Design and development of microcontroller-based temperature monitoring and control system for power plant generators

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Abstract. The protection of turbine generator systems is an important factor that must be considered in power plant for efficient production of electricity. This project deals with temperature level monitoring of the power generator and it will be compared with the predetermined standard value through an LM35 sensor. Once it exceeds the predetermined value then the cooling fan will automatically turn on which will be useful to prevent the generator from internal winding thermal failure. The protection system consists of 16x2 LCD display, LM35 temperature sensor, a coolant fan and a microcontroller [ATMEGA328P]. The internal winding temperature of generator is increased as the turbine is rotated at its axis which may lead to major damages in the axial position and shafts of the power generator. To overcome this, an LM35 sensor is connected and linked with the microcontroller which monitors the temperature and once it exceeds the standard temperature the coolant fan automatically is turned on by the microcontroller and the heat of the steam will be countered by the cooling air produced by the coolant fan. The fan runs continuously until the temperature is sensed to have dropped below the standard temperature. At the same instances, the LCD display outputs readable current temperature parameters for the operator. The protection of power generator system is a vital component in power plant for efficient production of electricity.

Keywords: Power generator, Temperature monitoring, Microcontroller, Sensor.

1. Introduction

Nowadays electrical energy plays vital role in many different industries like textile, chemical, steel, mining, petroleum, manufacturing industries. The protection of power generator systems is an important factor that must be considered in power plant for efficient production of electricity. The Mettur Thermal Power Station consists of four units with a generation of 840MW. Each generator has
a capacity of 210MW, 15.75kV, 3 phase output. The main aim is to improve cooling system of the generators used in thermal power plants which in turn results in improving the efficiency of the generator. When the efficiency is increased people will be benefitted due to increase in power production and the protection of generators improved. The winding temperature of the coil increases due the continuous generation of the power from the generator. Non conductivity water is used to reduce the generator winding temperature. This water system is known as Stator Water System (SWS). The SWS includes measurements of winding temperature that is conducted to cooling water and the current through the coil since temperature directly proportional to current. The existing system makes use of individual hard wires with relay logic, electrical contacts and individual monitoring system process complicates the present system.

In this paper, the intent is to design and develop a temperature monitoring and control system using microcontroller and Arduino pack. This is such that the controller will switch the cooling fan either ‘on’ when temperature exceeds the threshold value or ‘off’ when the temperature is lower than the threshold. This is to keep the temperature of the generator shaft and rotor low and avoid overheating. Furthermore, the system gives a user interface through an LCD display where the plant operator can visualize the temperature and status of the coolant fan.

2. Literature Review

Support Vector Machines (SVMs) were mainly used to represent binary classification[1]. In several proposed method, the construction of multiclass classifier is made up of the combination of various binary classifiers. The performance can be compared with three methods based on binary classification: “one-against-all”, “one-against-one” and DAG SVM. In this experiment “one-against-one” and DAG are more appropriate when compared to other methods. In larger problems, support vectors are enough for considering all data at once. New Results on Error Correcting Output Codes (ECOC) of Kernel Machine has interpreted the multiclass classification problem by using margin-based binary classifier in the structure of error correcting output codes[2]. This context addresses the decoding and model selection which are the two most important open problems. In this paper, new decoding function combines the margin over the class conditional probabilities. In model selection, tuning of hyper parameter can be performed by bounding the Leave One Out (LOO) occurred in the ECOCs kernel machines.

