Embedded Instrumentation for Smart Grid Equipment's Condition Monitoring

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***Abstract*— Renewable energy sources (RES) have been into prominence all over the world and wind energy is the most developed energy sources in RES. This research develops an induction motor fault diagnosis system during electricity production using Park Vector and Virtual instrumentation approach. Generally, it is very difficult to diagnose a machine fault by conventional methods based on mathematical models because of system complexity and the existence of nonlinear factors. In this research, Virtual instrumentation technology is applied to the fault diagnosis of the machine. By the learning of normal and abnormal states of the object system, a new-method with Virtual instrumentation is involved which can diagnose a fault of the machine. The fault diagnosis system is based on the park vector analysis of the signal from the operating machine. Under any abnormal condition in working of machines, these patterns get changed. The amount of variation can be detected and the nature of abnormalities can be analysed with the help of Virtual instrumentation to get an idea about the fault in the machine. The variation between normal and abnormal data becomes clearer by comparing park vector components data. It is suitable for the detection of the fault to utilize changes in data. Using this method, it is shown that it can detect unknown fault patterns. Through these results, the effectiveness of the fault diagnosis system is verified. The amount of deviation can be detected and the nature of abnormalities can be analysed with LabVIEW to get an idea about the fault in the machine.**

***Keywords*— Condition Monitoring, Wind Farms, Smart grid, Park vector approach, Virtual Instrumentation, LabVIEW.**

I. Introduction

Wind energy is the most developed of the renewable technologies for the electricity production. As the demand for wind energy continues to grow at exponential rates, reducing function and maintenance (F&M) costs and increasing reliability is now a top priority. So with low-cost, online condition monitoring systems that predict failures and maintenance requirements, it is possible to anticipate maintenance activities and lower O&M costs. Among the many troubles in production, the most vital aspect is for each machine systems to work in a normal state. In order to maintain an average condition of a machine system, fault prediction and analysis systems are necessary, especially for electric generators, which run continuously for a long time. When failures occur, the failures should be identified as soon as possible, because if these machines run continuously under abnormal conditions, it may result in great damage and even loss of human lives. Currently, though many kinds of identification methods have been developed, many of them have been based on the traditional method of establishing a geometric model analysing a variety of parameters and then judging the operating conditions of a machine system. However, because of the complexity of machine systems, the uncertainty of operating conditions and many nonlinear factors, it is, in most cases, very complex to set up a mathematical model of a machine structure and to know the operating conditions of a machine. Also, it is, in some cases, even impossible to detect failures that occur when a machine is running. So that motivates use of unconventional approaches such as virtual instrumentation for fault diagnosis. In approaches of fault diagnosis, perhaps the oldest and most widely used method is hearing the sound of the operating machine with the human ear. However, time series data of sound signals are very complex, and influenced by noise. Here, the park vector components data of the signal is used as fault diagnosis signal. In this method, the diagnosis learns from the already obtained data of both normal and abnormal operating conditions of the machine system through LabVIEW. Through these experiments, the effectiveness of the fault diagnosis method is shown.

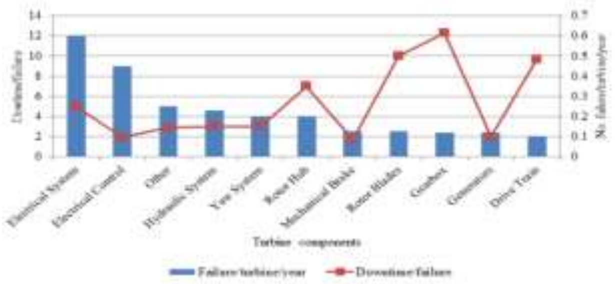

Fig. 1 Percentage Failures of Turbine Components [1]

This system is designed and implemented in LabVIEW environment, which can display the real-time Park vector transform plots, harmonic components. Main contribution of this study is the real-time detection and classification of different disturbances through visual displays. The objective

of the project is to find the solution to reduce the operation and maintenance cost and down time of smart grid equipment such as like the wind turbines using condition monitoring system.
1. The main work to develop the condition monitoring systems using Virtual Instrumentation software for wind turbine using different algorithms and standards.
2. Automatic status monitoring and Data logging of the Wind turbine with graphical interface program to be developed newly.
3. Easy access to offshore wind turbines through wireless communication.

