A REVIEW: MAGNETO-OPTICAL CURRENT TRANSFORMER FOR ELECTRICAL SYSTEM

Manoj Kumar, B.Tech, Department of Electrical and Electronics Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India
Revanth Kumar, B.Tech, Department of Electrical and Electronics Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India
Bala Jee, B.Tech, Department of Electrical and Electronics Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India
P.K.Dhal, Professor, Department of Electrical and Electronics Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India

Abstract:
This paper is investigated a current transformer with a core and winding to detect current. Traditional current transformers have gotten bulkier as a result of their increased short circuit capabilities and greater voltage levels, and their durability has been questioned because of their failures that result in fire and component damage from impacts. Therefore, we need new measurement technology that is reliable and accurate. The MOCT was developed to provide assistance with the aforementioned problem. A MOCT is an optical network current transducer that uses light to correctly measure rotation angle, detect current on high voltage systems, and provide a signal that is proportional to current. Variations in the operating wavelength, as well as faults in the optical axis' intersecting angle with the polarizer and analyzer, may have an effect on MOCT output. In the electricity business, MOCT provides total separation of energy and signal distribution. The essential variable in the majority of MOCTs that have been built is the polarization angle of light.
Key words: MOCT, faraday effect, polarization, transformer

I. INTRODUCTION

CT & PT are two of a high voltage substation's most crucial part. Voltage and current samples are taken for use in measurement and safety. For high voltage applications, porcelain insulators and oil-soaked materials must be used to generate insulation between the primary bus and the secondary windings. The insulating structure must be carefully constructed to avoid eventual collapse owing to electric field forces. The adoption of electromagnetic field-resistant signal transmission is an obvious solution to the issues. The magnetic field's rotation angle is detected by MOCT, which converts it into a signal of a few volts inversely proportionate to the electric current. The signal may be sent without the need of metallic cables. As a result, the insulating structure of a MOCT is less complex than that of a typical current transformer, and a MOCT poses no risk of fire or explosion. A MOCT can provide good protection against electromagnetic interference and increased frequency responsiveness in addition to the insulating effect. Low voltage outputs with a wide dynamic range that operate with the inputs of analogue to digital converters. They are suitable for reducing disturbance between electrical and computer systems. Variations in the operating wavelength, as well as faults in the optical axis' intersecting angle with the polarizer and analyzer, may have an effect on MOCT output.

