Mansoura Engineering Journal, (MEJ), Vol. 31, No. 1, March 2006. E. 62

Implementation of Transformer Static Differential Relay with Harmonic Blocking

مرحل تفاضلى ساكن ذو إعاقة فصل توافقية لوقاية محولات القوى

Mohammed El Gamal
Elect. & Cathodic prot. Dept.
Arab Petroleum Pipelines Co. (SUMED)
P.O.Box:158 El-Saray, Alexandria

Ahmed Lotfy Hussien Dessouki
Electrical & Comp.Control Eng. Dept.
Arab Academy for Science & Technology & Maritime Transport
P.O. Box 1029 Alexandria Egypt

ملخص - تقدم هذه الورقة مرحل تفاضلى ساكن يستخدم مرشحات الحزمة النشطة من الدرجة الثانية لتحديد نسبة التوافقية الثانية بما يمكن المرحل من عدم إصدار إشارة الفصل خلال تيار الإندفاع المغناطيسي لمحولات القوى. و يتميز المرحل المنفذ بإمكانية إستخدامه مع العديد من مقننات محولات القوى بتعديل منحنيات الخواص التفاضلية.

Abstract – In this paper a transformer static/electronic differential relay is implemented using second order active band-pass filters for detecting second harmonic ratio. Thus enabling a relay-blocking signal during transformer inrush current, also the relay allows for a fine adjustment of the differential characteristic curve to facilitate its use in variety of transformer ratings.

I. INTRODUCTION

One of the most important means of protecting a power transformer is differential protection based on the comparison of the transformer primary and secondary currents. When these currents deviate from a predefined relationship, an internal fault is assumed and the transformer is de-energized. However during transient primary magnetizing inrush conditions, the transformer can carry very high primary current and no secondary current. The resulting differential current can falsely trip the transformer. The most common technique used for preventing false tripping during the above condition is the use of second harmonic restraint. If the second harmonic content of the differential current exceeds a pre-defined percentage of the fundamental, inrush is indicated and the relay is prevented from tripping.

Nikola R. and Adam S. [1], presented a method for the simulation of the inrush phenomenon in which they considered the phenomenon as a quasi steady state as its slow attenuation makes time domain simulation difficult. C. E. Lin et al [2], related the transformer magnetizing inrush phenomenon to the non-linearity and hysterisis of the iron core, as it results in analytical complexity. They further presented a symmetrical discussion [3] for harmonic analysis due to magnetizing inrush currents in single-phase power transformers using the Fast Fourrier Transform (FFT). H .S. Bronzeado et al [4], stated that sympathetic inrush - which is the effect of transformer inrush current on other transformers already connected to the system - has been largely ignored. They reasoned the transient inrush current occurring in transformers to the transformer core saturation caused by switching on. Laszlo Priler et al [5], mentioned two causes of magnetizing inrush; the residual flux in the magnetic core and the transient flux produced by the integral of the sinusoidal supply voltage. When energizing

Accepted March 30, 2006

a transformer at zero crossing of the sinusoidal voltage, the prospective magnetizing current and the flux have their maximal values and delayed by 90 electrical degrees.

II. Static Relays In Protection

Static relays technology is a preeminent choice of protection. The application of these relays is in many ways simpler than that of EM relays, although there has no significant change in the principles of system protection and coordination.

David S. Baker et al [6] developed a static over-current relay and clarified how coordination time intervals are adjusted, and how reset characteristics and setting of accuracy are implemented. Bruce, Baily and Dan Jakominich [7] developed a static-digital over-current relay stating that digital technology has functionality that permits improved and expanded protection. B.T.Desai, Gupta and Vasantha [8] implemented an inrush activated blocking scheme for a static electronic differential relay based on an instantaneous level of differential current and its rate of change. This scheme is based on the waveform approach. They mentioned that the current magnitude and rate of change of current (di/dt) are low simultaneously for inrush for about 40-45 degrees from zero crossing of the positive rise of the rectified current wave, compared to normal fault current and load current.

