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Condition based reporting of multi-machine monitoring system using GSM

Jinia Datta(Das), Soumyajit Datta, Sumana Chowdhuri and Jitendranath Bera

Abstract- This work describes a condition based reporting technique of a multi-machine System using GSM technology. In this present approach, a dedicated microcontroller based hardware unit (DHU) has been developed to continuously measure the parameters of the motors viz. voltage, current, speed etc. to monitor the running condition of each motor in a plant. In a multi-machine monitoring system each motor is connected with one such DHU, which are also connected to a Global System for Mobile Communication (GSM) modem. The preliminary level of fault or abnormality in operation of each machine is diagnosed by the respective DHU and the fault or abnormalities details are reported to the pre-assigned operator through an SMS service. In extreme case, the provision of machine shut down by a return SMS is also provided. A proto-type lab model is set up and is working satisfactorily.

Index Terms- GSM Modem, Machine Fault Reporting, Multi-Machine Monitoring, SMS Service.

I. INTRODUCTION

Electrical machines, installed in different locations in a plant, are needed to be monitoring and control for their healthy operation and smooth running of the plant. It is not always possible, rather difficult, to keep track of all the machines at a time simply by days long manual observation. On the other side, modern civilization is advancing at very faster pace with the adoption of wireless technology. The convergence of wireless technology and the embedded technology with the different transducers makes these supervisory systems more reliable, much efficient as well as cost effective one. Keeping this in mind, the present approach has been made to apply the advantages of wireless communication and embedded technology towards electrical machines condition monitoring and automation. This work describes the development of a supervisory automated reporting system for remote condition based monitoring, analyzing and control of electrical parameters of different machines of a plant or in power station, sub-station etc so as to enhance the overall system performance using GSM (The Global System for Mobile Communication) communication.

A detailed discussion [1] on electrical drive condition based monitoring, diagnostic research and development is made for the smooth running of the machines. In Ref. [1] the authors dealt with a state-of-the-art discussion of the electrical drive condition monitoring, diagnosis, research and development, highlighting analytical and technical considerations as well as various issues related to different failures.

Among different parameters of induction machine monitoring of stator voltage, stator current, rotor speed are most important for early detection of fault in the machine. Speed and winding current estimation is helpful to determine the mechanical stresses like bearing failure or shaft failure, turn to turn short circuit, cracked/broken rotor [2]-[4],[8]-[10]. Continuous current monitoring to obtain the running condition of an induction machine is important and has been discussed in [5]-[7].

Now-a-days wireless and mobile communication is the major tool that can be used to provide the information to the operator or concerned authority for their supervisory control. These issues of mobile communication technology in the recent years have been extensively used in different form in different application areas [18], [19], [21]-[23].

The application of less expensive but more powerful microcontroller will lead this data acquisition system more simple. The convergence of microcontroller based hardware with the wireless communication system (like GSM, GPRS) is becoming very popular choice to the researchers and scientists for such type of fault detecting, reporting, diagnosis and control applications.

In this scheme, a state-of-the-art stand alone Dedicated Hardware Unit (DHU) is developed using microcontroller for monitoring the machine parameters like instantaneous voltage, current and speed of a machine in a typical plant. The DHU is responsible for measuring the machine basic parameters and controlling the supply to the motor and hence DHU is located at the machine site with one card per machine basis. The card is also interfaced with GSM modem for GSM based wireless accessing. There will be multiple cards for multiple machines system. Each DHU compares the measured value with pre-set or limiting values of the above mentioned parameters and if any abnormalities are detected an SMS is generated and is sent to the pre-located mobile or central station. The receiver may then send a return SMS requesting the details of the abnormalities. Upon receiving this request the details of the fault are then sent through another SMS by the DHU and it will take the appropriate action as per the content of the return message.

II. MATERIALS AND METHODS

The developed GSM based remote fault reporting system consists of three main blocks viz. DHU, GSM Modem, Mobile unit or central control Station as shown in Fig 1. In a plant with multi-machine operating, each machine is associated with a DHU for data acquisition to measure different parameters. All such units in this multi-machine system are interfaced with any remote mobile station through GSM technology. A preliminary level of abnormal running condition is detected by the DHU when the measured parameter exceeds beyond their set or limiting values. At this situation /stage, the DHU generates a message and sends it to the pre-assigned operator in form of SMS through GSM

modem. Realising the criticalness of the SMS or in case of an emergency situation the operator/the receiver of this SMS will be able to turn off this particular machine by sending another SMS from his/her mobile to that DHU. Hence the total work can be divided into two parts –where the development of microcontroller based DHU for different parameters measurement with some emergency control as first part and the development of GSM modem based SMS service system as second part.