The ever-increasing demand of electricity because of unprecedented use of gadgets in modern epoch, the total generation of electricity has also increased astonishingly in the past two decades. However, the quality of electricity has deteriorated to such an extent that it has become a serious concern for electric utilities as well as the customers.

A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users. Smart grids are required to co-ordinate the needs and capabilities of all generators, grid operators, end-users and electric equipments in the network of the grid to work efficiently as possible, minimizing overheads and ecological impacts while maximizing system reliability, resilience and stability. This project aims at monitoring equipments like induction machine in the renewable energy grid.

II. Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator. The Uno differs from all previous boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. This controller will act as s data acquisition card. The DAQ Card will collect the three phase current data from current probe and send to the Control room through wireless device. The Control room consist a Wireless receiver, the server process the received data and identify the faults using Virtual instrumentation [2].

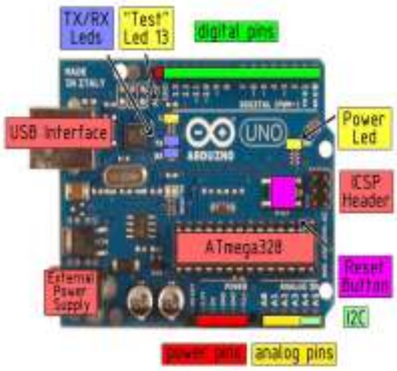

Fig. 2 Arduino UNO Microcontroller [2]

III. Implementation of LabVIEW Software

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) based on Graphic Language, is a type of opening platform and establishing tool for Virtual Instruments (VI). The software unit of the system can obtain, control and interfacing the data. Also it can analyse and process the measured signals. Due to its influential function module and communication protocol, LabVIEW significantly diminishes the software development period. Especially in measuring and controlling systems, it can acquire and analyse data expediently. We can have the further analysis and processing with the acquired data.

Its library contains several predefined functions, focusing on the following areas:
• Data acquisition;
• control devices;
• Data analysis;
• Display and data storage.
Labview programs are called virtual instruments (VI) and are based on the concepts of modularity and hierarchy tree. Thanks to the virtual instruments modular nature can be used both as main programs and subroutines in which case they are called "Sub VI". These subroutines have the advantage that they can be developed and tested independently. Labview applications have two distinct parts: the front panel and the block diagram. When the program is running these two windows carry out a continuous data exchange between them. The front panel is the graphical user interface that displays graphical elements as indicators or controls. For the front panel designing are available predefined objects such as buttons, graphics objects, switches, tanks, sliders etc. For the block diagram implementation are used nodes representing execution elements, terminals representing gates through which data is transferred and wires representing data flow block diagram.

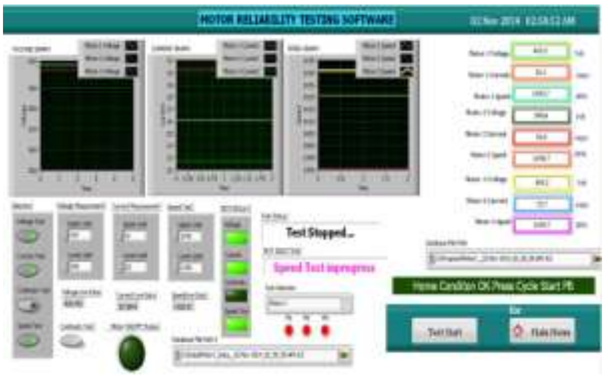

Fig. 3 LabVIEW Virtual instrument front panel

A. *Wind Turbine Condition Monitoring*

There are many techniques and tools available, which are used to monitor the condition of wind farm. Condition monitoring technology used for monitoring includes sensors, which may measure the speed of the rotor, wind speed, wind direction, generator output power quality, vibration, temperature etc. These sensors are together coupled with Wireless DAQ card. The Wireless DAQ card is connected to the wind farm central control station through wireless communication. The Monitor system consist a CPU and other required accessories for communication and data processing. This system will collect the sensors data's and send to the central server through Zigbee. The Separate monitor systems are installed to each Wind turbine.

