MOCT: MAGNETO OPTIC CURRENT TRANSFORMER

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Abstract: An accurate electric current transducer is a key component of any power system instrumentation. To measure currents power stations and substations conventionally employ inductive type current transformers with core and windings. With short circuit capabilities of power systems getting larger, and the voltage levels going higher the conventional current transformers becomes more bulky and costly.
It appears that the newly emerged MOCT technology provides a solution for many of the problems by the conventional current transformers. MOCT measures the rotation angle of the plane polarized lights caused by the magnetic field and convert it into a signal of few volts proportional to the magnetic field. Main advantage of an MOCT is that there is no need to break the conductor to enclose the optical path in the current carrying circuit and there is no electromagnetic interference.

***Index Terms* – Current, MOCT, Transducer, Transformer.**

I. INTRODUCTION

For high voltage applications, porcelain insulators and oil-impregnated materials have to be used to produce insulation between the primary bus and the secondary windings. The insulation structure has to be designed carefully to avoid electric field stresses, which could eventually cause insulation breakdown. The electric current path of the primary bus has to be designed properly to minimize the mechanical forces on the primary conductors for through faults. The reliability of conventional high-voltage current transformers have been questioned because of their violent destructive failures which caused fires and impact damage to adjacent apparatus in the switchyards, electric damage to relays, and power service disruptions.

The MOCT measures the electric current by means of Faraday Effect, which was first observed by Michael Faraday 150 years ago. The MOCT measures the rotation angle caused by the magnetic field and converts it into a signal of few volts proportional to the electric currant. It consist of a sensor head located near the current carrying conductor, an electronic signal processing unit and fiber optical cables linking to these two parts. The sensor head consist of only optical component such as fiber optical cables, lenses, polarizer's, glass prisms, mirrors etc. the signal is brought down by fiber optical cables to the signal processing unit and there is no need to use the metallic wires to transfer the signal. Therefore the insulation structure of an MOCT is simpler than that of a conventional current transformer, and there is no risk of fire or explosion by the MOCT. In addition to the insulation benefits, a MOCT is able to provide high immunity to electromagnetic interferences, wider frequency response, large dynamic range and low outputs which are compatible with the inputs of analog to digital converters. They are ideal for the interference between power systems and computer systems. And there is a growing interest in using MOCTs to measure the electric currents.[1]

II. MOCT-PRINCIPLE

The Magneto-Optical current transformer is based on the Faradays effect. Michael Faraday discovered that the orientation of linearly polarized light was rotated under the influence of the magnetic field when the light propagated in a piece of glass, and the rotation angle was proportional to the intensity of the magnetic field. The concept of Faraday Effect could be understood from the Fig.1.

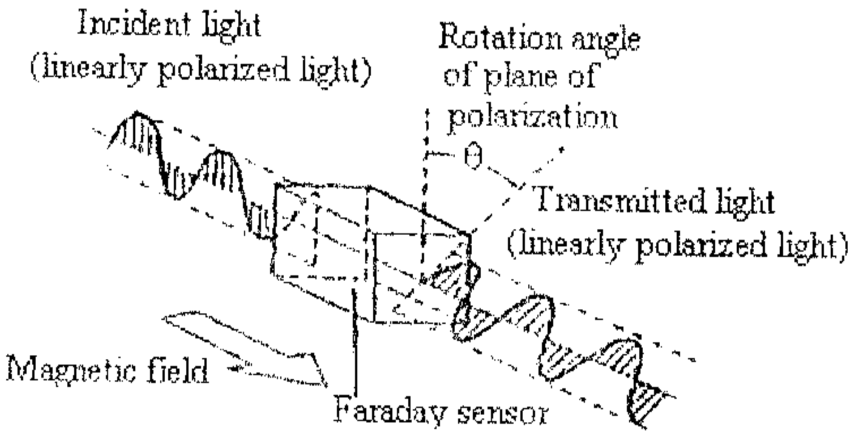

Fig.1: Concept of Faraday Effect

Generally, this phenomenon can be described as follows:

$$\theta = V\,dl \qquad (1)$$

'θ' is the Faraday rotation angle,
'V' is the Verdet constant of magneto-optical material
'B' is the magnetic flux density along the optical path
'l' is the optical path
When the linearly polarized light encircles a current carrying conductor eq(1) can be rewritten as according to Ampere's law as

$$\theta = n\mu VI \qquad (2)$$

'I 'is the current to be measured,
'μ' is the permeability of the material,
'n' is the number of turns of the optical path.
The Faraday effect outlined in (2) is a better format to apply to an MOCT, because the rotation angle in this case is directly related to the enclosed electric current. It rejects the magnetic field signals due to external currents which are normally quite strong in power system.

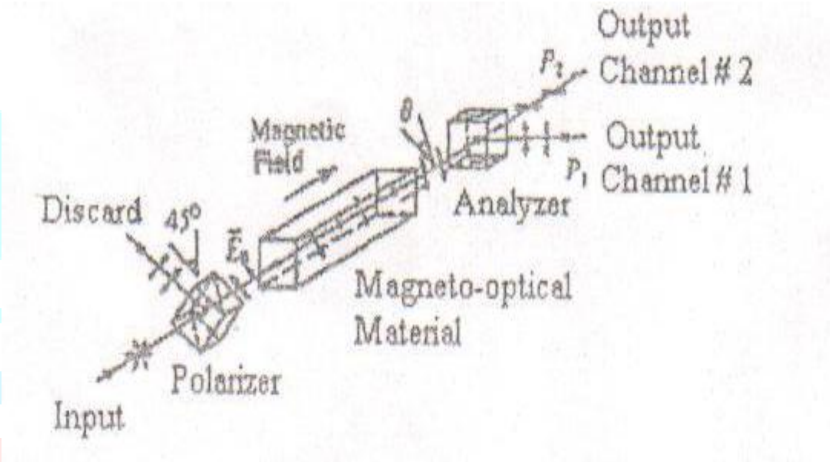

Fig.2: Typical application of Faraday Effect

The typical application of the Faraday effect to an MOCT is clear from Fig.2. A polarizer is used to convert the randomly polarized incident light into linearly polarized light. The orientation of the linearly polarized light rotates an angle θ after the light has passed through the magneto-optical material because of Faraday Effect. Then another polarization prism is used as an analyzer, which is 45degree oriented with the polarizer, to convert the orientation variation of the polarized light into intensity variation of the light with two outputs, and then these two outputs are send to photo detectors. The purpose of using the analyzer is that photo detectors can only detect the intensity of light, rather than the orientation of polarizations. The output optical signals from the analyzer can be described as,
P1 = (1 + Sin 2θ) P0/2
P2 = (1 - Sin 2θ) P0/2
P0 is the optical power from the light source,
θ is the Faraday rotation angle,
P1 and P2 are the optical power delivered by the detectors.

III. DESIGN

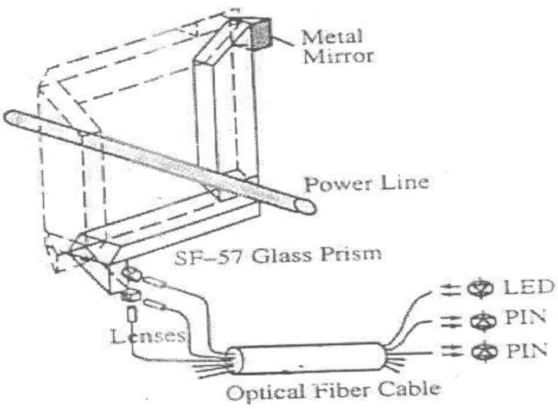

Fig.3: Structure of MOCT

Fig.3 shows the structure of this MOCT. The optical sensor consists of two separate clamp-on parts. In each part of the device, linearly polarized light is arranged to pass through the optical glass prism to pickup the Faraday rotation signal. The polarization compensation technique is applied at each corner of the prisms, so that the light passing through the prism remains linearly polarized. At the other end of the prism, a silver mirror reflects the light beam so that light beam comes back to its sending end via the same route while accumulating the Faraday rotations.[2]

