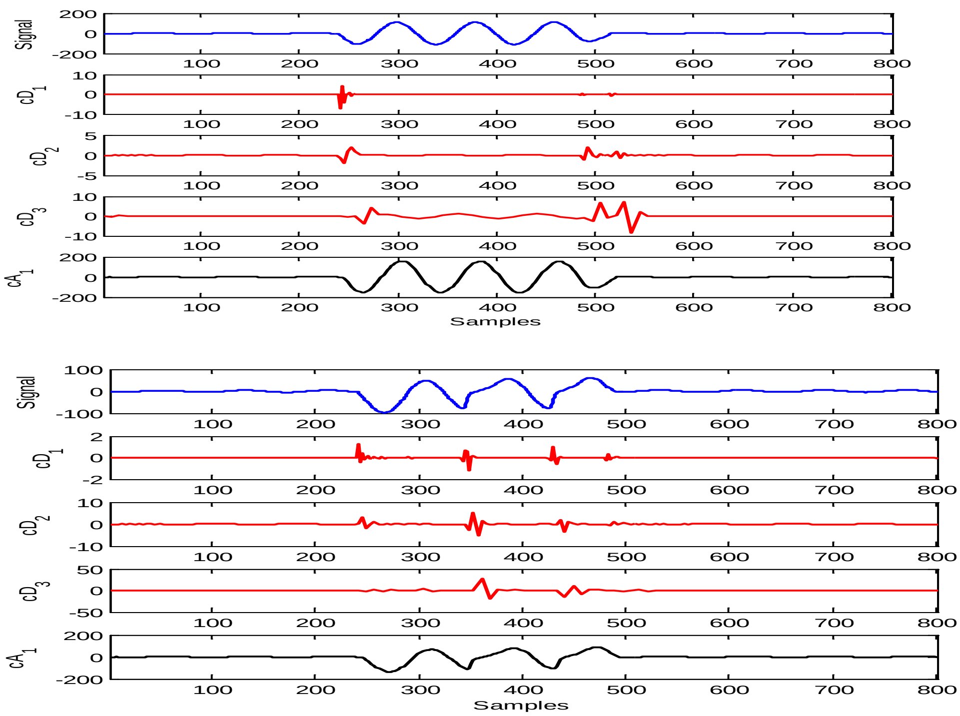

Figure5. The wavelet transforms of differential current of phase B during internal error (above) and external error (below) of transformer

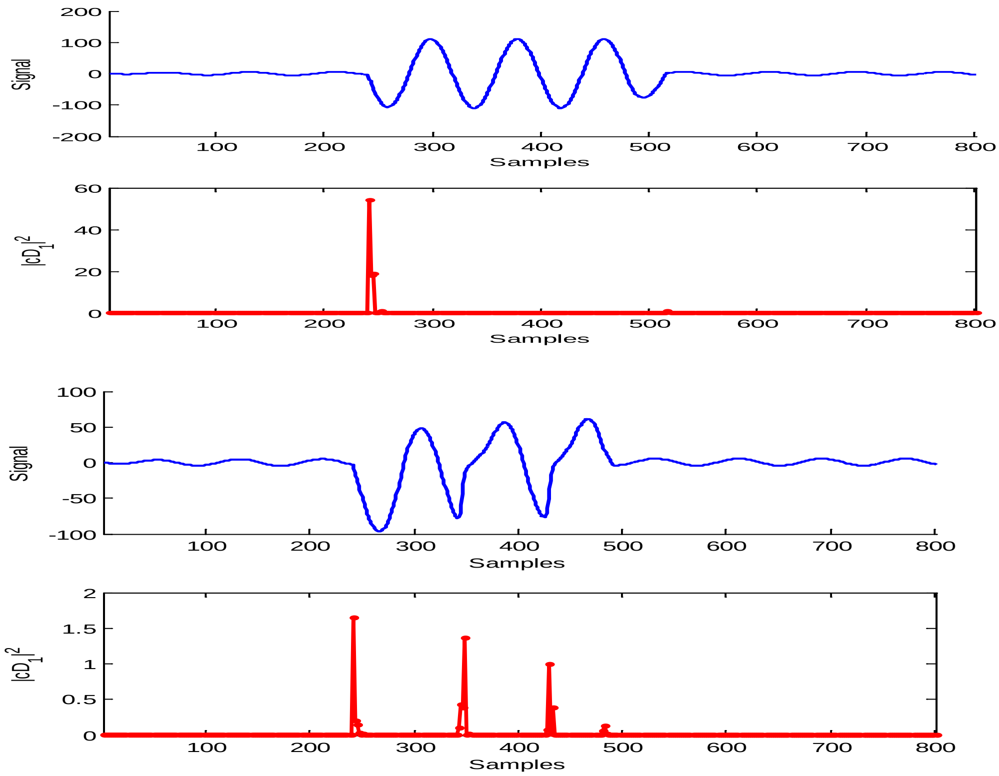

Figure6. The wavelet cD1 square of current of phase B during internal error (above) and external error (below) of transformer