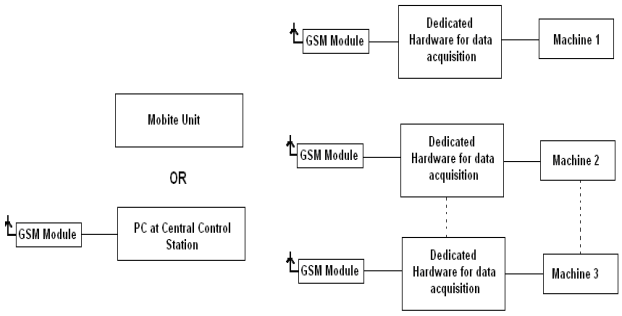

Fig. 1 Block diagram of PC based wireless monitoring of multi-machine system

A. Dedicated Hardware Unit for Data Acquisition

The DHU is designed around an 8 bit microcontroller along with different transducers for parameters measurements, as shown in Fig 2.

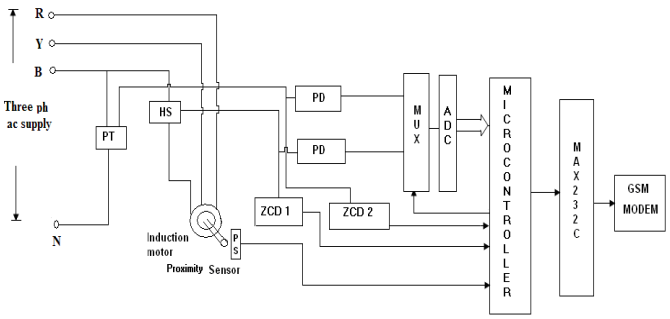

Fig. 2 Schematic diagram of a particular DHU

In each DHU, the microcontroller is interfaced with different sensors like potential transformer (PT), current transformer (CT) or hall sensor (HS), proximity sensor (PS) through proper hardware circuitry in order to measure the applied voltage, inflowing current and speed of the motor. The firmware is designed in such a way that it is able to detect preliminary abnormal situations like over voltage, under voltage, over current, over load, short circuit current, over speed, single phasing etc. The fault or abnormal conditions are also classified into different levels or priorities. Depending upon the priority of the type of abnormal conditions the DHU decides its action. In case of highest priority abnormal conditions the machine will be isolated from supply. Once a fault of such kind is initiated, other than taking the preliminary action the DHU also dictates the GSM modem to communicate the abnormality along with its type, as occurred in the system, by generating a fault respective SMS.

On receiving the SMS, the person or the operator at Mobile unit and/or central control Station may have some details query and accordingly a message requesting the details of the abnormal situation(s) can be sent to that DHU. On its reply, the DHU will send some details of voltage, current, speed etc. at the time of abnormal situation(s) through another message.

B. GSM Modem Interfacing with DHU

The GSM modem (i-300 GSM Modem. It supports GSM 07.07, 07.05 and SIMCOM enhanced AT commands) is built with a COM port with RS232 protocol based interfacing facility. Hence the microcontroller is connected with the modem using 9600, N, 8, 1 protocol after the necessary hardware interfacing for proper TTL to RS 232 level conversion. As the modem works on AT command sets, following AT commands are to be sent to the modem in order to execute the SMS services.

[1] First the microcontroller has to send "AT" command word. A response "ok" is returned from the GSM modem. The microcontroller sends another query by sending "AT+CPIN?" to get the PIN (Personal Identification Number).If the SIM card is ready for the use, the response "+CPIN: READY" is returned. After this, following AT commands are to be sent for the required SMS services.

[2] For the configuration of the GSM modem in text mode of SMS the AT Command AT+CMGF = 1 is to be sent.

[3] In order to send the SMS, the desired mobile number is to be sent with "AT+CMGS=+91xxxxxxxxxx"AT Command.

[4] The desired message, containing a maximum of 160 characters, is to be constructed and to be sent to the modem. After then the ASCII code for 'CTRL+Z' character is also to be sent to the modem in order to transmit the message to mobile phone +91xxxxxxxxxx.

In a similar way, any message received by the GSM modem will be sent to the microcontroller for its decoding and proper action.

C. Hand held Mobile unit or GSM Modem at the central control station

The Hand held Mobile station may be of any mobile unit who can roam around but still have the facility to monitor the status of the motor through SMS services with the corresponding DHU. In extreme case or for any emergency situations this station can stop the motor from its running through a return SMS. At the same time the operator at the central control station can be instructed for the due course of action based on the SMS from the DHU.