IV. COMMON FAULTS AND THEIR COMMON TECHNIQUES

The detection of common faults of induction motor with help of signal processing techniques is main focus of this research. A variety of faults can occur within three phase induction motor during the course of normal operation. These faults can lead to a potentially catastrophic breakdown if undetected. Consequently, a variety of conditions monitoring techniques have been developed for the analysis of abnormal condition. Signal processing techniques are also very effective for fault detection. Due to continuous advancement of signal processing techniques and related instruments, online monitoring with signal processing techniques has become very efficient and reliable for electrical machines [3].

A. *Faults in induction motors*

Short turn winding faults, rotor faults, bearing faults, gear fault and misalignment are common internal faults of induction motor. The common internal faults can be mainly Categorized into two groups [3]:

- Electrical faults
- Mechanical faults

Signal processing is the techniques for fault detection of induction motor. The first step for condition monitoring and fault diagnosis is to develop an analysis technique that can be used to diagnose the observed current signal to get useful information.

V. PARK'S VECTOR APPROACH

In three phase induction motors, the supply to the mains does not generally use the neutral line. Therefore, the main input current has no homo polar component. A two dimensional depiction can then be used for relating three phase induction motor phenomena, a suitable one being based on the current Park's vector.

As a function of mains phase variable (i_a ,i_b ,i_c) the current Park's vector components (i_d, ,i_q) are:

$$i_d = \sqrt{2}/\sqrt{3}\, i_a - 1/\sqrt{6}\, i_b - 1/\sqrt{6}\, i_c \qquad \text{-----------------(1)}$$

$$i_q = 1/\sqrt{2}\, i_b - 1/\sqrt{2}\, i_c \qquad \text{-----------------(2)}$$

Under ideal conditions, three phase currents lead to a Park's vector with the following components:

$$i_d = \sqrt{6}/2\ I \sin\omega t \qquad \text{-----------------(3)}$$

$$i_q = \sqrt{6}/2\ I \sin\omega t(\omega t - \pi/2) \qquad \text{-----------------(4)}$$

where
I = maximum value of the supply phase current
ω_s =supply frequency
t =time variable

Its representation is a circular pattern centred at the origin of the coordinators as illustrated by Figure 4. This is very simple reference figure that allows the detection of abnormal conditions by monitoring the deviations of acquired patterns.

The Park's vector approach can be used to diagnose the faults in induction motor. Every change that occurs in the operating condition of the induction motor has the effect on supply side phenomena i.e. stator current [4]. Therefore, any change in the operating condition of stator and / or rotor has the effect on supply side phenomena. The result was obtained for Park's vector approach under healthy conditions, which is show in figure 5. In park's current vector approach, the result gives circular pattern for healthy condition of the induction motor.

The stator short turn faulty conditions are introduced in the induction motor and the faulty conditions are analysed with Park's vector transformation approach using LabVIEW.

A. *Interturn Faults*

Moreover, it is generally believed that a large portion of stator winding-related failures are initiated by insulation failures in several turns of a stator coil within one phase. This type of fault is referred as a "stator turn fault"[5].

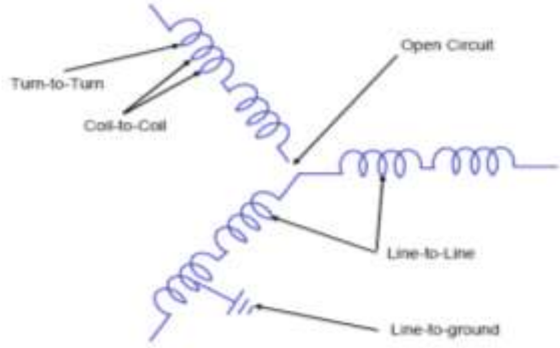

Fig. 4 various types of short winding faults [3]

