VIBRATION SENSOR FOR HEALTH MONITORING OF ELECTRICAL MACHINES IN POWER STATION

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Abstarct:
Vibration monitoring in high power electric machines, such as generators and transformers, presents some difficulties due to the insulation and EM immunity requirements .However, the negative influence of the electromagnetic interference (EMI) can be a real problem when electrical signals are used to detect and transmit physical parameters in noisy environments such as electric power generator plants with high levels of EMI. Such problems can be solved using optical fiber sensors, which allow *in situ* measurements and remote control without electrical wires. The present paper describes a novel fiber optic vibration sensor for health monitoring of electrical machines, which utilizes relatively simple technologies and offers moderate costs. The sensor is optimized for detection of mechanical vibrations in the frequency range 20-100 Hz. Design details and experimental results are reported.

Keywords: Optical fiber, Optical to electrical converter, frequency multiplier**.**

1. Introduction

Condition monitoring of heavy electromechanical equipment is commonly accomplished in the industry using vibration analysis. The new technologies, combined with advances in optical transducers, have enabled remote vibration monitoring using compact portable instrument packages in highly localized parts of electrical machinery with inherent electrical isolation, superior dielectric properties, and immunity to electromagnetic interference [Medlock,R. (1989) and Demjanenko'et al'(1992)]. In addition, optical fiber sensors can offer noncontact, perturbation-free means of monitoring as they provide a new approach to vibration monitoring in electromechanical equipment. The above features, along with compactness and reliability, counterbalance the more complex technologies and higher costs of traditional piezoelectric sensors.

There have been many techniques, mainly based on capacitive and piezoelectric accelerometers, applied for predictive maintenance. Some different types of fiber optic sensor have been proposed based on laser Doppler velocimetry [Kyuma(1981)], microbendings [Miers 'et all'(1987)], gratings [Udd. and Turek(1985)] and photoelastic effects[Yoshinaga(1986)].The present paper describes a novel fiber optic vibration sensor which utilizes relatively simple technologies and offers moderate costs[Binu et al.(2007)] . Noncontact dynamic displacement sensors are commonly used for vibration detection. A reflective scheme is used to detect vibrations where one fiber is used as an emitter source and one or more fibers are used as collectors [Yoany 'et al'(2010)].The sensor, designed for a remote applications in a high power electric machines, makes it possible to operate on variable frequency in the range of even few hertz . However, although intensity-based fiber optic sensors are easy to build, a significant error can be introduced due to changes in the light source power. Optical fiber is generally defined on the basis of electrical power. Absolute optical power, in Mw or dbm and is a key parameter for all optical sources.The characteristics of the state of the art optical power meters is as follows:

- ±2% uncertainty at calibration conditions
- ±3% to 5% uncertainty at operating conditions
- ±0.5% non-linearity for a power range of 50db or more,
- An approximate power range -90 to 0dbm(attenuation needed for higher power measurement)

2. Experimental Set-up

2.1. Sensor working principle

An enclosed holder made up of aluminum is used to hold the mirror which has been used as a reflecting diaphragm. A simple mirror was used for this purpose. This mirror was fixed over a surface mounted on the plunger inside the holder. A holder for the fiber was fixed over the mirror holder. In the fiber holder, a hole of the same dimension as a bifurcated fiber diameter was made. One fiber acts as input fiber and was connected to output of the optical power meter. This fiber was used to direct the light on the mirror. The other fiber acting as an output fiber was connected to the input of the optical power meter. Noncontact dynamic displacement sensors are commonly used for vibration detection. A reflective scheme is used to detect vibrations where one fiber is used as an emitter source and one or more fibers are used as collectors shown in fig 1. The reflection from the surrounding surfaces near the target can be minimized using data treatment techniques [Vento(1999), Perrone (2009)].

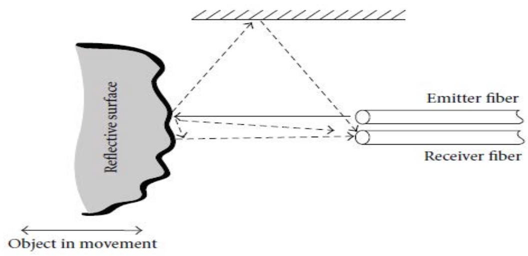


Fig1. Configuration of dynamic intensity based vibration sensor

2.2. Sensor Design and Construction

The fiber probe was fixed over the mirror holder keeping the mirror and the fiber tip at the distance till where the power changes recorded by the optical power meter were the maximum.

This maximum distance was determined by clamping the fiber probe on to a holder fixed to a Vernier Calliper's movable Vernier scale shown in fig.2 The mirror was kept stationary on the base and the distance between the fiber probe and the mirror was varied by the movement of the fiber probe. It was observed that after a particular distance, the power changes as recorded by the optical power meter did not change appreciably. This distance was noted down as the maximum critical distance. Any vibration which could deflect the mirror up to this distance could be measured. The variations of the distance measured in above experiment are given in graph1. It can be seen that as the relative distance between the mirror and the fiber probe decreases, the power measured increases.