II. LITERATURE SURVEY

The angle of light polarization is the most significant MOCT characteristic to date, according to Yuri S. Didosyan (2000) [1]. The measurements are non-contact, and a light beam transmits the signal across optical fibers. Measurement errors occur from ferromagnet’s substantially higher Faraday rotation value, which depends on the crystal's temperature. Temperature fluctuations in Faraday rotation, interruptions, and variations in the incoming beam have no direct influence on the measurement findings. According to Sulthan Mohyuddin (2018) [2], electric current transducers are an integral component of any power system instrumentation. Inductive type current transformers are commonly used to measure current in power plants and substations. As a result, MOCT technology provides a solution to many of the problems associated with standard current transformers. The Faraday Effect is employed by the MOCT to detect electric current. According to Jinwei Li's (2013), recommendation, the necessary power system metrics must be assessed in order to ensure the economic functioning of the power system's security. Variations in the operating wavelength and faults in the optical axis' intersecting angle with the polarizer and analyzer may have an effect on the MOCT's output. The operating wavelength of the light source and the incorrect intersecting angle of the optical axis are two critical parameters that impact the accuracy of MOCT measurements [3]. Magneto photonic current transformers are becoming more common in power systems, according to Sadik Kucuksari (2010) [4]. MOCTs outperform other conventional transformers in terms of steady-state, frequency response, and transient response, as well as the influence of ambient temperature, proving that MOCTs can replace other traditional instrument transformers. Field record, experimental, and laboratory values, as well as error, are all assessed. T. Bosselmann (1994) [5] proposed that utilizing optical current sensors in MOCT that take use of the Faraday effect has substantial advantages. In the electricity business, MOCT provides total separation of energy and signal distribution. Cross sensitivity to temperature and vibration may severely limit the technology's real applicability. The current sensitivity is temperature dependent due to inevitable residual linear fibrinogen in the Faraday medium and can be rectified by an external temperature measurement at the sensor head. This temperature dependency is often decreased by an external temperature sensitive Verdet constant. MOCTs, according to T.Sawa (1990) have grown so common that it is believed that they would be able to fulfil the rising needs for increased performance and reliability as power facilities evolve toward higher voltages, bigger capacities, more compactness, control, and protective systems. MOCT, on the other hand, has several advantages, including the use of light for signal transmission, which enhances electrical insulation, the reduction of electromagnetic noise, the rationalization of electrical insulation, and the extension of frequency band dynamic ranges [6]. To reduce these consequences, Ziorelys Araujo (2012) advises strengthening the current transformers that feed the power measuring devices and safety equipment. MOCT has minimal transformation losses since no ferromagnetic materials were used in its development, which mitigates the effects of nonlinearity and magnet interference [7]. When transitory events occur, MOCT acts normally, considerably lowering the harmonic content of such occurrences. According to Li Xiaoming, transformers are critical equipment for electric energy monitoring and relay protection (2012) [8]. Two variables influence MOCT measurement accuracy: the operating wavelength of the light source and the intersecting angle error of the optical axis. The intersecting angle inaccuracy of the optical axis causes direct current and attenuation, which affects MOCT measurement accuracy. T.W.Cease [9] detailed the development of an optical voltage sensor as a component of an entirely optical sensor-based revenue metering system in 1991. The magneto optic or Faraday effect was used to develop a magneto optic voltage transducer (MOVT). The use of the magneto optic effect in the design of the voltage sensors allows for the creation of a revenue metering system using just optical sensors. Straight light path type OCTs offer high reliability and easy optical paths, according to Xiao Zhihong (2016) however they are subject to interference from the external magnetic field [10]. The investigation demonstrates that the interference magnetic field works by either changing the sensing coefficient of the straight light path type OCT or by changing the target magnetic field and increasing the magnetic resistance qualities of the straight light path type OCT. According to M. Takahashi, high precision and cost savings are just two advantages of utilizing an optical current transformer (2003) [11]. The optical CT has demonstrated its capabilities, particularly in the case of a digitally controlled substation, by assuring insulation performance and being free of network damage caused by di-electric air insulated switchgear. Kurosawa (2005) discussed the evolution of optical current sensors and presented examples of their applications. The optical current sensors based on the Faraday Effect were expected to replace standard current transformers in long lines with compact, high-performance current sensors. The sensors developed are tiny, flexible, and easy to connect to the current conductor [12]. They are also robust to external environmental influences like as vibration and temperature variations. F. Rahmatian discussed optical current and voltage sensor applications in 2006. Because of their broad bandwidth, linearity, high precision, and low weight, these

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sensors are suited for a wide range of applications such as capacitor bank imbalance protection, regular protection applications, and high-accuracy wide dynamic range revenue metering [13]. Because of their low weight and ease of deployment, both the flexible-head optical CT and the optical VT are suitable portable calibration systems for live in-situ calibration and monitoring applications.

III. COMPARISION ANALYSIS OF LITERATURE SURVEY

Author name	Work done	Work not done
[1].Yuri S.Disodyan	The novel sensor's working principle in an ortho-ferrite plate and rotational temperature characteristics in an optical fibre	A transducer is used to measure current. Faraday rotation angle does not function. MOCT steady-state and transient response.
[2]. Sulthan Mohyuddin	Temperature characteristics was studied about the rotator output with variation in temperature	There are no OCPs with adaptive theory that employ accuracy in the steady state and transient responsiveness of MOCT.
[3].Jinwei Li	The wavelength of the light source and the angle error of the photic axis are investigated.	The rotation angle of a magnetic field is converted into a corresponding electric field.
[4].Sadik Kucuksari	The MOCT and conventional CT steady-state and transient responses were examined and compared.	The output of the rotator fluctuates with temperature, and stress-induced linear fibrinogen in the sensing material causes inaccuracy and instability.
[5]. T Bosselmann	The intrinsic temperature measurement increased the accuracy of a MOCT by signal analysis and rectification.	The MOCT and traditional CT tests' steady-state and transient responses, as well as their comparability.
[6]. T. Sawa	The prototype was created, tested, and computed in terms of ratio error, phase displacement, and transient characteristics.	The wavelength of the light source and the angle error of the photic axis are not investigated.
[7]. Ziorelys Araujo	MOCT reacts in presence of transitory event resulted in decrease in harmonic content connected with them	No ferromagnetic material used in the construction.
[8]. Li Xiaoming	Angle error of optical axis will lead to attenuation which effect accuracy of MOCT measurement	Principle of operation of the new sensor in ortho-ferrite plate and temperature characteristics.
[9].T.W.Cease	Development of a revenue metering system through the design and use of optical sensors that use the magneto optic effect	The orthoferrite plate system was not employed for the optical sensor. The topic of fire and explosion is being studied.

