Automation of Windmill Gearbox Testing

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Abstract- *Automation in the testing procedure would be carried out by replacing the manually performed activities and operations with the technologically advanced methods to achieve the same functions that manual activities used to accomplish. Automation would reduce human interface in the testing procedure drastically. The major advantage of automatization would be improved quality of results and real time data, which would be vital for determining the life and characteristics of the test product, in our case windmill gearbox. The Procedure of Automation is modest in nature; we evaluated our current statistics and worked out scope for improvements in those procedures thus determining the objective of the project.We research about the constraints involved in the problem statement that we needed to find resolution for. The solution was devised to replace manually performed activities by automated processthus introducing the concept of quad tester with adjustable frame and arms having sensor mountings to take parameter measurement. The sensors were connected to modular PLC and SCADA and results can be displayed on screen. Thorough report and web based monitoring can also be enabled on the test subject according to users need.*

Keywords- Automation, gearbox, PLC, quad-tester, SCADA, Testing, windmill,

I. INTRODUCTION

Windmill gearbox is one of the key components of the windmill construction elements, employed for harvesting electrical energy from the wind energy in more efficient manner. The major customer for the gearbox are the windmill companies within and outside India, following diagramatical representation shows the contents of the windmill and the position of the gearbox within the windmill body. The gearbox is a single stage helical type model with reduction ratio about 1:39.98 with the nomial power to be calculated as 250 KW having oil volume about 70 liters, the gearbox is attached to main shaft from rotor side and flexible coupling via generator side. Thus completing the series of components in windmill from hub to generator.

The windmill gearbox has a main housing, A bottom cover and a top cover with additional features like magnetic plug, breather and temperature transmitter. In the windmill gearbox two shafts are employed namely, Input shaft and integral shaft pinion. Also Two gears namely high speed gear and Input gear. Windmill gearbox has a total of six bearing used in its constrution, of different types such as Cylindrical roller bearings, spherical roller bearings and ball bearings, In gearbox, Breather, Magnetic plug for oil and dirt removal, dipstick as an oil level indicator and temperature transmitter are provided.

II. IDENTIFICATION OF OBJECTIVE, RESEARCH AND DATA COLLECTION

For the free run testing of the gearbox, physical parameters such as **Temperature, RPM, Vibration and Noise level** play a vital role in determining the life of the gearbox, after all, these physical quantities are the governing variables in testing procedure of the gearbox.

Temperature: The primary and the most significant physical testing parameter in the gearbox testing is the temperature. The temperature is the degree of relative hotness or coldness of any object, which determines the amount of thermal energy. The temperature plays a decisive role in determining the life of a gearbox. Temperature in gearbox is calculated as the temperature of bearings and the temperature of lubricating oil present in the sump. The temperature between the bearings and the lubricating oil is interdependent, it is this lubricating oil that is allowed to percolate in the bearings surfaces and continue to form a thin film of oil, for proper functioning of the bearing.

Revolution per minute: RPM

Revolution per minuteor commonly known as RPM is another factor that is important in measuring the quality and life of the gearbox. RPM is the sole parameter that is used to decide the output power of the gearbox. RPM is required to calculate the reduction ratio, which is used to calculate size of gearbox and mechanical power ratings. The reduction ratio is the algebraic ratio between the input shaft rpm to output shaft rpm.

Gearbox input speed n_1 (RPM)
Gearbox output speed n_2 (RPM)

Windmill Gearbox is always used for speed increment. Lower speed of the rotor is increased to higher speed required for the generator. Gearbox input speed is lower than output speed: **n1 < n2**, the shaft of the gearbox connected to the rotor is input shaft and the shaft connected to the generator is output shaft. If the gearbox is connected to the rotor with a coupling, the input speed is equal to the rotor speed. If the gearbox is connected to the rotor via a belt system, the input speed of the gearbox changes according to the ratio of the pulleys. Reduction ratio **i = n1: n2**. The ratio of the input speed to the output speed is the reduction ratio. In gearbox, the reduction ratio is **1: 39.98** which means for one complete rotation of input shaft, the output shaft will rotate nearly **40** times.

These Physical parameters are measured as follows, temperature by temperature gun, RPM by tachometer, Noise level by noise meter and vibrations by vibration meter

Temperature Gun: An infrared thermometer infers temperature from a portion of the thermal radiation sometimes called blackbody radiation emitted by the object being measured. Non-contact thermometers or temperature guns, describe the device's ability to measure temperature from a distance. By knowing the amount of infrared energy emitted by the object and its emissivity, the object's temperature can often be determined.