Integration of Low-cost consumer electronics for In-situ condition monitoring of wind turbine blades has interpreted the wind turbine blades as resistant to fatigue and robust to loading but it not too heavy [3]. The most important materials used in the construction are glass, reinforced plastic, wood and steel. Hence it is difficult to predict the lifespan of the turbine blades, so it is monitored continuously. The Condition Monitoring (CM) system of turbine blades is not extensively used. In this paper, the changes occurred in the dynamic properties of the turbine blades are detected by the in-situ vibration of CM system. Wireless Sensor Networks (WSN) in Smart Grid holds the advantages when compared to the traditional communication in current electric power system [4]. Presently, WSN enhances the generation, delivery and utilization of the current electric power system for the future generation electric power system. This is to say smart grid. This paper describes WSN applications along with the opportunities, challenges and future work in the application of smart grid. By using field test on compliant with IEEE 802.15.4 WSN, noise in background, characteristics of channel and 2.4-GHz frequency band attenuation can be measured. Transformer Fault Diagnosis Using Self-Powered RFID Sensor and Deep Learning Approach has interpreted that the fault diagnosis is performed based on deep learning and Radio Frequency Identification Sensor (RFID) whereas in transformers[5], the RFID sensor tag functions (signal collection, data storage and wireless transmission) act as a power source for electromagnetic field. In deep learning technique, Stacked De noising Auto encoder (SDA) is essential for learning strong features in the measured signals. The power supply can produce DC voltage of 2.5V and for efficient power buck-boost converter topologies are used for both increasing and decreasing the voltage to regulate it[6].
Shichen Zou et al., has interpreted the substantial increase in cyberattacks by the usage of vast internet connections. Abnormal behaviour detection system plays a vital role in computer network security[7][8][9]. Moreover, the rapid increase in the intrusions diversity, the existing method of intrusion system uses machine learning approach(learning of classifier based on handcrafted feature vector) is used to detect high false alarm rate in these attacks. The abnormal behaviour occurred in the large-scale traffic data network uses the combination of both deep feature extraction and ensembled multilayer SVMs in a distributed network. Literature survey supports available guide to a specific topic. Fuzzy logic control is also one of the methods that have proved to be efficient in temperature response control when compared to PI control in simulation for a plastic extrusion plant[8]. To further reduce the signal distortion in monitoring and control, intelligent controllers such as microcontrollers can be implemented[9]. The literature review for the stator water cooling system of power generators gives an overview for the topic and provide a solid background for the paper. It helps to define the problem on cooling system for power generator in stator winding and used to solve the previous problem on the cooling system by introducing new technology. The problem occurs in the operation of the cooling system of power generators by implementing LM35 sensor. Recently the technology has been developing in the area of operation and maintenance of power generator with good potential for further developments.

3. Methodology
In proposed work, using Arduino, the step response is given to the solenoid value which can circulate and control the temperature by automating the coolant fan to turn on so that the stator can maintain the winding temperature at constant level. The stator cooling water plants disperses and supervises the cooling water (neutral water contains very less oxygen content and electrical conductivity). The proposed work methodology is achieved by interfacing various components being temperature sensor, coolant fan and LCD display to the Arduino board. Figure1 shows the block diagram of the proposed system. The power generation of LMW turbine generator is normally high. Due to continuous generation of the power from generator, the winding temperature of the generator coil will be increased. As a result, the coolant fan must be used to reduce the generator winding temperature. The winding temperature of the generator is reduced by using the coolant fan if it exceeds the predetermined temperature.

3.1 Arduino
Arduino is an openly accessible paradigm consisting of both hardware and software. The Arduino Software works based on AVR RISC architecture commonly applied for Arduino boards[10]. It gives
a platform for the microcontroller (ATMEGA328P) to be loaded and reprogrammed according to user composed code in an intrinsic environment for a rapid microcontroller base project development [11].

In this case, the use is to receive analogue input from LM35 and give digital output to motor driver and LCD display. Arduino UNO board synchronize the temperature of the power generator winding as an input to the Arduino. The input is measured by using the temperature sensors in the analogue form and this gets converted into digital form using Analogue to Digital Convertor (ADC) which is inbuilt in the microcontroller. The predetermined value of the temperature is programmed into the Arduino. The actual input that is the temperature is compared with the predetermined value which is programmed in Arduino. If there any variations occurring in the compared value, then it sends the signal to the driver circuit to automate the coolant fan to control the temperature of the generator.

3.2 Temperature sensor
An authentic IC temperature sensor (LM35) whose analogue output corresponds to temperature (in °C) with a linear scale factor[12] of 10mV is used for temperature monitoring. The sensor is such that it does not need external recalibration. Its circuitry is sealed hence it does not undergo oxidation and self-heating. By using LM35 sensor, the temperature can be evaluated precisely than that of a thermistor. Temperature sensor is used to figure out the heat evolved in winding of the generator in analogue pattern and the data is delivered to the Arduino in digital pattern through an input pin of the chip configured with ADC.

3.3 Coolant fan
The coolant fan is fixed to the Arduino which is connected to the LM35 sensor. Once the temperature of the winding generator exceeds the predetermined value, the coolant fan will be automatically turned on and the temperature will be compensated by the cooling air produced by the coolant fan and it will help to maintain the temperature of the generator.

