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High Pressure Turbine Casing Expansion Measurements in Thermal Power Stations Using Smart Sensor

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Abstract:
The high pressure steam generated in thermal plant is forced to the high pressure turbine with high temperature which results in the expansion of its casing. Currently this measured by using Linear Variable Differential Transformer (LVDT), which is a contact type device. Due to the high temperature in HP turbine the heat is transferred to the LVDT which cannot sustain and causes it to fail. Instead Ultrasonic sensor which is a non-contact type controlled by microprocessor can be employed. The main advantage of this sensor is that it can sustain very high temperature and has accuracy in any kind of operating condition. It also reduces the conduction losses. This sensor is cost efficient when compared to LVDT. Thus, by using microprocessor module we can pre-set a value for alert system. Thus, when the determined value is in excess of the pre-set value the buzzer initiates an alarm and when the determined value exceeds the critical preset value this module provides a trip signal which stops the further ongoing process.

Keywords: *casing expansion, LVDT, ultrasonic sensor, microprocessor, cost effective.*

I. Introduction

In thermal power stations heat energy is converted to electric power and this output is diverted to various applications. Globally, majority of the turbines used are driven by steam. An electric generator is steam driven by a steam turbine, by using the steam generated by heating the water. It follows the Rankine cycle, in which the steam is passed through the turbine, and it gets condensed in a condenser and then recycled to where it was heated. Globally every thermal power station is installed in a variety of ways and have different designs based on the different heat sources among which the fossil fuel dominates; although solar and nuclear energies are also utilized. The term energy center is most frequently used as they are used to generate electrical energy from the developed heat energy. In general, thermal power stations are designed to generate energy for specific purposes like industrial usage, water desalination, etc. in addition to generating electrical power.

The majority of such thermal power station has its energy efficiency ranging from 33% to 48%. In general, heat engines are governed by the thermodynamics laws and they have limited efficiency. The power stations have different efficiency limitations with respect to its type and design. The majority of such stations in the United States are about 90% efficient in the process of converting the generated energy from water into electricity while 59.3% is the efficiency of a wind turbine. The energy from the thermal power station that are not put into effective usage in power production is ejected the environment in the form of heat. In thermal plant, the high pressure steam generated is forced to the high pressure turbine with high temperature which causes its casing to expand and is measured by using LVDT, which is a contact type device. Due to the high temperature in hp turbine the heat is transferred to the LVDT which cannot sustain and causes it to fail. To overcome the disadvantages of LVDT, a non contact type measurement made by ultrasonic sensor can be employed which in turn is controlled by microprocessor.

The sections are arranged as follows: in section II various techniques and the related works and techniques that are already in use are discussed. Section III deals with the existing system and its drawbacks. Section IV explains the proposed system. The section V elaborates the conclusion.

II. RELATED WORKS

The following is the related works found in the literature. [1] Discusses about the complete structure of a steam turbine used in thermal power stations and the advantages of using steam turbines. Hence startup flexibility of steam turbines can be improved by analyzing their dynamic thermal behaviour. In [2], during cold-start conditions, expansion between rotor and casing was examined which is a prime parameter to examine the startup conditions and to avoid rubbing by controlling the space between rotating and stationary components. The examination was conducted with a turbine thermal simplified model. The initial step during the inspection was to extend and redefine the modelling tool in order to encompass thermo mechanical properties also. A twofold comparison with a higher order finite element (FE) numerical model is used for the validation of the applicability range of the model along with the data that has been measured under cold start conditions from an installed turbine. Sensitivity studies were conducted to identify the modeling assumptions in order to capture the turbine's correct thermal behavior. It was found that the assumptions have a large influence ranging between ±25% from the measured values for the intercasing cavity temperatures and bearing oil. The sensitivity study also involves reducing the peak of differential expansion by increasing the initial temperature of the casing. This accounts to 30% improvement. These studies establish a basic foundation for the understanding of differential expansion during start and establishes new strategies to control it during the transient operation of the turbine. [3] Suggests that the ultrasonic sensors provide the cheapest ways of measurement technique when compared among various feasibilities. In this work, ultrasonic transmitter, receiver and a microcontroller is employed to provide distance measurement of an obstacle. [4] Suggests a sensor that comprises of low cost components only and it is self-adapting in nature to a wide variety of conditions and to provide the best results. In [5], a verification approach based only on the differential and absolute thermal expansion measurements in the steam turbine's vicinity is conducted and modeled. [6] Develops a physical model to prevent the rotors from cracking due to the cyclic transient thermal stresses. [7] Discusses the design techniques used and the method of implementation of electric circuits to enhance the steam power plant's performance and discusses a wide range of techniques associated to artificial neural networks that are employed to control turbine. In [8], an accurate and reliable non linear model is employed by which the turbine-generator mechanical system is simulated and validated. In this damper windings are used to overcome the vibrations caused as a result of disturbances in the by power system circuits. [9] gives an analysis of steam turbines and its types.