Tachometer: A tachometer is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine. The device usually displays the revolutions per minute (RPM) on a calibrated digital displays. The word comes from Greek *ταχος* (*tachos* "speed") and *metron* ("measure"). Essentially the words tachometer and speedometer have identical meaning: a device that measures speed.

Testing Procedure: The Manual testing procedure of the windmill gearbox is carried over four hours to completely test the gearbox to its limits and to meet its requirements.

The testing procedure starts with the mounting of V-belt on the pulley of the flexible coupling according to the requirement of the scenario and attached to the driving motor of required power. Also the tightness of all the screws and bolts is checked to ensure minimal vibrational characteristics from the gearbox. The ISO grade VG 320 or VG 460 oil grade is used to as lubricating oil in the gearbox. The oil is filled up to a level that is previously marked on the dipstick attached on the main housing. Radium stickers that emit certain wavelength are pasted on both the H.S. Shaft and the input shaft to check their RPM with the help of digital tachometer that works on the laser principle sensing the emitted wavelength and delivering the result.

The electric motor is started and the shaft coupled to it also starts to rotate, gradually increase the RPM of input shaft up to desired level i.e. 1600 rpm, and begin the free run test on the gearbox while noting down i/p and o/p RPM with the help of digital tachometer. The primary physical test parameter of the testing procedure is temperature, thus the temperature of sump, H.S. cover, L.S. Cover, Interim cover (H.S. side) and interim cover is measured. The specific temperature rise in the temperature of the components is permitted to be 30 – 35 degrees above the ambient temperature. Noise level of the gearbox and surrounding environment is also important factor in testing of gearbox. This noise level is measured with the help of noise meter in decibels. Last but not the least, oil leakage from the housing of the gearbox is checked at equal interval of 30 mins for 4 hour.
Disadvantages of manual testing of windmill gearbox can be summed up as follow:

1. Manual testing of gearbox is often **prone to human error** in observation or calculation of the readings.
2. **The data is not precise** as the readings are not taken at the same instance of time.
3. **Data collection varies** from operator to operator based on operator, apparatus etc., thus making it tedious.
4. The test **operator's time is unutilized** for when he is not involved in testing.
5. That directly **affects the productivity** of the labour as well as company.
6. Environmental factors influence the testing procedure, causing errors in data.
7. It **causes fatigue to the operator** due to its uneven procedure

Automation will bring out positive changes in the existing practices and ease the process; following are the reasons to employ automation process.

1. To **reduce human error** in the testing procedure.
2. To **obtain accurate data** at the same instance of time.
3. To fix the boundary conditions and have a **precise watch over data**.
4. To **minimise the influence of environmental factors** on the procedure.
5. To save, value **and optimize the testers time** in productive works.
6. To **reduce investment of time** and wage in the procedure.

7. To **improve the productivity** of the procedure more efficiently.

III. CONCEPT OF QUAD TESTER AND AUTOMATION DEVICES.

PLC (Programmable Logical Controller): NEMA defines PLC **as:**
"A digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions by implementing specific functions such as logic sequencing, timing, counting, and arithmetic to control, through digital or analog input/output modules, various types of machines or processes".

Every PLC system needs at least these three modules:

- CPU Module
- Power Supply Module
- One or more I/O Module

SCADA: Supervisory control and data acquisition (SCADA) is a control system architecture that uses computers, networked data communications and graphical user interfaces for high-level process supervisory management, but uses other peripheral devices such as programmable logic controllers and discrete PID controllers to interface to the process plant or machinery. The operator interfaces which enable monitoring and the issuing of process commands, such as controller set point changes, are handled through the SCADA supervisory computer system. However, the real-time control logic or controller calculations are performed by networked modules which connect to the field sensors and actuators.

SCADA system is composed of 3 main elements.

1. RTU (Remote Telemetry Unit)
2. HMI (Human Machine Interface)
3. Communications

HMI: Human machine interface (HMI) The user interface in a manufacturing or process control system. It provides a graphics-based visualization of an industrial control and monitoring system. Previously called an (MMI) man machine interface, an HMI typically resides in an office-based Windows computer that communicates with a specialized computer in the plant such as a programmable automation controller (PAC), programmable logic controller (PLC) or distributed control system (DCS).

Instrumentation and Sensors

Instrumentation is a collective term for measuring instruments used for indicating measuring and recording physical quantities, and has its origins in the art and science of Scientific instrument-making.