3.4 Liquid Crystal Display (LCD)
LCD screen is a digital display component that can be interfaced with Arduino. An in-built Liquid Crystal library in Arduino gives control over LCD such that it can be interface with the coded program for display purposes. A 16x2 LCD module has capability to be configured to either 4-bit mode or 8-bit mode. In the project it is configured such that only the 4 input pins to the modules will be used, that is 4-bit mode. The model is chosen because it uses less connections and can be used more effectively compared to 7-segments displays. All these operations are monitored in LCD display which is interfaced with Arduino. It displays the predetermined value of the temperature. In abnormal condition, the variations in the temperature will also be displayed in the LCD display. According to the variations the coolant system is activated, and the status of the coolant system is also displayed.

3.5 Motor driver
A conventional Motor driver (L293D) which is bidirectional can provide current up to 600mA given a voltage range of 4.5V to 36V. It admits DC motor to drive in either direction. L293D16-pin IC is designed with capability to drive and regulate a set of two DC motors together in either direction as it chores on the H-bridge circuit approach[13][14]. Since a single L293D chip consists of two H-Bridge circuits inner to the IC, it can drive two dc motors individually[15]. However, each bridge pair ought to be enabled through the enable pin which keeps it active. H-bridge circuit allows voltage to flow in either of the two directions. The change in direction of the motor is either clockwise or anticlockwise and it is with respect to voltage direction change. H-bridge IC is therefore hypothetical for driving a DC motor. Because of its size and bidirectional drive properties, it is notably used in robotic application and servo motor drives to control the DC motors.
4. Result and Discussion

Arduino’s microcontroller is loaded with a coded one by Arduino IDE software. The code takes charge of the whole system operation, being to monitor, control and regulate all parameters. Furthermore, the microcontroller is separately provided with a set standard temperature value. The 50Hz, 230Vac input is supplied to a step-down transformer and rectified 5Vdc supply is fed to the Arduino through rectifiers and capacitor filters. This is to power up the Arduino pack, LCD, motor and enables the motor driver chip. A parameter from model stator winding is provided as a stimulus to the sensor. Temperature sensed from LM35 is given to the Arduino as analogue input. During simulation in proteus, when there is any variation in the actual value and the standard value then it sends the signal to the driver circuit, either to start cooling or to stop the cooling fan. When temperature exceeds the set threshold value (29°C), Arduino chip gives input pin of the H-bridge a digital signal to drive the motor, hence the coolant fan runs accordingly at 1500rpm to reduce the temperature to normal standard temperature. All these operations are also monitored in LCD display which is interfaced with Arduino in 4-bit mode through data pins DB4, DB5, DB6 and DB7. Simulation diagram of the proposed system is shown in Figure 2. Figure 3 shows the coolant fan at off condition and Figure 4 shows the coolant fan at on condition where the temperature is above the cut in point.

![Simulation diagram of the proposed system](image-url)

**Figure 2.** Simulation diagram of the proposed system
Figure 3. Coolant Fan at Off Condition

Figure 4. Coolant Fan at On Condition

As visualised in Figure 4, when pin 2 is logic HIGH at 5V, the LCD screen goes on. The display contrast is controlled by a 10K potentiometer connector to pin 3 (VEE). Varying the potentiometer controls the current to the background lighting diodes of the screen. Pin 4 is always logic HIGH provided by Arduino output pin 12. This function selects DATA register. When logic LOW, it will go to the COMMAND register. The DATA register allows display of interpreted data through data pins. Furthermore, pin 5 is in logic LOW (connected to ground) to keep the LCD in WRITE mode. Pin 6 of the LCD display is the ENABLE pin, which keeps the module enabled to receive and display. It is at logic HIGH when the system is running. This state is maintained by digital output pin 12 of the microcontroller.