[10]. Xiao Zhihong	For analyzing sensing characteristics &functional mechanism Jones matrix was established	Temperature parameters of the rotator output with temperature fluctuation were not investigated.
[11]. M.Takahashi	Faraday effect-based DC current measurement through reflection Sagnac-interferometer	Types that change There is no magnetic field-based current measurement.
[12]. Kurosawa	A flint glass that is resistant to vibration and temperature fluctuations was created.	MOCT steady-state and transient response data are not available. MOCT accuracy is insufficient for usage in power systems.
[13]. F.Rahmatian	Because the OCT's head is flexible, it is an excellent tool for calibration and monitoring applications.	A flint glass system, which is affected by vibration and temperature fluctuations, was not created. Material sensing generates inaccuracy and instability.

IV. MAIN OBJECTIVE OF MAGNETO-OPTICAL CURRENT TRANSFORMER IN ELECTRICAL SYSTEM

- The device can run on a current source that can be adjusted from 0A to 4000A.
- MOCT measures the magnetic field-induced rotation angle and converts it to a few volts proportionate to current.
- The glass prism employed in this instance is crucial for polarization. Faraday first found this effect in (1846).
- It can run at low temperatures of -50°C and below and has no impact on global warming or ozone depletion.

V. DETAIL DESCRIPTION OF MAGNETO-OPTICAL CURRENT TRANSFORMER

Fig1: Magneto Optical Current transformer 3D view

It has three categories

a) Primary Sensing Head

b) Polymer insulator column

c) Secondary Transformer

A. Magneto Optical sensor

- The sensor head is made up of optical components such as fibre optic cables, lenses, polarizers, glass prisms, and mirrors.
- The glass prism is made up of SF-57 as it has larger Verdet constant. [Another material is also used known as SF6 due to its low temperature dependency.
- Polarizer used here is to produce linearly plane polarized light. Analyzer is used to decide whether the light is plane polarized or not and another polarizer prism used as an analyzer which measure light beam into corresponding amount of light intensity.
- Fibre optic cable is made up of very thin strands of glass or plastic that use light-based technologies to transmit data. We employ multi-mode optical fibre in this application because of its capacity to collect light and simplify connections.

B. Electronic Circuit

- In this part it contains LED, Amplifier, Analog to Digital converter, Power level adjustment, Digital signal processing, Output channel for metering and relay.

Table 1: Faraday rotation for some common material

	SF-57	SF6	BK-7	SiO2
Refractive index	1.847	1.805	1.517	1.458
Maximum operating temperature(K)	414	605	557	1000
Co-efficient of thermal expansion	8.3	9	7.1	0.55
Density	5.51	3.37	2.46	2.2