IV. ELECTRONIC CIRCUIT FOR THE MOCT

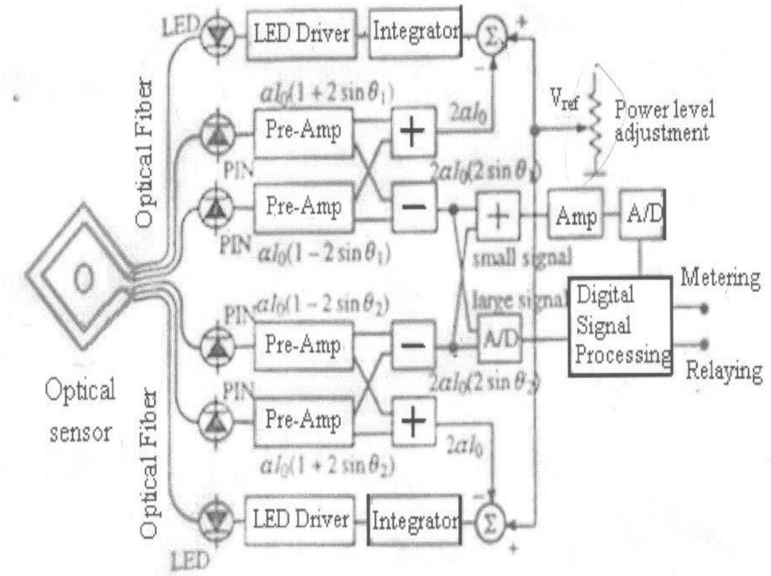

Fig.4: Electronic circuit for the clamp-on MOCT

Fig.4 shows the schematic diagram of the electronic circuit for the clamp-on MOCT. In order to make use of the dynamic range of the digital system as well as the different frequency response requirements of metering and relaying, metering signal (small signal) and relaying signal (large signal) are treated differently. Two output stages have been designed accordingly. One stage, which has 1 KA dynamic range, is for power system current metering, and other stage, which operate up to 20 KA, provides power system current signals for digital relay systems.

In each part of the device, the sum of the two receiving channels signals, which have the same DC bias αI0, differenced at junction with a reference voltage Vref from the power level adjustment potentiometer. Then an integrator is used to adjust the LED driver current to maintain 2αI0 to be the same as the Vref at the junction. Because the reference voltage Vref is the same for both the sides, the DC bias αI0 and the sensitivities 2αI0 of the two halves of the clamp-on MOCT are considered to be stable and identical.

The difference of the two receiving channels signals 2αI0 (2Sinθ1) and 2αI0 (2Sinθ2) in each part of the device are added directly and then fed through an amplifier for the small signals. At the same time these two signals are processed digitally to do a sin-1 calculation on each and then summed together for the large signal situation when the non-linearity of the MOCT can no longer be ignored. The ratio responses of the two output stages of the clamp-on MOCT are designed as 10V/KA and 0.5V/KA and frequency responses are 4KHZ and 40 KHZ respectively.[3]

V. SYSTEM ANALYSIS OF MOCT

The equipment configuration is a current source, adjustable from zero to 4000 amperes, whose output is passed through a precision CT and the MOCT rotator. The output of these two sensors is measured by an instrument package which computes the ratio of the MOCT output with respect to the ct output. This method permits comparison of ratio stability of the MOCT against a known standard. In addition, the ct output is applied to a watt-hour standard.[4]

i. Temperature Characteristics:

The first test was to characterize the rotator output with variation in temperature. The rotator and interface electronics were placed in an environmental chamber that allowed temperature profiles to be run on the system while it was operating, and the effect of temperature measured.

