Turbine Protection by Using Microcontroller

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Abstract
Protection of turbine generator systems is an important factor that has to be considered in power plant for efficient production of electricity. Turbine protection involves axial shift of turbine shaft, lubricating oil pressure and condenser vacuum. Axial shift measurement is very important to monitor the mechanical balance between the turbine and generator rotor. If there is any variation in the mechanical balance the turbine shaft will be damaged. The lubricating oil is used for the lubricating turbine bearings. It is maintained at the pressure of 1.2 kg/cm². If the Lubricating oil pressure is reduced to below 0.6 Kg/cm² the turbine bearings temperature will increased. The condenser vacuum pressure is considered for turbine protection because it is responsible for steam flow from low pressure turbine to condenser. Condenser vacuum is maintained at -670 mmHg. If there occur decrease of -540 mmHg, a back pressure is created in the Low Pressure Turbine and also Turbine efficiency is reduced. The existing system of protection in turbine generator system is relay and hard wired system. This system has lot of disadvantages such as high power consumption, slower operation rate, high maintenance cost, consists of so much of wires, improper operation at critical stage, is not safer, since using of dc supply. These disadvantages are eliminated by using PIC controller. PIC 16F877A is a controller which is used for the protection of turbine generator system. PIC controller operates at very low voltage and it consumes lesser power. It uses simple user friendly programming and reduces the hardware components. Program used in the PIC can be easily altered and effectively controlled. PIC IC is used for real time monitoring of data that can be done in relay system.

Keywords: Turbine protection, axial shift of turbine shaft, lubricating oil pressure, condenser vacuum pressure, PIC controller
INTRODUCTION

Adequate and Reliable protections shall be provided for safe guarding the various equipments under abnormal and dangerous operating conditions. The Operation of Protections shall be accompanied by visual and audible annunciations which will provide definite indication of the Primary cause of Operation of the Protection. Equipment will be again put into Operation only after elimination of the fault causing the operation of Protection. Turbine protection involves axial shift of turbine shaft, lubricating oil pressure and condenser vacuum. The mechanical balance between the turbine and generator rotor depends upon the axial shift measurement. If the axial shift exceeds – 1.7 mm or + 1.2 mm the turbine has to be tripped and bring the turbine to rest as soon as possible by opening the vacuum breaker. Another important consideration for turbine protection is the lubricating oil which is used for the lubrication of turbine bearings. The pressure of lubricating oil is to be 1.2 Kg/cm\(^2\) at 40\(^\circ\)C and when the pressure is reduced below 0.6 Kg/cm, ACLOP will come in to service with an annunciation of “Lube oil pressure low”. If the lube oil pressure drops to 0.5 Kg/cm, DCLOP will come in to service. If the lube oil pressure further drops to 0.3 Kg/cm, Turbine will trip with an annunciation of “Lube oil pressure very low”. Simultaneously vacuum breaker will open to bring the turbine to rest as quickly as possible. If the set is on barring gear, barring gear motor will trip and also vacuum breaker gets open.

The condenser vacuum pressure is very important for steam flow from low pressure turbine to condenser. Condenser vacuum is maintained at -670 mmHg. If condenser vacuum decreases, steam entered in LPT may not get condensed and thus positive pressure will be developed in the condenser. Exhaust hood temperature may rise drastically. LPT blades may get damaged. If Vacuum drops to – 650 mmHg, “Vacuum low” will be annunciating. If Vacuum further drops to – 540 mm Hg, turbine will be tripped with an annunciation of “vacuum very low”. The range of the turbine speed in plant is 0-4000 rpm. Actual Turbine Speed is 3000 rpm. When the value of the turbine speed exceeds 10% of 3000 RPM (3030 RPM), the turbine was tripped. For protection of these critical parameters of turbine, PIC microcontroller is used since it has many advantages over the existing system. The controller used in this paper is PIC 16F877A. This controller operates at very low voltage and it consumes lesser
It uses simple user friendly programming and reduces the hardware components. Program used in the PIC can be easily altered and effectively controlled. PIC IC is used for real time monitoring of data that can be done in relay system.

EXISTING SYSTEM
The existing turbine protection system consists of Turbovisory relay panel, OPDR (Oil Pressure Device Relay) panel and Turbo supervisory instrumentation panel. These relay contacts are connected with hardwires and protection will activated. OPDR panel consists of 3 Nos of lubricating oil pressure switches and 3 Nos of vacuum switches. Turbovisory instruments panel consist of axial shift measuring and control circuit’s electronic cards and turbine speed sensing electronic cards. Individual protection will operate under the predefined relays [1, 2]. Those relays are connected to so many hard wires. If any fault will occur on turbine protection system, trouble shooting of fault analysis is very difficult and more time to take find out the fault. If any protection relay will fault during plant running condition, the faulty relay replacement is not possible. Now a day’s existing current and voltage operated relays are not available in original manufacturer and open market.