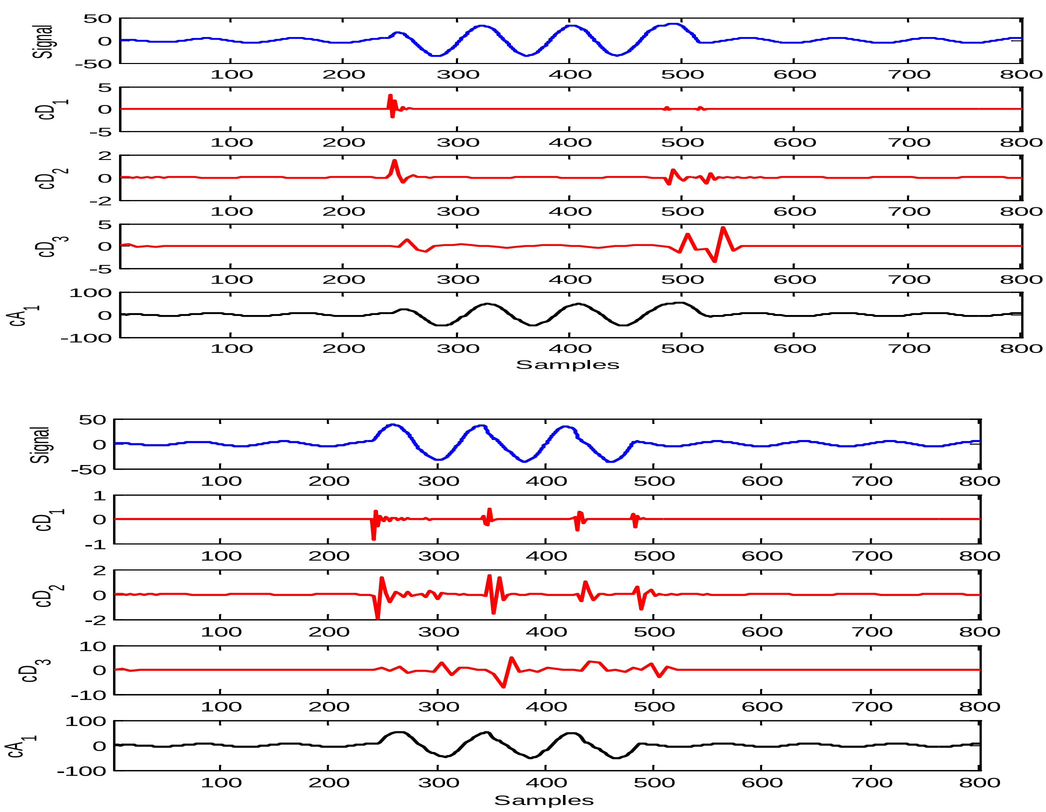

Figure7. The wavelet transform of differential current of phase C during internal error (above) and external error (below) of transformer