Sensors are sophisticated devices that are frequently used to detect and respond to electrical or optical signals. A **Sensor** converts the physical parameter (for example: temperature, blood pressure, humidity, speed, etc.) into a signal which can be measured electrically.

Temperature Sensors: This device collects information about temperature from a source and converts into a form that is understandable by other device or person. There are two basic types of temperature sensors: Contact sensors and Non-contact sensors

RPM Sensor

A sensor is essential to sense shaft speed. Typically, devices used for this purpose are shaft encoders, photoelectric (optical type) sensors and magnetic rotational speed (proximity type) sensors. All of these sensors send speed data in the form of electrical pulses. Shaft encoders offer a high resolution of typically 1-5000 pulses per revolution (PPR) and clearly defined, symmetrical pulses. Proximity sensors provide medium (or low) resolution sensing, depending on the number of pulses measured per revolution. Photoelectric sensors usually sense a reflective target on the rotating shaft.

Automation Framework:

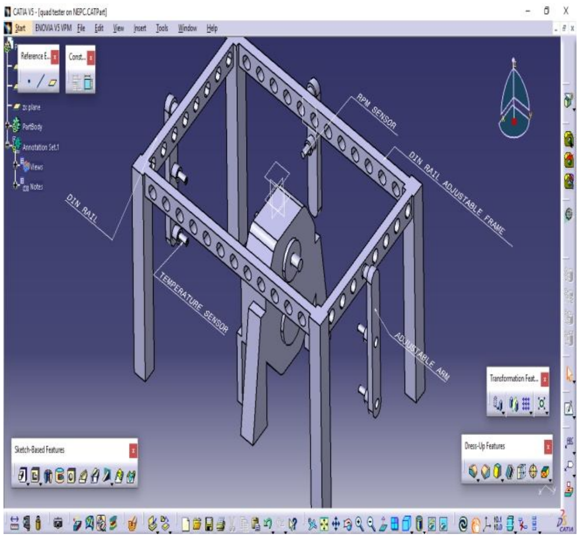
Setup Description
The set up primarily consists of following items

- DIN Rail adjustable frame
- Adjustable arm
- Sensor Mountings
- Sensors

Quad tester is a test bed accessory that assembles on the test bed for the testing of gearbox. **The Quad tester** is a rectangular Frame made of stainless steel or aluminium according to the use and ease of operation. The tester can be assembled on site before the testing procedure, according to the dimensions of the gearbox, its height, length, width etc. The tester's height can be adjusted by bolting the frame onto the legs.

The Frame consists of several attachment openings for mounting arms of the tester. Again the frame can be adjusted according to the length and width of the gearbox, leaving some additional space between then for operation.

The Arms of the gearbox tester are the principle components, carrying the sensors on the sensors mountings. The temperature sensors are mounted perpendicular to the arm and RPM sensors are mounted at 45^{o} to the arm in the direction of shaft.



Pre-Testing Procedure

Pre Testing procedure is as follows:

Mounting of gearbox:

- Gearbox is moved to testing area next to testing motor and mounted with v belt on pulley or coupling as per testing requirement.
- Radium sticker is pasted on both the shafts.

Assembly of Quad tester:

- The quad tester will be assembled around the gearbox, leaving sufficient safety space.
- The legs and the frame of the tester can be adjusted slightly above the gearbox height and assembled according the length and width respecively.

Assembly of Arms and sensor mountings:

- Arms of the tester will be assembled parallely to the face of bearing sealings and perpendicular to the axis rotating shafts.
- The Arm of the tester will be double slider arm to mount the sensor at precise location.
- The arms will hold the sensor mounting for temperature and RPM sensors.

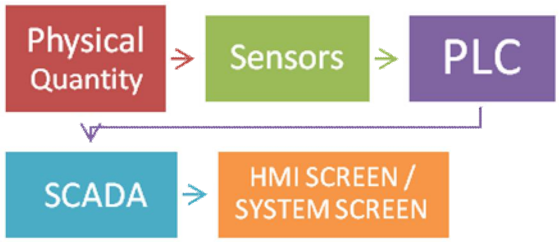
Sensor Mountings:

- Temperature sensors will be mounted perpendicular to the arm facing the sealings, the operating distance must be upto 800mm [0.8m].
- RPM senors will be mounted up to 760mm [0.76m] and 45 degrees from target on the arm to sense the radium sticker.