VI. BLOCK DIAGRAM OF MAGNETO OPTICAL CURRENT TRANSFORMER

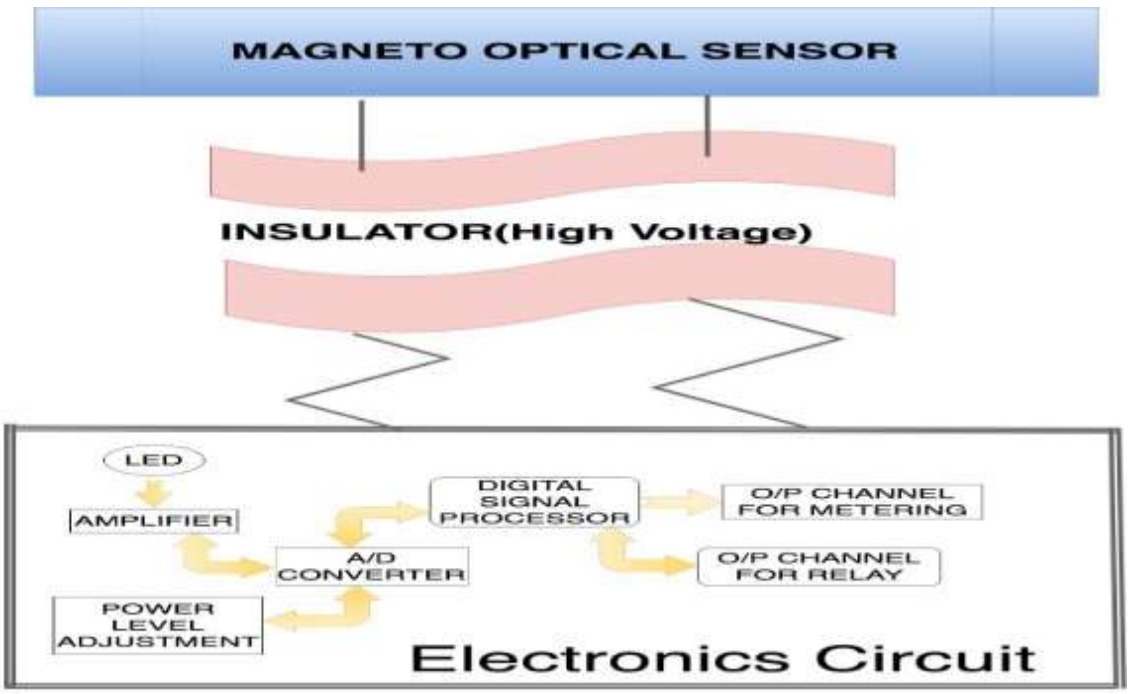

Fig2: Block Diagram of MOCT

VII. DIMENSION DETAILS

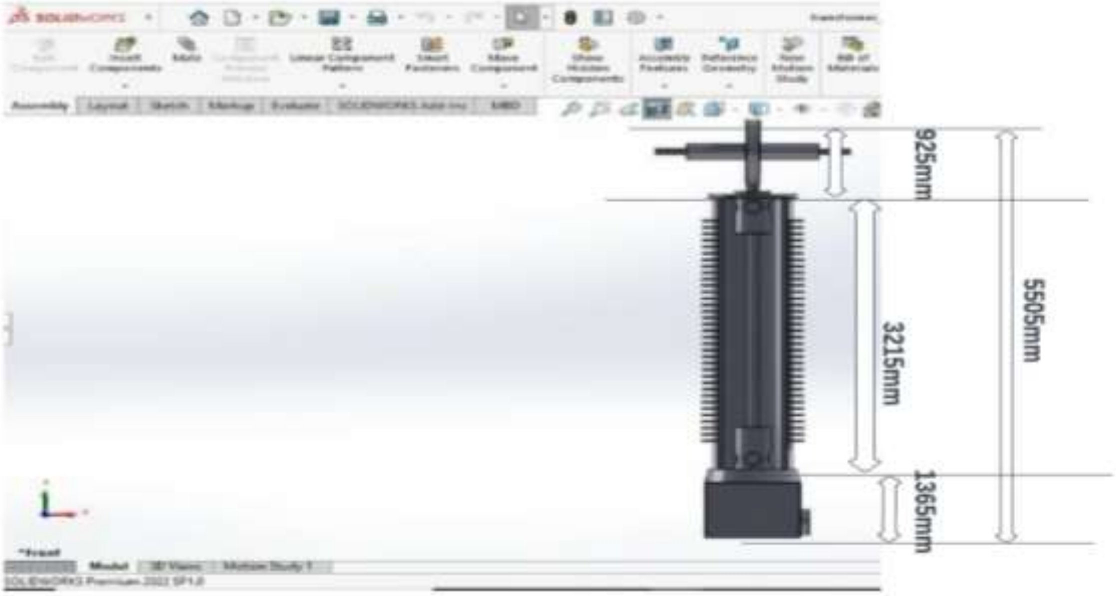