Two temperature effects were studied. First, the change in the MOCT output that could be related to shifts in the steady state operation due to temperature excursions possible in field conditions. This sets the extremes of the temperature range. Second, it was known that temperature induced stress on the optical system could result in short term changes in the output levels: therefore, a study of the effect of rate of change in temperature was important to characterize the system. A typical temperature profile for a test run is obtained. This is considered to be an extreme worst case test condition as it stresses the MOCT system by changing the temperature in a 24 hour period, approximately 10 degrees per hour. Examination of the temperature profiles taken during the field test shows this to be a good assumption for the Tennessee area.[5][6]

	Temperature conditions applied for testing			
	Time in mins.	Air Temp °C		
	0	20		
	10	-30		
	20	-30		
	30	-30		
	40	-20		
	50	-10		
	60	0		
	70	20		
	80	40		
	90	60		
	100	70		
	120	80		
	130	95		
	140	96		
	150	95		

Table1: Testing data gathered

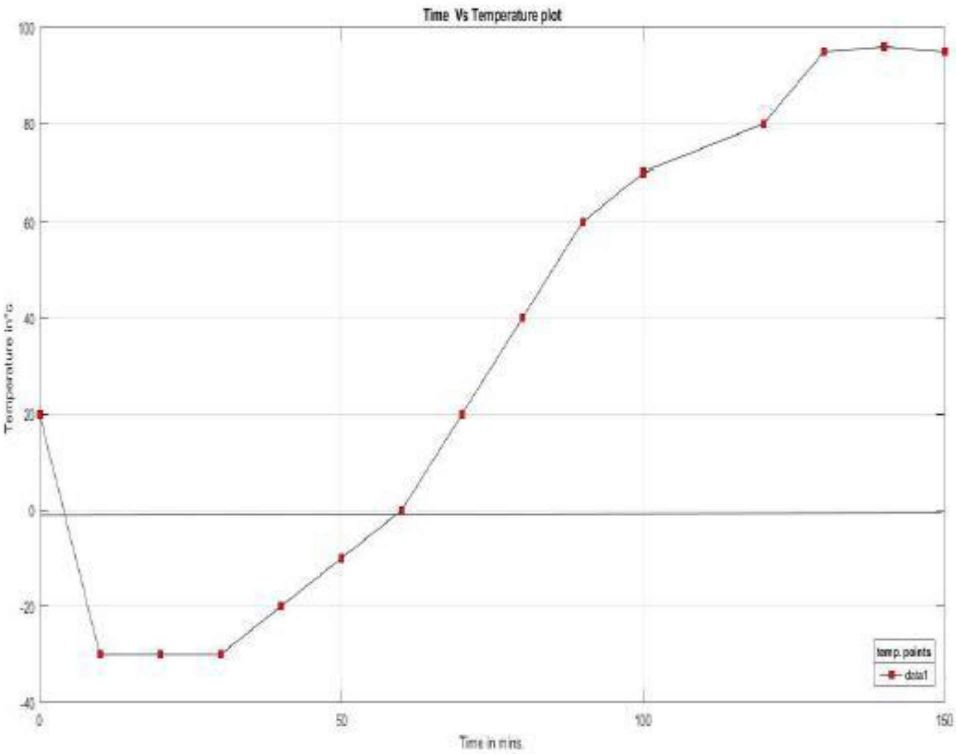

Fig.5: Simulation done on Matlab for temperature vs. time data

VI. APPLICATIONS

The MOCT is designed to operate in a transparent manner with modern electronic meters and digital relays, which have been adopted for a low energy analog signal interface. Typically, the design approach is to redefine the interface point as to input the analog to digital conversion function used by each of these measurement systems.[7][8]

VII. ADVANTAGES AND DISADVANTAGES

Advantages

ii. No risk of fires and explosions.
iii. No need to use metallic wires to transfer the signal and so simpler insulation structure than conventional current transformer.
iv. High immunity to electromagnetic interference.
v. Wide frequency response and larger dynamic range.
vi. Low voltage outputs which are compatible with the inputs of digital to analog converters.