PROPOSED SYSTEM
Turbine lubricating oil pressure value is monitoring with the help of Pressure transmitter. The Pressure transmitter was fitted on the lubricating oil line. 24 V DC power supply connected to Pressure transmitter. The range of that transmitter is 0 to 2.5 Kg/cm2. Normal operating condition the lubricating oil pressure is around 1.2 Kg/cm2. Output of transmitter is 4–20 mA for the selected span range. The mA current output is converted into voltage signal with the help of resistor. The voltage signal is directly connected to analog input pin of microcontroller.

Axial shift sensor is fixed on 2nd bearing of turbine. The measurement range is 0 to 2.5 mm. That sensor is eddy current type sensor. The movement of turbine shaft the corresponding eddy current signal is received from that sensor. This signal is converted into corresponding voltage signal and connected to microcontroller. The proximity signal sensor is fixed on front pedestal of turbine. The rotation of turbine shaft is measured with the help of that proximity sensor. This signal is converted into voltage. The range of turbine speed is 0 to 4000 RPM. Actual turbine speed is around 3000 RPM. RTD is used to measure the temperature of lubricating oil. Resistance is varying with
the temperature. Based on the temperature variation the resistor value will be changed. This unknown resistance value is connected with wein bridge circuit and corresponding current signal will get. This signal is converted into voltage and connected to microcontroller. Vacuum switches are used to measure the Condenser vacuum which is placed in OPDR panel. 3 Nos vacuum switch contacts are connected by 2/3 logics and finally we get two wires are laid between OPDR panel Turbovisory relay panel. Those switches are calibrated by 0 to -760 mmHg range. If the condenser vacuum goes to below -650 mmHg the “Vacuum Low” annunciation will appeared. If the condenser vacuum goes to below -540 mmHg the “Vacuum Very Low” annunciation will appeared and turbine trip circuit coil will energized.

**Block Diagram**

![Block Diagram](image.png)

**Fig. 1: Block Diagram.**

From the Figure, the four digital inputs are SW-1, SW-2, SW-3, SW-4 and they control four relays as,  
- SW-1: Condenser Vacuum Low.  
- SW-2: Condenser Vacuum Very Low.  
- SW-3: Turbine Trip.
• SW-4: Boiler Trip.
Input voltages of all switches are higher voltage. So opto-coupler is used to isolate switch input voltage from low voltage input of microcontroller. Analog inputs are connected to ADC block and converted into digital bits and then connected to microcontroller. Microcontroller digital output is connected to relay driver circuit and operate the individual relay. LCD is directly connected to microcontroller.

Microcontroller
The pin diagram of PIC controller is as shown in the Figure 2. A microcontroller is an integrated chip that is often part of an embedded system. The microcontroller includes a CPU, RAM, ROM, I/O ports, and timers like a standard computer, but because they are designed to execute only a single specific task to control a single system, they are much smaller and simplified so that they can include all the functions required on a single chip [3]. The great advantage of microcontrollers, as opposed to using larger microprocessor, is that the parts-count and design costs of the item being controlled can be kept to a minimum. They are typically designed using CMOS (complementary metal oxide semiconductor) technology, an efficient fabrication technique that uses less power and is more immune to power spikes than other techniques.

![Pin Diagram of PIC 16F877A](image-url)

**Fig. 2: Pin Diagram of PIC 16F877A.**
It has high performance RISC CPU. There are only 35 single-word instructions to learn. All the instructions are single-cycle instructions except for program branches, which are two cycle instructions. Operating speed is of DC – 20 MHz clock input, DC – 200 ns instruction cycle. Up to 8K x 14 words of Flash Program Memory, up to 368 x 8 bytes of Data Memory (RAM) and up to 256 x 8 bytes of EEPROM Data Memory.

**Ports of 16F877A**

PIC 16F877 series normally has five input/output ports. They are used for the input/output interfacing with other devices/circuits. Most of these port pins are multiplexed for handling alternate function for peripheral features on the devices. All ports in a PIC chip are bi-directional. When the peripheral action is enabled in a pin, it may not be used as its general input/output functions. The PIC 16F877A chip basically has 5 input/output ports.