In this paper a more developed scheme of an electronic differential relay is implemented. The relay avoids the dependence on the current waveform pattern in which case it is not always guaranteed that the current waveform will maintain certain specifications under various loading or even inrush conditions.

The present relay allows for second harmonic ratio detection using active band-pass filters by which mal-operation due to inrush condition is avoided. Furthermore, it is possible to adjust the slope of the characteristic curve electronically. The schematic and realization of the relay is depicted below.

III. Signal Conditioning

The primary and secondary currents of the power transformer are passed through current transformers then transformed to voltage signals by the 0.2Ω precision resistor as shown in figure (1). The primary and secondary signals are passed through two inverting amplifiers such that the gain of the secondary signal is one half that of the primary one.

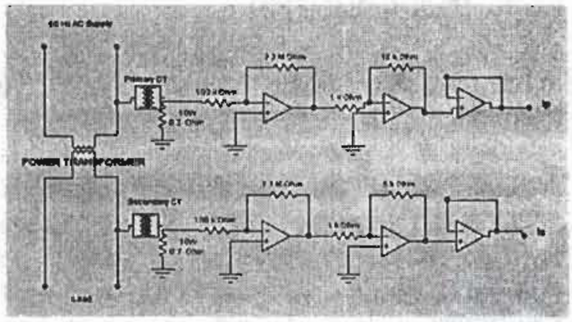

Fig. (1) Signal conditioning circuit.

To create signals corresponding to the primary and secondary currents for use in calculating differential and restraining currents of the characteristic curve, both signals are passed through active rectifiers as shown in figure (2) to create dc levels corresponding to the primary and secondary currents.

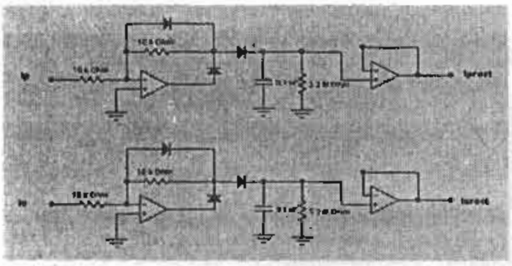

Fig. (2) Active rectifiers for primary and secondary signals.

IV. Characteristic Curve Implementation

The relay's characteristics are defined according to the following set of equations:

$$I_{diff} = (I_p - I_s)$$
$$I_{rest} = (I_p + I_s)/2 \quad \rightarrow 1$$
$$I_{diff} > k * I_{rest}$$

The dc levels corresponding to the primary and secondary currents are modified as shown in figure (3) to give an output relevant to the restraining and differential currents using differential and adding amplifiers. A precision potentiometer resistor is used to adjust the required percentage (K).

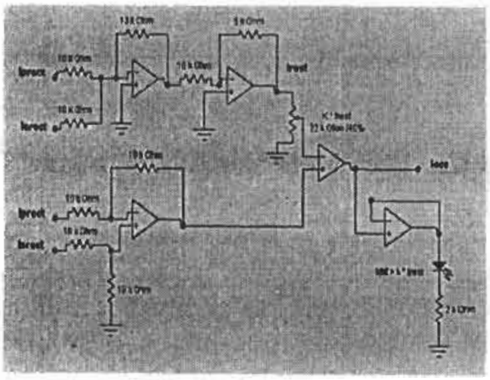

Fig. (3) Electronic Implementation of characteristic curve.

V. Detection of second harmonic ratio

The ac primary signal corresponding to the primary current is passed through a second order active band pass filter tuned to give high gain for the 100 Hz signal as shown in figure (4), to detect the second harmonic. The signal is also passed through another active band pass filter tuned to give high gain for the 50 Hz signal to detect the fundamental frequency.

To calculate the second harmonic constraint percentage (ε), the 50 Hz filter output is passed through a precision variable resistor by which we can select any percentage (ε) from the 50 Hz signal (e.g. 0.12) to be compared to the 2^{nd} harmonic signal.