The DHU can also send the same SMS to the central control station where a PC based monitoring, and reporting system is installed. On receiving the SMS from DHU or getting instruction from the hand held station the operator at the central control station performs the required task through a return SMS to the DHU. The PC software has the capability to store this communications for future analysis.

A GSM modem is thus installed at the central control station in order to have the SMS communication with the DHU and it is connected with the PC through its COM port.

The SIM numbers of the hand held station as well as the central station must be pre-loaded to the DHU.

III. PARAMETERS MEASUREMENT TECHNIQUE

A. Voltage and Current Measurement

Input voltage to the drive is reduced for the measurement purpose to a level, by Potential Transformer (PT) and Potential Divider (PD), compatible to ADC of DHU. The transformation

ratio from input to DHU end will enable to find out the actual voltage. The transformation ratio and the gain of the PD are adjusted so that +5V and 0 V at the ADC input corresponds to + 360.6 V and -360.6 V peak value of supply voltage.

The measurement of current is accomplished by Hall Sensor (HS), with sensitivity (S). The sensor's output is current which is converted to voltage by passing this output current through the series resistor, R_m as an ohmic drop. Here also this output voltage across the series measuring resistance R_m (100Ω-320 Ω) of HS, is reduced by Potential divider (PD) accordingly to make it compatible to ADC. The current is calibrated as,

$$i = \frac{V}{S \times R_m} \quad (1)$$

B. Speed Measurement

Shaft speed information is provided by using one Proximity Sensor (PS) mounted on the stator housing along with one metallic screw connected to the rotor shaft. This arrangement generates pulsed output, the frequency of which depends on speed of the motor. This signal is fed to the interrupt pin of the microcontroller of DHU for its measurement, where it interrupts the microcontroller at its every falling edge. The interval between successive interrupts i.e. the pulse period is measured with a 16 bit counter where the counter increases its count value at the clock frequency f_{clk} which is generated by the over flow rate of timer 0 of microcontroller. If N_{sp} be the count value of the counter for the pulse period, which is actually the counts between successive edges, the speed in rpm (ω) can be calculated by the equation as,

$$\omega = \frac{f_{clk} \times 60}{N_{SP}} \quad (2)$$

The timing diagram of the reference clock frequency and different count values for the measurement of speed, frequency and power factor is shown if Fig.3.

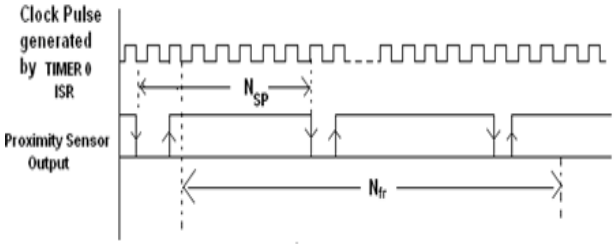

Fig. 3 Timing diagram to measure speed

C. Abnormality detection state Chart Diagram with DHU

An elegant way to depict a real time system is to use state Chart Diagram [22].In this work the abnormality detection and GSM activation by DHU is represented by state chart (Fig 4). Here different states are represented by rectangular boxes. For example, Voltage, current and speed are measured continuously. If any abnormality appears the DHU sends warning to the GSM modem or otherwise if any request comes from the remote station then DHU also sends the requested information. Depths of different states are indicated by drawing small boxes within the large box. The state transitions are indicated by the arcs joining the boxes. Concurrencies of different states are indicated by dotted lines.