III. EXISTING SYSTEM

The existing system uses a LVDT which is a transducer device that is of contact type that senses the real time data and from which the collected data is sent to the controller circuit. The controller circuit constantly compares between the reference value and the obtained real-time value. When the obtained real-time value exceeds the reference value, a critical condition is produced

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due to which further operation of turbine is stopped. LVDTs are rugged and absolute linear position/displacement transducers; that are innately frictionless, and have a limitless life cycle virtually, when properly used. The AC operated LVDTs do not contain any electronics, and can be operated at cryogenic temperatures or up to 1200 °F (650°C), even in harsh environments, with very high vibration and shock levels. LVDTs have been widely used in a wide range of applications and have low hysteresis and excellent repeatability.

The linear cutaway view of an LVDT is shown in Fig.1, wherein the primary coil at A drives the current, and in turn induces current to be generated through the secondary coils at B.

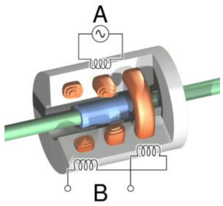


Fig. 1 Linear cutaway view of LVDT

In practice the method of coupling between primary and secondary results in minor variations in the output. This results in quadrature error that is due to the small residual voltage. It is an issue in closed loop control systems because of the resultant oscillations about the null point, and this factor is not acceptable in applications that require even simple measurements. This is because of the usage of demodulation that is synchronous in nature, with direct deduction of the secondary voltages at AC. The LVDTs should be fault tolerant LVDTs, for modern systems [10], and the normally each secondary is demodulated separately; using precise rectifiers either half wave or full wave, and the difference is computed by deducing the DC signals. If the excitation voltage is constant, then the sum output of the two secondary voltages is almost stable throughout the operation of the LVDT. Its value remains within a small range and can be monitored such that any internal failures of the LVDT will cause the sum voltage to deviate from its limits and be rapidly detected, thus causing a fault to be identified easily. This method does not produce quadrature error, and the difference voltage which is position dependent passes smoothly through zero at the null point. Even though digital processing in the form of a microprocessor or FPGA is available in the system, it is customary for the system to be fault tolerant and also accuracy has to be improved. This can be achieved by dividing the difference in secondary voltages by the sum of the secondary voltages, to make the measurement independent of the exact amplitude of the excitation signal. It is becoming commonplace to use this to generate the sinusoidal excitation via a DAC if sufficient digital processing capacity is available, multiplexed ADC is used to perform the secondary demodulation. When the core is displaced toward the top, the voltage in the top secondary coil increases and the voltage in the bottom decreases. This results in an inphase output voltage with the primary voltage. The output voltage increases from zero, but in opposite phase when the core moves in the reverse direction. The phase of the output voltage dictates the direction of the displacement (up or down) and amplitude dictates the amount of displacement and the direction of displacement can be determined using synchronous detector. The design of LVDT is such that the output voltage is completely linear with respect to the displacement up to several inches (several hundred millimetres) long because of its long thin coils. The LVDT can also be used as a sensor to determine the absolute position. LVDT shows the constant output, and no positional information is lost during restart after the power is switched off. If the LVDT is properly configured, then repeatability and reproducibility are its biggest advantages. Also, other than the uni-axial linear motion of the core, any other movements such as the rotation of the core around the axis will not affect its measurements. LVDT is also highly reliable and is completely sealed against the environment without any sliding or rotating contacts.

The following are the disadvantages of LVDT and to overcome this; ultrasonic sensors are used

- Temperature dependent performance.
- Sensitivity to stray magnetic field.

IV. Proposed Sysem

The proposed system consists of an ultrasonic sensor (smart sensor) to manipulate the real time data. Such that, the data is further sent to a PIC microprocessor circuit in which the obtained data is processed and is compared with the reference data. Ultrasonic sensor can operate in a stable manner at even high temperatures. When the obtained data exceeds the reference value the trip signal is enabled which further stops the operation of the turbine. The block illustration for the proposed methodology is as shown in Fig. 2.