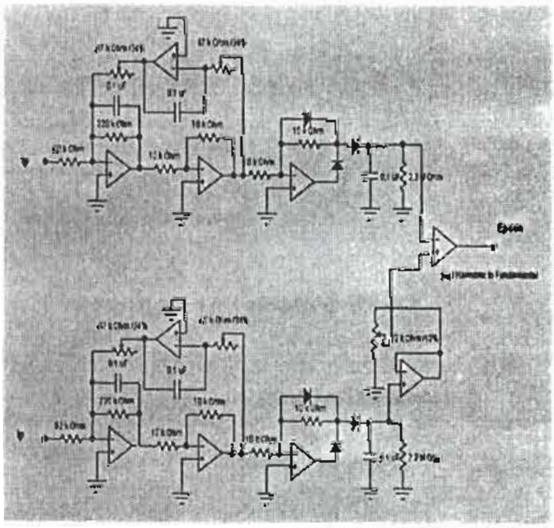

Fig. (4) Electronic detection of 2^{nd} harmonic ratio.

VI. Tripping Circuit Logic

Finally our target is to send the tripping signal when the point of the characteristic curve is located in the operating zone in which $I_{diff} > I_{rest}$ AND the value of the second harmonic ratio is less than "ε". As shown in figure (5), the signal "ε" is passed through the clock of a D-Q flip flop its Q' signal is connected to the cathode of a diode whose anode is connected to the signal corresponding to the logic of the characteristic curve via a resistor. As shown in the figure the transistor will not be triggered except when the point of the characteristic curve is in the operating zone AND Q' is high ("ε" is low) i.e. the 2^{nd} harmonic ratio is less than 0.12.

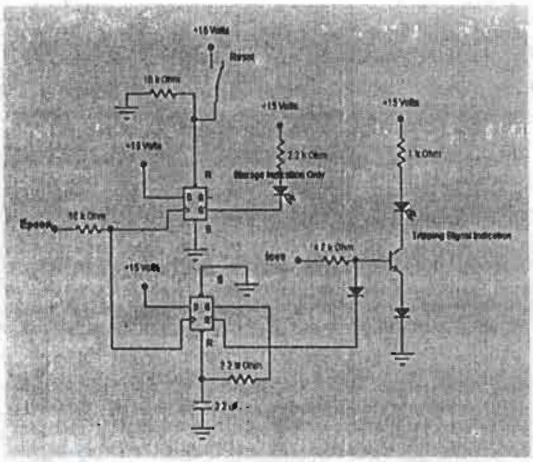

Fig. (5) Tripping circuit logic.

VII. Experimental Results

A digital storage oscilloscope was applied to measure the primary and secondary currents of the transformer during various operating conditions. The figures were captured using a digital camera. The inrush current signal captured by the relay in no-load condition is shown in figure (6). A light emitting diode is used to indicate this condition.

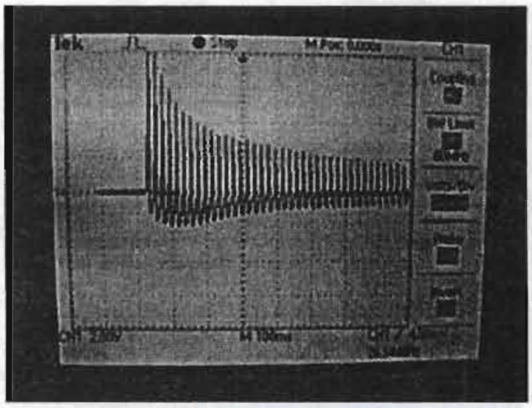

Fig. (6) Inrush current in no-load.

The inrush current signal in load condition is captured in figure (7) in which case also the 2^{nd} harmonic LED remains on.

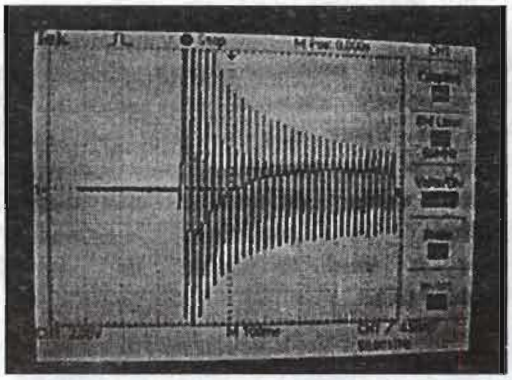

Fig. (7) Inrush current during load .