Fig 3(a): Front view of MOCT

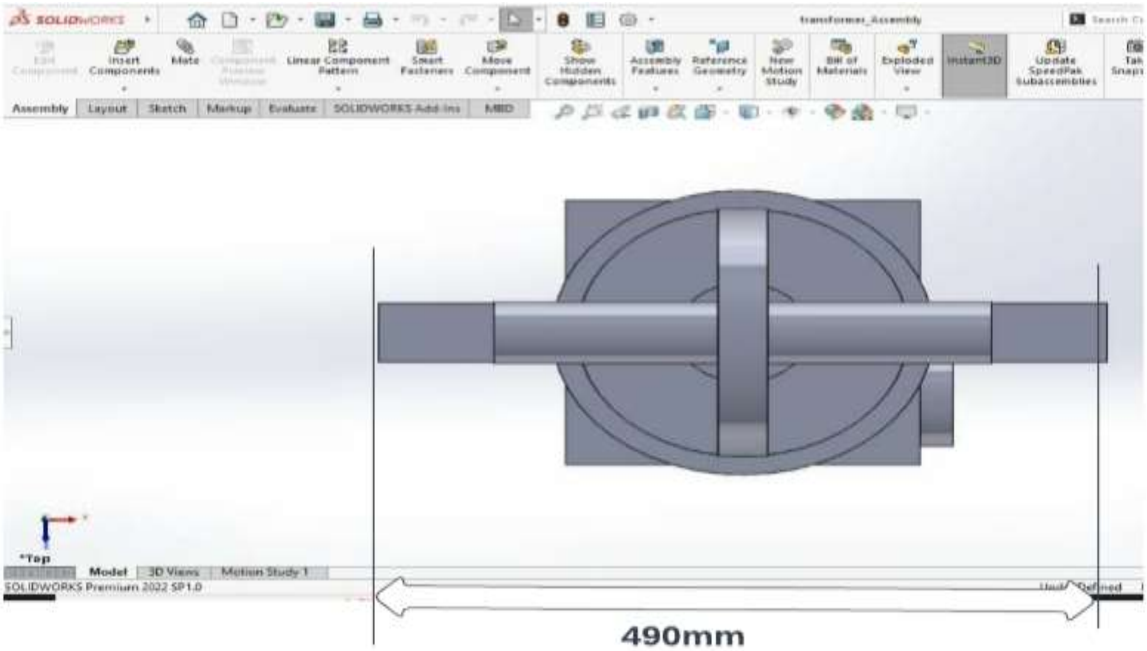

Fig 3(b): Top view of MOCT

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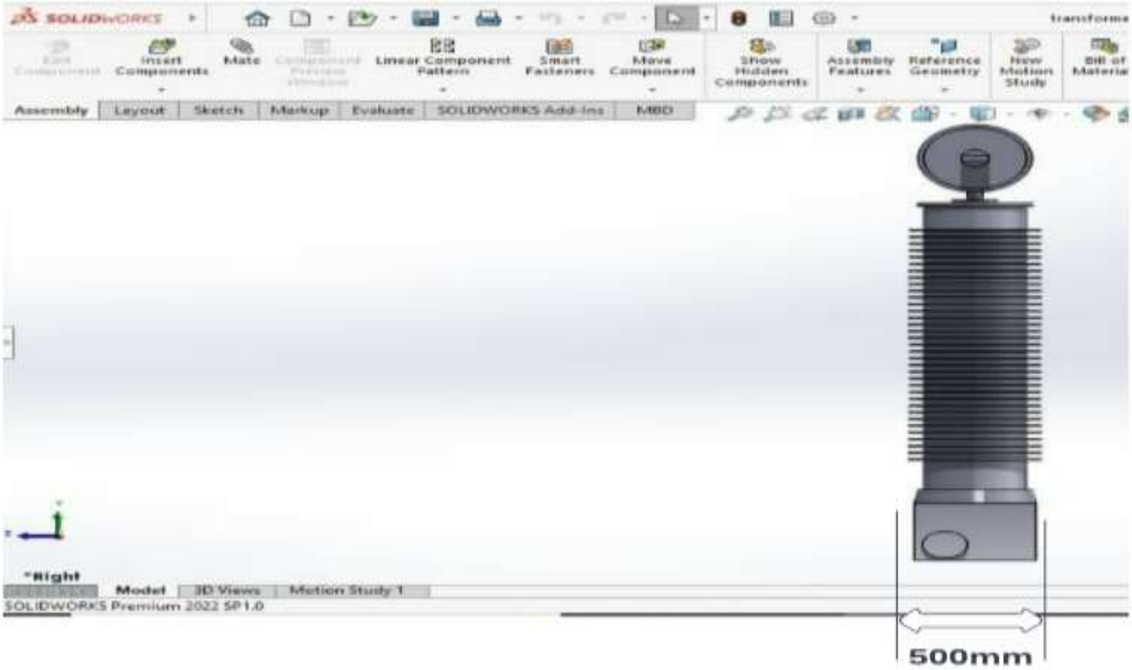