Temperature is measured and monitored continuously using the LCD display as shown in Figure 5. When the temperature of the winding is less than or equal to 29°C then the system is in normal condition. In Figure 6, the temperature is 29°C which is in normal condition. Throughout the normal temperature, the state of the coolant fan is in OFF condition as shown in Figure 6.
At abnormal condition, the winding temperature increases above 29°C and the value of abnormal temperature will be visualised in LCD display as shown in Figure 7 together with the state of the coolant fan. At abnormally high condition the temperature is high, and the value is displayed in the LCD display as shown in Figure 8 through the data pins. At the same time, Arduino operates the driver circuit through digital output pin 7 of microcontroller chip being logic HIGH hence input 1 pin 6 of the motor driver is also logic HIGH and the coolant fan gets activated and runs accordingly until the temperature returns to normal. The photograph of the proposed project hardware module is also shown in Figure 8. Furthermore, LCD display is used to demonstrate the current (based on calculation ratios in the code) and temperature of the winding.
5. Conclusion
The stator cooling system will increase the efficiency of power generator by reducing the heat developed in the winding of the power generator by using cooling air from the coolant fan. This is achieved by automating the coolant system to turn on when the temperature is higher than normal value. The control is done by a coded microcontroller. In this system the stator winding temperature of power generator was fully monitored in the LCD display. Flow of cooling air into the stator will lead to effective control and maintenance of the temperature in the stator winding with more sensitivity.
which prevent overheating in windings in case of any sudden increase in the load of the power generator. When this project is executed, it makes it easier and user friendly to control and monitor temperature of the power generator. The outcome of the project will have more sensitivity and accuracy. The project can be developed further by incorporating measurement, monitoring and control of additional parameters such as stator water flow, stator water conductivity, stator core temperature and implement sealed oil cooling system for both stator and rotor protection from high temperature.

References

[1] Hsu C W and Lin C J 2002 A comparison of methods for multiclass support vector machines IEEE Trans. on Neural Net. 13 2 pp415-25
[2] Passerini A, Pontil M and Frasconi P 2004 New results on error correcting output codes of kernel machines IEEE Trans. on Neural Net. 15 1 pp45-54
[3] Esu O O, Lloyd S D, Flint J A and Watson S J 2014 Integration of low-cost consumer electronics for in-situ condition monitoring of wind turbine blades 3rd Renewable Power Gen. Conf. (Naples) pp1-6
[4] Gungor V C, Lu B and Hancke G P 2010 Opportunities and challenges of wireless sensor networks in smart grid IEEE Trans. on Industrial Electronics 57 10 pp 3557-64
[5] Wang T, He Y, Li B and Shi T 2018 Transformer fault diagnosis using self-powered RFID sensor and deep learning approach IEEE Sens. J. 18 15 pp6399-411
[6] Ravi S, Mezhuyev V, Annapoorani K I and Sukumar P 2016 Design and implementation of a microcontroller based buck boost converter as a smooth starter for permanent magnet motor Indonesian J. of Electrical Eng. and Comp. Sci. 1 3 pp 566-74
[7] Zou S, Lin J, Wang H, Lv H and Feng G 2019 An effective method for service components selection based on micro-canonical annealing considering dependability assurance Frontiers of Comp. Sci. 132 pp264–79
[8] Ravi S and Balakrishnan P A 2010 Temperature response control of plastic extrusion plant using Matlab/Simulink Int. J. of Recent Trends in Eng. and Technol. 3 4 pp 135-40
[9] Ravi S, Rajpriya G and Kumarakrishnan V 2015 Design and development of microcontroller based selective harmonic elimination technique for three phase voltage source inverter Int. J. of Applied Eng. Research 10 13 pp 11562-78.
[10] Halvorsen H P 2018 Programming with Arduino (Norway) ISSN 978-82-691106
[11] Santos J C M, Patino O A and Ortiz S H C 2017 Influence of arduino on the development of advanced microcontrollers courses IEEE revista iberoamericana de tecnologias del aprendizaje 12 4 pp 208-217
[12] Texas 2016 L293x Quadruple half-H drivers Texas instruments incorporated (Texas) pp1-6
[13] Khanna A and Ranjan P 2015 Solar-powered android-based speed control of dc motor via secure bluetooth SihInt. Conf. on Comm. Sys. and Net. Technol. (Gwalior) pp 1244-49
[14] Lapshina P D, Kurilova S P and Belisky A A 2019 Development of an arduino-based CO2 monitoring device IEEE Conf. of Russian Young Researchers in Electrical and Electronics Engineering (EIConRus, Saint Petersburg and Moscow) pp 595-97
[15] Kumar R and Khalkho A N 2016 Design and implementation of metal detector using DTMF technology Int. Conf. on Signal Processing, Comm., Power and Embedded Sys. (SCOPES, Paralakhemundi) pp 368-71
[16] A. A. Stonier, S. Murugesan, R. Samikannu, S. K. Venkatachary, S. Senthil Kumar and P. Arumugam, “Power Quality Improvement in Solar Fed Cascaded Multilevel Inverter With Output Voltage Regulation Techniques,” in IEEE Access, vol. 8, pp. 178360-178371, 2020, doi: 10.1109/ACCESS.2020.302778