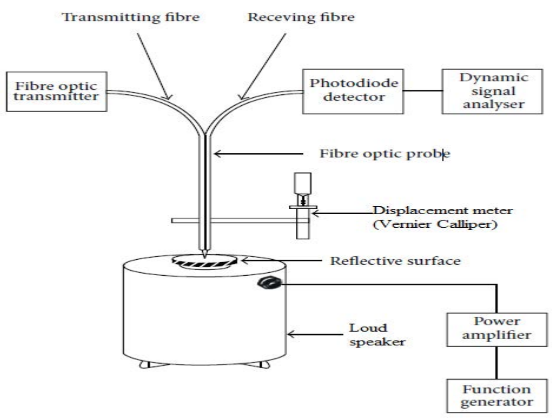
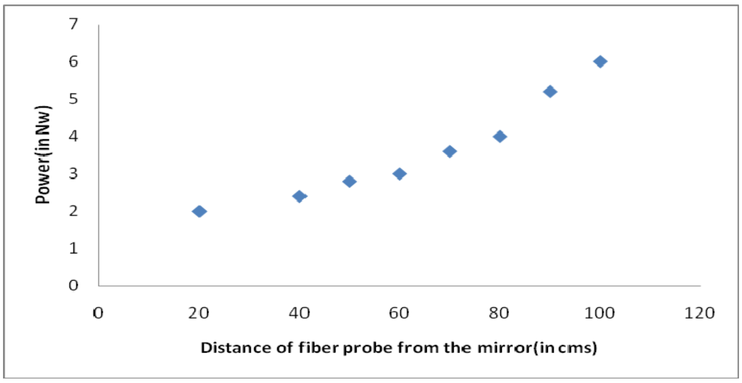
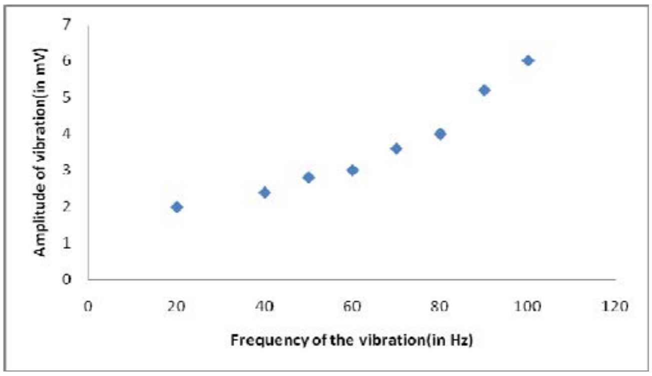


Fig.2 Schematic set up of fiber optic vibration sensor for the measurement of distance of fiber probe from the reflective surface



Graph 1 Results from vernier caliper and power meter

By using these results, vibrations of a loud speaker were measured. The speaker input was from signal generator and frequency was varied to obtain different levels of vibration of the speaker. The vibration sensor was clamped on to the speaker and one fiber of the bifurcated fiber was connected to an optical Power meter, the Led of which formed the light source. The light after reflection from the mirror entered the second fiber which was connected to an optical to electrical converter. The output of the O/E converter was given to CRO where the waveform of the output vibration amplitude and frequency was obtained. The readings of the vibration amplitude and the frequency are given in graph2



Graph2 Results of the vibration measurement of the vibration diaphragm

The speaker used was an 8 Ohm, frequency used was 100Hz and was varied with a frequency multiplier. It was observed that with reduction of frequency the amplitude of vibration also gets reduced resulting into smooth vibrations. It was observed that the quantity of light absorbed and transmitted was considerably improved by using a plastic fiber of greater thickness and the incident power on the fiber was improved to 30db by the use of multimode plastic fiber of 1mm diameter in place of silica fiber of thickness 80/125 microns.

Conclusion:

The sensor was designed to work for applications in high power electrical plants where insulation and EM immunity requirements make fiber optic sensing the most suitable choice. A fiber optic sensor is developed to measure the vibrating body's vibrations and if their amplitude and frequency exceeds the safe operating level, the machine is not operated. The sensitivity of this sensor can be increased by reducing its weight and making the deflecting diaphragm-spring system more flexible as suited to the requirements of the particular machinery. The sensor will find its applications in checking the vibrations of the heavy shafts over which stator rotors are fixed, of heavy electrical motors and generators, and of other electrical appliances. Another advantage of this vibration sensor is that it can be used in condition monitoring of machines in areas far away from the operator as use of optical fiber can transmit the output signal without any loss irrespective of the distance between the machine and the operator. In this way the machine can be saved from failure due to excessive vibrations.

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