The primary and secondary current captured signals in normal and internal fault conditions are shown in figures (8) and (9) respectively. During the normal operation all LEDs are not activated, while during the internal fault condition the differential current LED and the tripping LED is activated.

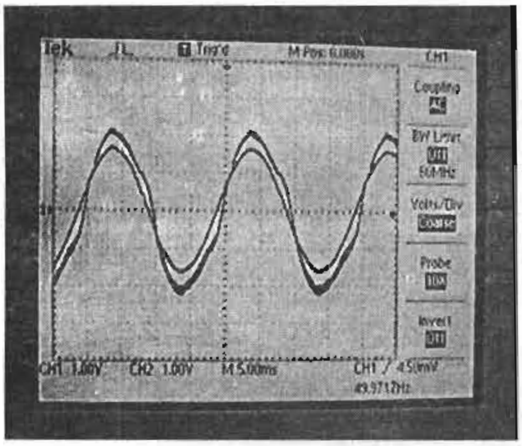

Fig. (8) Primary and secondary currents in normal operation.

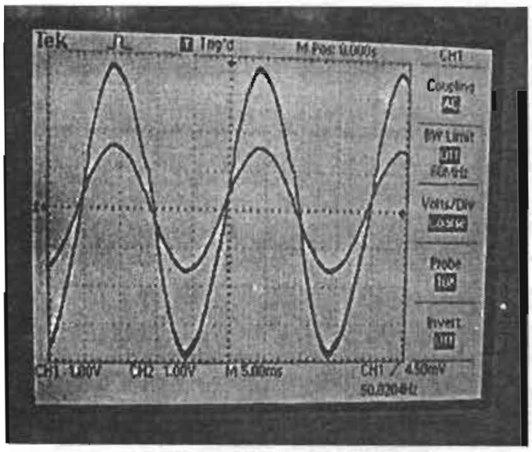

Fig. (9) Primary and secondary currents during internal fault.

VIII. Conclusion

A developed static differential relay is implemented and tested under various operating conditions. The relay allows for harmonic blocking using second order active band-pass filters. Furthermore the shape of characteristic curve is adjustable, making it applicable to the protection of transformers with different ratings.

REFERENCES

[1] Nikola Rajakovic and Adam Semlyen, "Investigation of the inrush phenomenon a quasi-stationary approach in the harmonic domain", IEEE transactions on power delivery, vol.4, October 1989.

[2] C.E.Lin, C.L.Cheng, C.L.Huang, and J.C.Yeh., "Investigation of magnetizing inrush currents in transformers (part-I numerical simulation)", IEEE transaction on power delivery, vol. 8 No. 1, January 1993.

[3] C.E.Lin, C.L.Cheng, C.L.Huang, and J.C.Yeh., "Investigation of magnetizing inrush currents in transformers (part-II numerical simulation)", IEEE transaction on power delivery, vol. 8 No. 1, January 1993.

[4] · H.S.Bronzeado, P.B.Brogan, and R.Yacmini, "Harmonic analysis of the transient currents during sympathetic interaction", IEEE transactions on power systems, vol.11,No. 4, November 1996.

[5] Laszlo Prikler et all, "Reducing the magnetizing inrush current by means of controlled energization and de-energization of large power transformers", International conference on power system transients – IPST 2003 in New Orleans, USA.

[6] David S. Baker et all, "Application considerations of static overcurrent relays: A working group report", IEEE 1997.

[7] Bruce Baily, Dan Jakominich, "Static-Digital overcurrent relays permit enhanced protection", IEEE 1998.

[8] B. T. Desai, H. O. Gupta, and M. K. Vasantha, "New one-cycle static blocking scheme for inrush in differential relay" IEE proceedings, Vol. 136, pt. c, No. 1, January 1989.