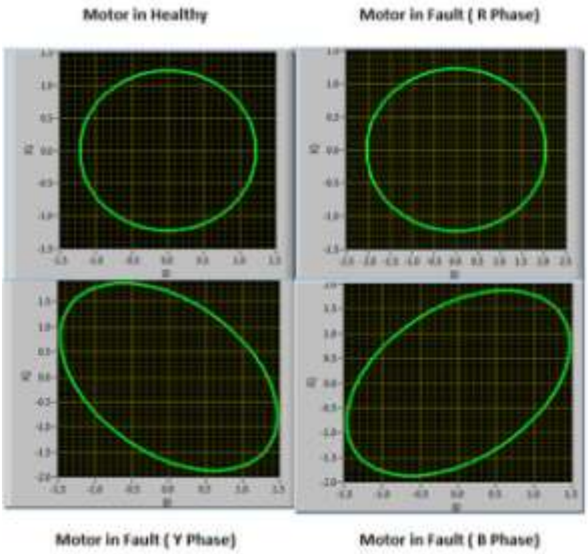

Fig. 5 Park vector transformation result

VI. FUTURE WORK

The approach is tested on proto type experimental test module and results given above are validated. Research is in progress toward verifying the experiment on wind generator modules for various types of malfunction.

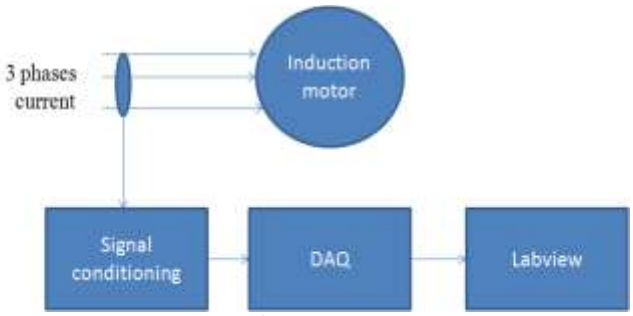

Fig.6 Structure of monitoring and diagnosing system

Fig. 7 Experimental test setup

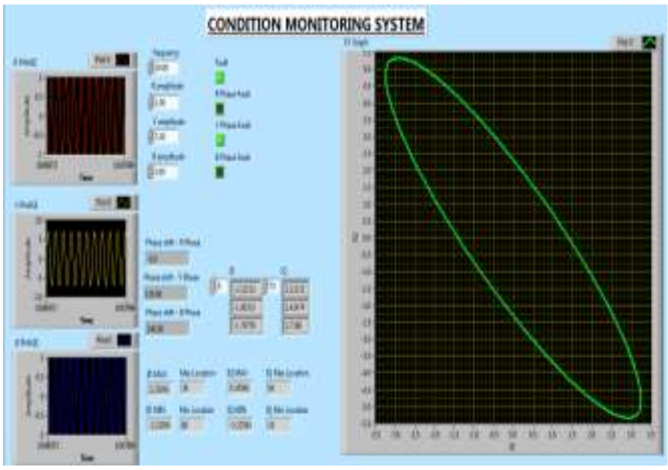

Fig. 8 Condition monitoring software

By applying park's vector technique, R phase single phasing fault, the circular pattern of the healthy condition induction motor is changed to elliptic pattern. With Y phase single phasing fauIt, the elliptic pattern is shifted to quad 2&4 directions. With B phase single phasing fault the elliptic pattern is shifted to quad 1&3. The sample results obtained during fault diagnosis is shown in figure 5.

VII. CONCLUSIONS

This paper has investigated a method of detecting faults in induction motor using Park's Vector approach. It has been shown through experimental and simulation results. The Condition monitoring system has a capability to indicate the faults in which phase. The fast growth in applications of the induction motors in sensitive areas such as wind plants has increased the need for continuous condition monitoring of motors. A wireless sensor network-based condition monitoring system has been developed for Wind farms. The condition monitoring system will offer a inexpensive solution for the regular maintenance information of the wind turbines installed on anywhere. Use of virtual instrumentation for the measurement and monitoring of power system improves the performance as well as reliability of the system. Virtual instrumentation can save extra expenditure, time and energy for setting up of traditional instrumentation system.

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