Fig 3(c): Right view of MOCT

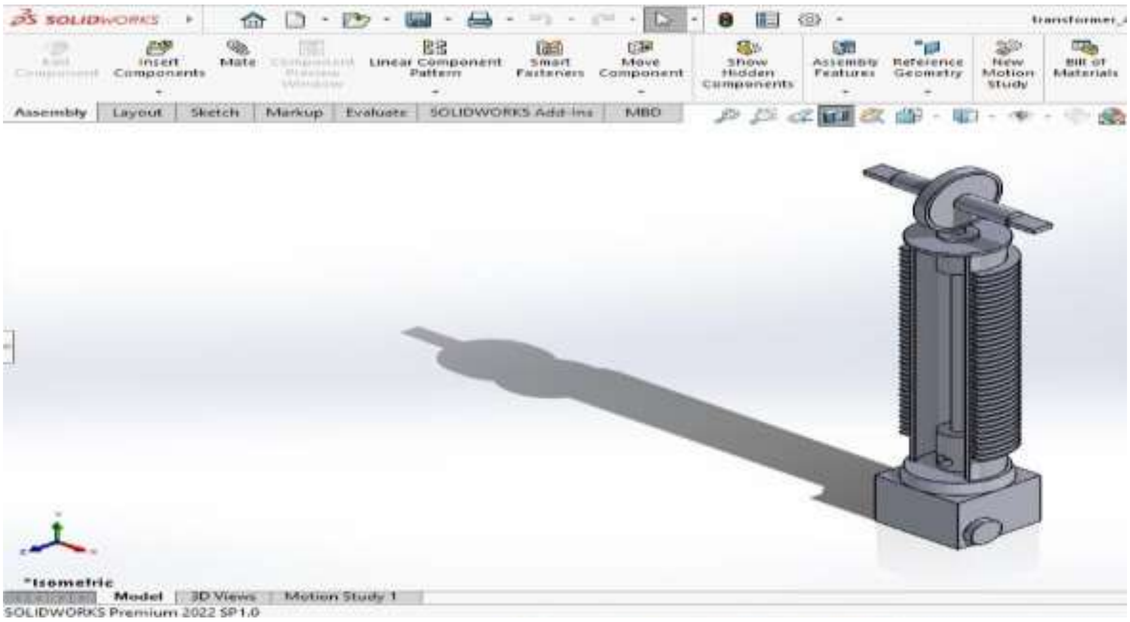

Fig 3(d): Isometric view of MOCT

VIII. RESULT ANALYSIS AND DISCUSSION

The Faraday Principle is employed to power the Magneto-Optical Current Transformer. It depicts the rotation of light's polarization as it propagates in the direction of the magnetic field. When a light beam passes through a material, the polarization of the light is rotated by the angle depending on the intensity of the magnetic field parallel to the light.

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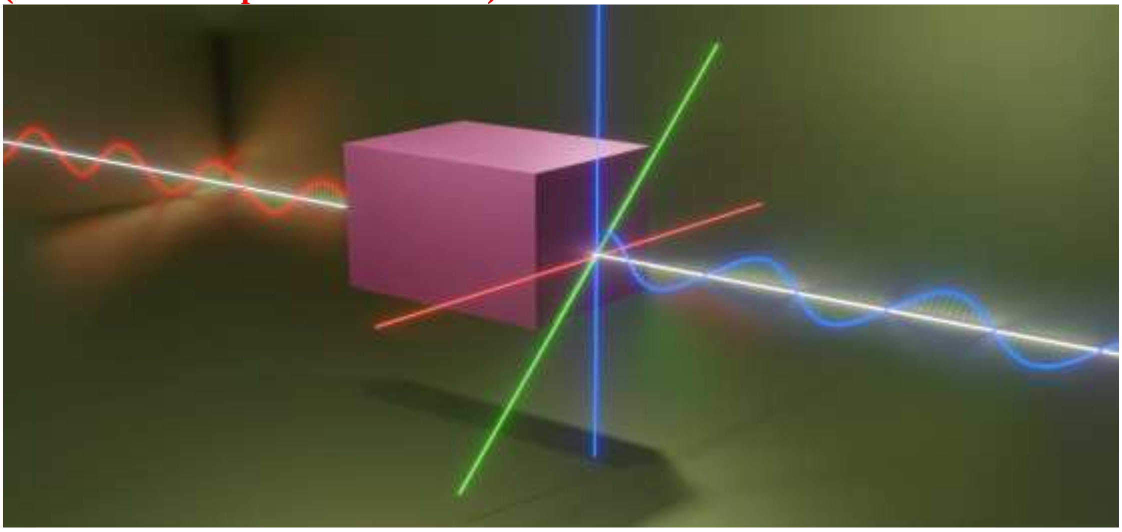

Fig 4: Concept of Faraday effect (3D Model)

The Faraday phenomenon is related to the materials magnetic.