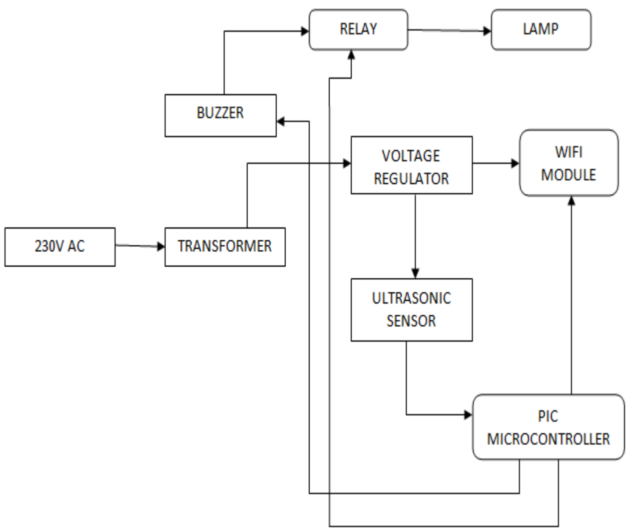


Fig.2 Block illustration of proposed method

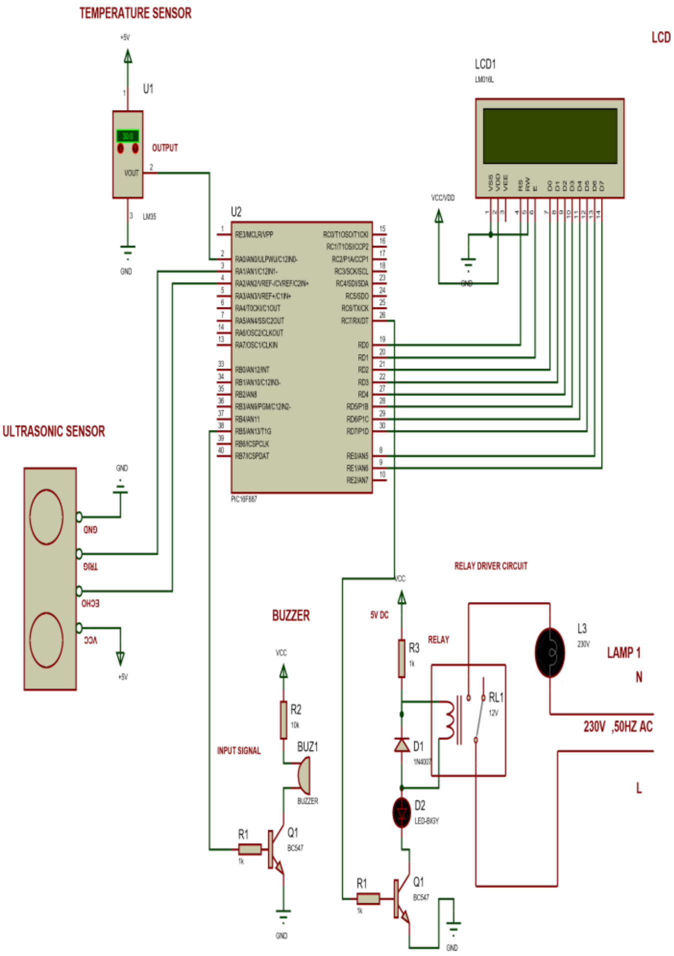
Initially this module consists of a PIC microcontroller which is used to compare the reference value and the obtained real time data and provides the output signal to various modules. Initially, the first basic operation consists of setting up of reference value and the critical value. Such that, the ultrasonic sensor is employed to estimate the expansion value of the turbine casing and provides the measured data to the PIC microcontroller. The PIC microcontroller in turns provides the real time data to the WIFI module from which the data is fed to a common network a platform through Internet of Things (IOT) process.

Thus, the observer can monitor and retrieve the data anytime. When the data measured by the ultrasonic sensor exceeds the reference value, a signal is sent from the PIC microcontroller to the buzzer which initiates an alarm signal. Whereas, when the measured signal exceeds the critical signal the PIC microcontroller provides a signal to the relay which terminates the operation. The obtained data is fed to a common network platform using IOT techniques. Thus, the real time data can be monitored and the data can be retrieved whenever required.

HARDWARE IMPLEMENTATION

The kit consists of a transformer to which the supply is provided. Since a transformer is used to step down the voltage to a desired level. Supply voltage of about 12 V is sent to the PIC Microcontroller. The supply is also fed to the voltage regulators and to the buzzer circuit. From the voltage regulator, the regulated voltage is sent to the ultrasonic sensor and WIFI Module. The buzzer is connected to a relay which is enabled when the measured real time voltage exceeds the reference voltage. The ultrasonic sensor is connected to the PIC Microcontroller which provides the real time data. Thus the PIC Microcontroller compares the reference value and the measured value and provides the processed data to the WIFI module. The WIFI module, feds the real time data in a common platform in internet from which the user can retrieve / monitor the real time data which gets updated every time. The circuit diagram of the hardware implementation for the proposed system is shown in Fig.3.

When the measured value fed by the ultrasonic sensor exceeds the reference value the PIC Microcontroller initiates a signal to the buzzer which in turns produces alarm sound, when the measured value exceeds the critical value the relay operates.



V. CONCLUSION

This module can even operate at high temperatures without any issues regarding efficiency and stability and act as a contact-less type measurement system. As this system is also based on Internet of Things, the real time data can be fed to a common platform in which the data can be observed and recorded by the observer and can be retrieved at anytime.

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The above mentioned ideas and the processed output are our own to the best of our knowledge.

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