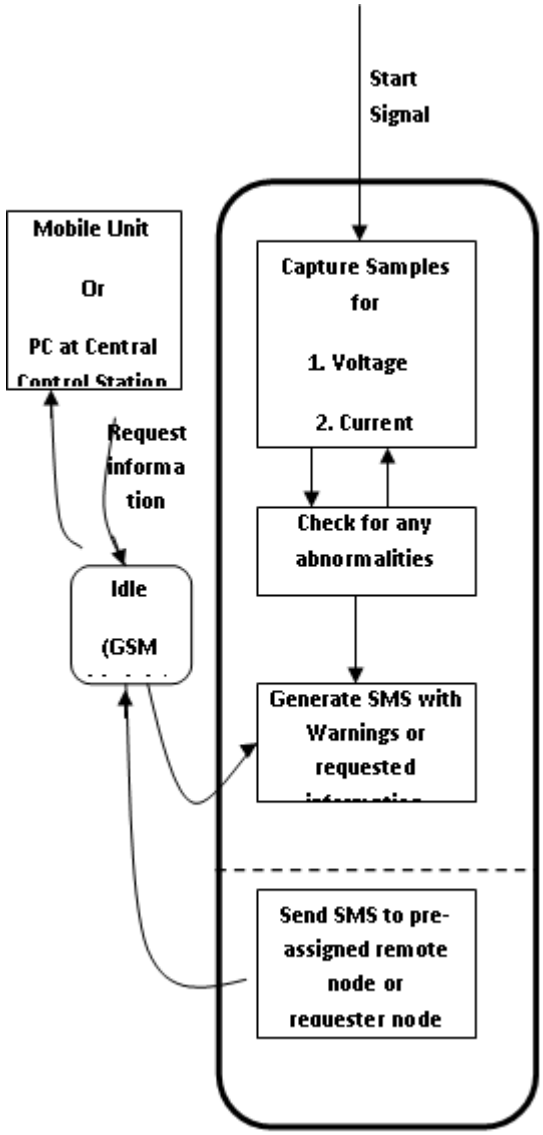

Fig. 4 State Chart diagram of DHU algorithm

IV. GSM BASED SMS REPORTING STRUCTURE

In case of an emergency situation or faulty condition the DHU generates the SMS and sends it to the pre-assigned node number /operator through GSM Modem. Then the operator gets notification about the type of fault, caution level and details of the fault through this message.

SMS structure generated by the microcontroller will be as follows

M	/	C	␣	N	O	␣	n	n	n
␣	V	␣	-	␣	m	m	m	␣	V
␣	A	␣	-	␣	q	q	A	␣	
N	␣	-	␣	P	P	P	P	␣	R	P	M

Where ␣ represents the blank space, Machine (M/C) number (NO) is represented by a three digit number (nnn), running Voltage (V) is three digit value (mmm) V, current (A) is two

digit value (qq), speed (N) is four digit (pppp) RPM. This is a 40 digit message structure.

If abnormal condition occurs or if request comes from central station then the message structure will be as below followed by the type of abnormality.

♂	A	B	N	O	R	M	A	L	♂

C	O	N	D	I	T	I	O	N	♂

DHU generates SMS to indicate the cause of abnormality. There are different levels of fault detection (UV) and over voltage (OV) detection is made. But in case of current there are three levels of abnormal condition. Like up to a certain percentage of rated current the system will show over current (OC), then above this value up to another level the system shows over load condition (OL) and beyond another level of current the system gives short circuit (SC) condition (Table 2). In speed messaging only one level (OS) is detected. Among all these abnormal conditions, DHU may be then dictated for shut down in some of the extreme cases.

Table 1: Different levels of fault conditions

Conditions	**Message indication**
Over Voltage	OV
Under voltage	UV
Over Current	OC
Over Load	OL
Short Circuit Current	SC
Over Speed	OS

V. RESULTS

The experimental setup of multi-machine system from remote mobile station is shown below

Fig. 5 Experimental Set-up

The SMS format for reporting of a particular type fault of multi-machine system from remote mobile station is shown below

Table 2: Current based SMS level status

Rated Current	**Current Drawn**	**Report Status**	**Probable action from operator via replay message**
1 Amp	< 1Amp	Nil	Allow
1 Amp	1.1 Amp	Over Current	Allow
1 Amp	1.5 Amp	Over Load	Take necessary action
1 Amp	Above 2 Amp	Short Circuit Condition	Shut down

VI. DISCUSSION AND FUTURE SCOPE

The uniqueness of the proposed system is that the abnormal running conditions of electric machines installed at different geographical locations in a plant are detected, diagnosed and reported to any mobile and /or central control station.

The self developed DHU, other than sending the SMS to any desired SIM of mobile unit or central control station, can also take the preliminary action to stop the motor either of its own or by an instruction received from a return SMS.

The desired SIM numbers are pre-loaded within the memory of each DHU and the same message is sent to all of them one by one.

In the central control station, a PC is interfaced with the GSM modem which will store the messages for any future analysis of the faults. Simple VB based software is developed to capture the SMSs through its serial port and to store them in a DOC file.

The prototype system is tested with one Induction machine and it can easily be extended to any number of machines by connecting the DHU and the GSM modem.

The GPRS technology can also be incorporated for details diagnosis of the system monitoring continuous data of the machine from the central control station.

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AUTHORS

First Author - J. Datta(Das) is with the Birbhum Institute of Engineering and Technology, Suri (corresponding author)
Email id - dattajinia@gmail.com

Second Author – S. Datta is now with the Department of Applied Physics, Junior Research Fellow, University of Calcutta.
Email id - sjit.cordite@gmail.com

Third Author – Dr. S. Chowdhuri is with the Applied Physics Department, University of Calcutta, Kolkata
Email id - sumana_cu05@rediffmail.com

Fourth author: Dr. J. N. Bera is with the Applied Physics Department, University of Calcutta, Kolkata
Email id - jitendrabera@rediffmail.com)