Testing Procedure

The testing procedure on the quad stand is as follows:

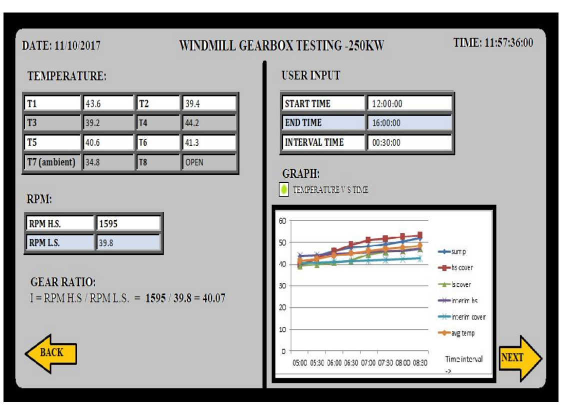
- The power is switched on, thus supply will be obtained by power module of PLC and by each sensor connected to it.
- Some of the data is to be entered manually for eg. Start time, end time, interval time.
- The physical quantity such as **temperature is measured** by the **temperature sensor and RPM is measured by RPM sensor.**
- The **sensors senses** the parameter, **converts it into signal** and the inbuilt transmitter **sends the signal to modular PLC** for further actions.
- **PLC processes the data** and acts as an data processing element, performing pre defined function via ladder programming such as checking parameter limit.
- This **signal from PLC is again sent to SCADA** software which is either installed in the system or a separate hardware connected to the system and PLC.
- Here is the actual work done, the **data is presented on to the display of HMI** or the system screen in well tabulated format for ease of understanding.
- The test result is displayed on the screen, a real time temperature and RPM monitoring and their values at the respective time interval.
- The PLC has a provision of setting up limiting values for the parameters, so that if the **value exceeds thelimiting value, the red signal or a hooter is indicated**.
- The **SCADA system can generate graphical representation** of the physical quantities according to the user's need.



Post Testing Analysis

The post testing data analysis consists of various operation that can be performed on the data simultaneously during the testing and data can be obtained later. The various operations include plotting temperature v/s time graph, calualation of mean, deviation,and various statistical operations according to users need. Following are some of the ideas of operations that can be processed on the data during testing:

- Plotting Temperature v/s Time graphs.
- Plotting RPM v/s time graphs.
- Calculating mean, mode, median of the data
- Diagnostics run of the model
- Data can be made avaliable to end users during and after testing through web monitoring.
- All relevant calculations of power output, power input, gear ratio etc can be made availabe through programming according to the need.
- Full range of dynamic reports can be created through SCADA softwares.



Advantages and Disadvantages:

The main advantages of automation are:

- Increased throughput or **productivity**.
- **Improved quality** or increased predictability of quality.
- **Reduced direct human labor** costs and expenses.
- Automation gives **high degree of accuracy** wherever required.
- The testing data can be stored and **accessed from cloud storage.**
- **Data back-up is available** in case of power outrage.

The main disadvantages of automation are:

- **A very large initial investment is needed** in comparison with the unit cost.
- **Skilled personnel** are required for running the procedure smoothly from **coding, troubleshooting** and obtaining end results as per requirement.
- Continuous and **uniform power supply is needed** for the testing duration for the sensors to work, uneven power supply might damage the sensors.
- Setup may **consume space** for testing and **more time for assembly** of set up.
- **Threat of Virus or Malware remains** if the system is not secured with Anti-virus.

IV. CONCLUSION

The Primary objective of this Project was to automize the testing procedure of the Windmill Gearbox interfacing it with the help of PLC and SCADA, which would reduce human intervention in the gearbox testing procedure, thereby eliminating manual errors in the testing observations and calculations.Thus it would optimize the accuracy and efficiency of the testing procedure by getting the performance and data directly on the screen with all the required parameters involved.

We formulated an approach towards seeking the solution for the problem. In our case of gearbox, solution must be devised to replace manually performed activities by automated process. This is where all the technical aspects of the project come into being, we looked over designs, constraints and formulated the solution that best fits for the application of the need. Designing a general purpose testbed solution that is feasible for testing every gearbox irrespective of its design constrains and interfaces it with PLC and SCADA with the help of sensors.

PLC and SCADA System is used for monitoring the various test parameters. Alternatively, SCADA and PLC communication system make it possible to integrate protection control and monitoring test parameter together for maximum benefit. HMI included will provide easy user interface for test monitoring and control. Hybrid system benefiting from the real time detection capacity of a software based method and the high localization accuracy of a hardware based technique, along with other specific advantages of both approaches, seem to be very reliable for testing. Result report will generate on the main computer server and these reports can be archived in the computer memory for records.

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