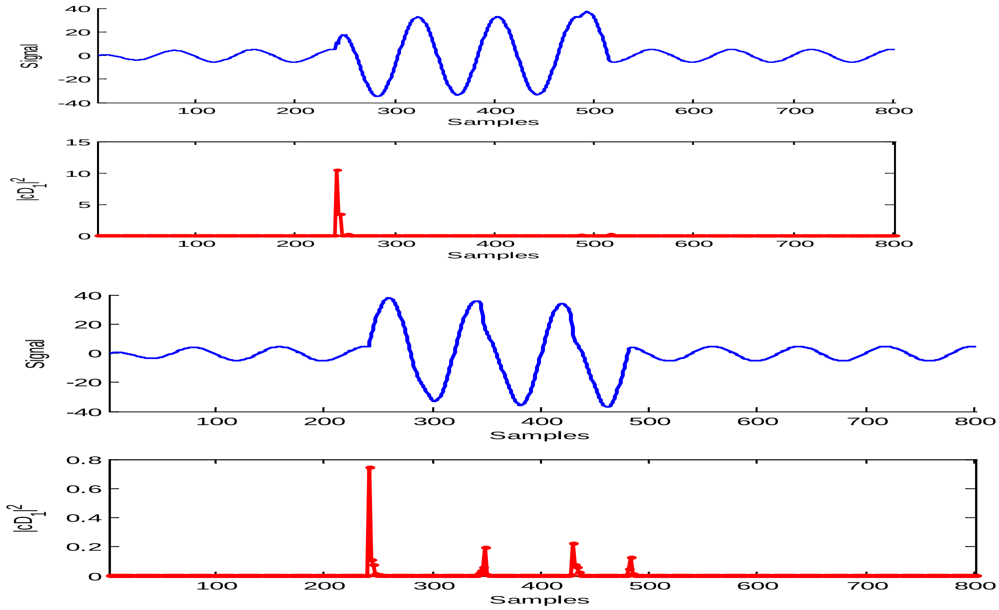

Figure8. The wavelet cD1 square of current of phase C during internal error (above) and external error (below) of transformer

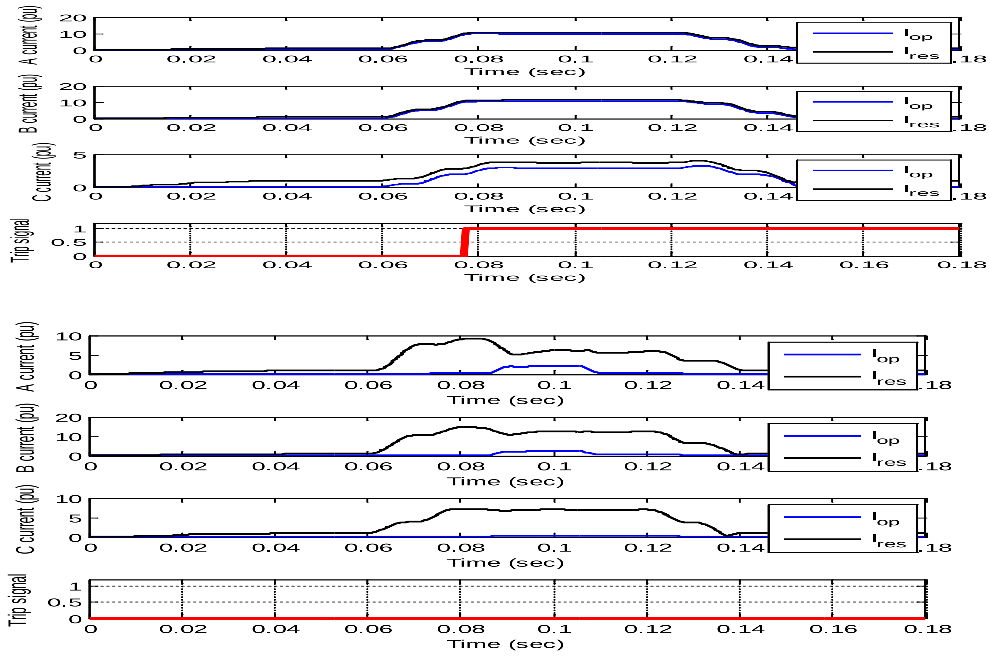

Figure9. The operate and restrain currents of transformer differential protection during internal error (above) and external error (below) of transformer