$\Theta = \int k M dl$

'θ' is the faraday rotation angle,

'dl' is the optical path in the magnetic optical material,

'M' is the magnetization,

'k' is the constant.

The magnetization and polarization rotation of paramagnetic and diamagnetic materials are virtually proportional to the magnetic field intensity. The rotation may therefore be characterized using the magnetic field strength H and the Verdet constant V, as shown in the equation below.

$\theta = \int V H dl$

where 'V' is the specific rotation of the material and is defined over

$V = \mu . \theta/(B.l)$

V is obtained by the magnetic properties of the material. B is the component of the magnetic flux density parallel to the light propagation direction.

According to Ampere's rule, when linearly polarized light encircles a current carrying conductor.

$\theta = n\mu VI$

'n' is the number of turns of the optical path

'μ' is the permeability of the material,

'I 'is the current to be measured

Because the spinning direction is related to the contained current, the preceding equation provides an excellent framework for using a MOCT. It excludes magnetic field signals due to external current. he polarization prism analyzer converts the polarized light orientation variation into intensity variation with two outputs. Photo detectors sense light intensity rather than polarization orientation.

$P1 = (1 + \sin 2\theta) P0/2$

$P2 = (1 - \sin 2\theta) P0/2$

'P0 'is the optical power from the light source,

'P1','P2' are the optical power by the detectors.

A. *Advantages of MOCT*

- No risk of fire and explosion.
- High immunity to electromagnetic interference.
- They can withstand high mechanical load.
- Lack of magnetic saturation. Due to Lack of core, there is no saturation which solves many protection and measurement problems
- There is no need for metallic wires to convey the signal, resulting in a simpler insulating construction than a standard current transformer.

B. Disadvantages of MOCT

- Error and instability are caused by temperature and stress-induced linear birefringence in the sensing material.
- MOCT accuracy is currently insufficient for usage in power systems.

IX. CONCLUSION

This article demonstrates the Magneto Optical Current Transformer, a new type of current transformer that addresses many of the shortcomings of existing transformers. MOCT stands for passive optical current transducer, and it employs light to precisely measure current on high voltage systems, as well as to identify the rotation angle and transform it into a signal of a few volts proportionate to the current. Using the MOCT working principle, the influence of the operating wavelength and intersecting angle between the polarizer and analyzer optical axes on the MOCT output signal is examined. Using Faraday's principle, this transducer makes measuring current easier and more precise. MOCTs are appropriate for power system protection and may be used in factories and substations to replace standard transformers. They also have the distinct benefit of being easy to install, making them more suitable for field use.

FUTURE SCOPE

Magneto Optical Current Transformer Outlook (2022-2032)-Future Market Insight

The report previews the global **MOCT market**, which is valued at ***US$ 232.4 million*** as on 2022, is expected to be evaluated at around ***US$ 563.6 million*** in 2032 and grow at a *CAGR* of *9.3%* through 2032.The report analyses rapid advancements in the field of Electrical and Electronics technology, growing demand for electricity across sectors, and many more factors have led to upsurge of **MOCT market**.

Global Magneto Optical Current Transformer Market Analysis (2028)-The Insight Partners

This study goes into detail on a specialised and in-depth study of the electronics and semiconductor industries, with a particular emphasis on worldwide market trend analysis. The report's goal is to give an overview of the MOCT market, as well as complete market segmentation based on type, application, and geography. During the projected period, the worldwide MOCT transformer market is predicted to rise rapidly. The report includes important information on the market position of the main MOCT industry players, as well as key market trends and opportunities.

Magneto Optical Current Transformer Market-Allied Market Research

The research offers a detailed analytical picture of the worldwide MOCT market share, as well as current trends and future projections to identify potential investment areas. This research provides important information on the primary drivers, restrictions, and possibilities. The present market is quantitatively examined from 2019 to 2026 in order to demonstrate the industry's financial competency. Investors will obtain a thorough understanding of the major companies in the MOCT sector as well as their future projections. Furthermore, readers will gain a clear understanding of the high demand and unmet consumer needs that will increase.

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