Disadvantages

i. Temperature and stress induced linear birefringence in the sensing material causes error and instability.
ii. The accuracy of MOCT is so far insufficient for the use in power systems.

VIII. CONCLUSION

This paper presents a new kind of current transducer known as magneto optical current transducer. This magneto optical current transducer eliminates many of the drawbacks of the conventional current transformers. In an conventional current transformers, there is a chance of saturation of magnetic field under high current, complicated insulation and cooling structure, a chance of electromagnetic interference etc.

By applying Faraday's principle this transducer provides an easier and more accurate way of current measurement. This MOCT is widely used in power systems and substations nowadays. And a new trend is being introduced, which known as OCP based on adaptive theory, which make use of accuracy in the steady state of the conventional current transformer and the MOCT with no saturation under fault current transients.

IX. FUTURE SCOPE

Market News:

Research focused on the magneto optic current transformer market analysis 2017-2022

This report studies the Magneto Optic Current Transformer market status and outlook of global and major regions, from angles of players, regions, product and end Type/industries; this report analyzes the top players in global and major regions, and splits the Magneto Optic Current Transformer market by product and Type/end industries.

"Global Magneto Optic Current Transformer Market Research Report 2017"elaborates the complete details covering product definition, product type, and application. The report covers useful details which are categorized based on Magneto Optic Current Transformer production region, major players, and product type which will provide a simplified view of the Magneto Optic Current Transformer industry.

The Magneto Optic Current Transformer market report presents the competitive scenario of the major market players based on the sales revenue, customer demands, company profile, the business tactics used in Magneto Optic Current Transformer market which will help the emerging market segments in making vital business decisions.

Benefits of Global Magneto Optic Current Transformer Market report:

The Magneto Optic Current Transformer report helps identify the biggest opportunities in Magneto Optic Current Transformer industry space and offers accurate latent demand forecasting that empowers quantitative decision making among Magneto Optic Current Transformer market players and new entrants. Investors will gain a clear insight on the dominant players in Magneto Optic Current Transformer industry and their future forecasts. Furthermore, readers will get a clear perspective on the high demand and the unmet needs of consumers that will enhance.

REFERENCES

[1]. IEEE Transactions on Power Delivery, Vol. 5, No. 2, April 1990, Paul Johnston [2].Westinghouse Electric Corporation Raleigh, North Carolina.

[3]. S. Saito, J. Yamasaki, Y. Fuji, K. Yokoyama, and Y. Ohio, "Development of the laser current transformer for extra high-voltage power transmission lines', IEEE J. Quant. Elec., vol QE-3, pp. 569-597, Nov. 1967.

[4]. A.J. Rogers, "Method for the simultaneous measurement of current and voltage on high-voltage lines using optical techniques," Proc. lee, Vol. 123, pp. 957-960, Oct. 1976.

[5]. S.C. Rashleigh and R. Ulrich, "Magneto-optic current sensing with bi fringing fibres', Appl. Phys. Lett., vol. 34, pp. 766-770, June 1979.

[6]. D.C. Erickson, "The use of fibre optics for communications, measurement, and control within high voltage substations,' IEEE Trans. on Pwr. Appr. and Syst., vol. PAS-99, pp. 1057-1065, May/June 1980.

[7]. R.H. Stolen and E.H. Turner, "Faraday rotation in highly birefringent fibers", Appl. Opt., vol. 19, pp. 842-845. 15 March 1960.

[8]. G.w. Day, D.N. Payne, A.J. Barlow, and J.J. Ramskov Hanson, "Faraday rotation in coiled, monomode optical fibers: Isolators, filters, and magnetic sensors', Opt. Lett., vol. 7, pp. 238-240, May 1982.