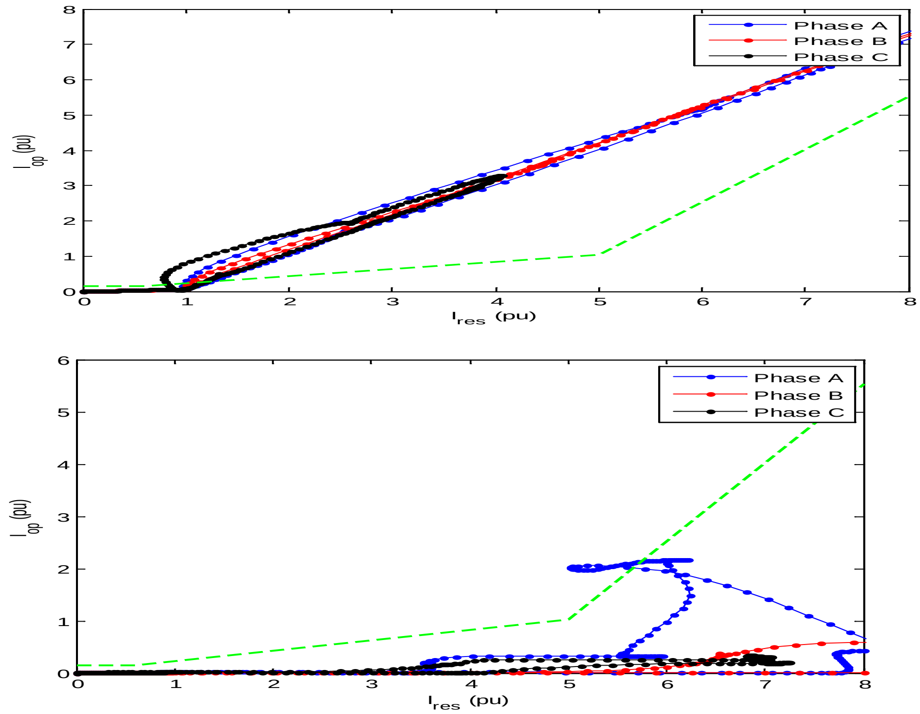

Figure10. The characteristic of transformer differential protection during internal error (above) and external error (below) of transformer

Conclusion and Suggestion

According to the results of the previous section, following suggestions are provided

- Wavelet transform, due to the use of different filters in order to extract the upper and lower frequencies of waveform, is a very convenient method for analyzing disturbances in power systems.
- The most suitable family of wavelet, according to simulations carried out in this study to detect current transformer saturation, is the Daubechies family which is briefly represented by dbN.
- Current transformers saturation can cause trouble in the performance of protection relays, including differential and distance.
- With current transformers saturation in terms of short circuit, the amount of observed current in the relay will be less than the actual amount. For this reason, in differential relay, operate and restrain characteristic is directed to the right side and in distance relay, the seen impedance is greater than actual value and the relay does not detect the error.
- In this paper, in order to detect short circuit certainly, two algorithms were supposed for distance and differential relays. They can be used to improve the mentioned relays.

In order to continue what done in this article, the following doings can be carried out.

- To use wavelet transform to detect the point of current transform saturation and its end point in the event of a short circuit in the network.
- To distinguish the internal error of transformer from inrush current by logically combining wavelet transform and Fourier transform, it means the occurrence of errors or inrush current is detected by Fourier transform and then the two are distinguished by Wavelet Transform.
- To use fuzzy logic for correct decision making on detection of type of error occurred in protection relays by taking into account current transformer saturation.

References

1. Meyer Y. and Ryan R.D., "Wavelets Algorithms & Applications," *Society for Industrial and Applied Mathematics*, 1993.

2. Burrus M.S., Gopinath R.A., and Guo H., *Introduction to Wavelets and Wavelet Transforms.*: Prentice Hall, 1998.

3. Goswami J. C. and Chan A. K., *Fundamentals of Wavelets, Theory, Algorithms and Applications.*, 1999.

4. Lee C. H., Wang, Y. J., and Hang W. L., "A Literature Survey of Wavelet in Power Engineering Application," in *Proceeding Natinal Science Counc. ROC* , 2000, pp. 249-258.

5. Wayne Galli and Nielsen, O. M., "Wavelet analysis for Power System Transients," in *IEEE Computer Application in Power*, 1999, pp. 58-60.

6. C. Fernández, "An impedance-based CT saturation detection algorithm for bus-bar differential protection," *IEEE Transaction on Power Delivery*, 2011.

7. L.Sevov, G.Brunello B.Kasztenny, *Digtal low-impedance bus differential protection-problems and solutions.*: (B30 GE relay)GE power management, 2000.

8. N. Suga, Y. Murakami, and K.Inamura F. Andow, "Microprocessor-based busbar protection relay," in *Proc. IEEE 5th Int. Conf. Development in Power System Protection*, 2003.

9. G. Phadke and J. S. Thorp, *Computer Relaying for Power Systems*. U.K.: Somerset, 1988.

10. P.A. Dolloff, A.G. Phadke L. Yang, "A microprocessor based bus relay using a current transformer saturation detector," in *Proc. 22nd Annual North American Power Symposium*, 1990.

11. G. Ziegler, *Numerical Diffrential Protection, Principles and Applications.*: Publicis Corporate Publishing, SIEMENS, 2005.

12. N. Villamagna and P. A. Croossley, "A CT saturation algorithm using symmetrical components for current differential protection," *IEEE Transaction on Power Delivery*, 2006.

13. IEEE Power System Relaying Committee Publication. CT Saturation Theory and Calculator. [Online]. http://pes-psrc.org/Reports/CT_SAT%2010-01-03.zip.

14. S. H. Ok, and S. H. Kang Y. C. Kang, "A CT saturation detection algorithm," *IEEE Transaction on Power Delivery*, 2004.

15. IEEE Guide for the Application of Current Transformers Used for Protective Relaying Purpose," ANSI/IEEE C37.110, 1996.