As shown in Figure 3, Port A is a 6-bit wide bi-directional port; the direction of this port is controlled by TRIS A data direction register. Setting a TRIS A (=1) makes corresponding Port A pin as an input, clearing the TRIS A (=0) making the corresponding Port A pin as an output Pin RA4 is multiplexed with the “Timer0”

![Fig. 3: Ports of 16F877A.](image-url)
module clock input to become the RA4/T0CKI pin and functioning either input/output operation or Timer 0 clock functioning module. The RA4/T0CKI pin is a Schmitt Trigger input and an open-drain output. All other Port A pins has TTL input levels and full CMOS output drivers. Other Port A pins in this microcontroller multiplexed with analog inputs and the analog Vref input for both the A/D converters and the comparators.

As in Figure 3, Port B is also an 8 bit bidirectional Port. Its direction controlled and maintained by TRIS B data direction register. Setting the TRIS B into logic ‘1’ makes the corresponding “Port B” pin as an input. Clearing the TRIS B bit make Port B as an output. Three pins of Port B are multiplexed with the In-Circuit Debugger and Low-Voltage Programming function: RB3/PGM, RB6/PGC and RB7/PGD for performing its alternate functions.

Port E has only three pins (RE0/RD/AN5, RE1/WR/AN6 and RE2/CS/AN7) as in Figure 3 which is individually configurable as inputs or outputs [4]. These pins controllable by using its corresponding data direction register “TRIS E”. These pins also have Schmitt Trigger input buffers. In this mode, the user must make certain that the TRIS E bits are set and that the pins are configured as digital inputs. TRISE register which also controls the Parallel Slave Port operation. Port E pins are multiplexed with Analog inputs. When selected for Analog input, these pins will read as ‘0’s. TRIS E controls the direction of the RE pins, even when they are being used as Analog inputs.

Software Used

The software used for simulation is proteus. Proteus (PROcessor for TExt Easy to USE) is a fully functional, procedural programming language created in 1998 by Simone Zanella. Proteus incorporates many functions derived from several other languages: C, BASIC, Assembly, Clipper/dBase; it is especially versatile in dealing with strings, having hundreds of dedicated functions; this makes it one of the richest languages for text manipulation. Transforming data from one form to another is the main usage of this language. Proteus was initially created as a multiplatform (DOS, Windows, Unix) system utility; to manipulate text and binary files and to create CGI scripts [5]. The language was later focused on Windows, by adding hundreds of specialized functions for: network and serial communication, database
interrogation, system service creation, console applications, keyboard emulation, ISAPI scripting (for IIS). Most of these additional functions are only available in the Windows flavour of the interpreter, even though a Linux version is still available. Proteus was designed to be practical (easy to use, efficient, complete), readable and consistent. Its strongest points are:

- Powerful string manipulation.
- Comprehensibility of Proteus scripts.
- availability of advanced data structures: arrays, queues (single or double), stacks, bit maps, sets, AVL trees.

The language can be extended by adding user functions written in Proteus or DLLs created in C/C++. At first sight, Proteus may appear similar to Basic because of its straight syntax, but similarities are limited to the surface:

- Proteus has a fully functional, procedural approach.
- Variables are untyped, do not need to be declared, can be local or public and can be passed by value or by reference.
- All the typical control structures are available (if-then-else; for-next; while-loop; repeat-until; switch-case).
- New functions can be defined and used as native functions.

Data types supported by Proteus are only three: integer numbers, floating point numbers and strings. Access to advanced data structures (files, arrays, queues, stacks, AVL trees, sets and so on) takes place by using handles, i.e. integer numbers returned by item creation functions.

Type declaration is unnecessary: variable type is determined by the function applied – Proteus converts on the fly every variable when needed and holds previous data renderings, to avoid performance degradation caused by repeated conversions. There is no need to add parenthesis in expressions to determine the evaluation order, because the language is fully functional (there are no operators).

Proteus includes hundreds of functions for:

- Accessing file system.
- Sorting data.
- Manipulating dates and strings.
- Interacting with the user (console functions).
- Calculating logical and mathematical expressions.

Proteus supports associative arrays (called sets) and AVL trees, which are very useful and powerful to quickly sort and lookup values. Two types of regular expressions are supported:

- extended (Unix like);
- basic (Dos like, having just the wildcards "?" and "*").
Both types of expressions can be used to parse and compare data. The functional approach and the extensive library of built-in functions allow to write very short but powerful scripts; to keep them comprehensible, medium-length keywords were adopted. The user, besides writing new high-level functions in Proteus, can add new functions in C/C++ by following the guidelines and using the templates available in the software development kit; the new functions can be invoked exactly the same way as the predefined ones, passing expressions by value or variables by reference. Proteus is an interpreted language: programs are loaded into memory, pre-compiled and run; since the number of built-in functions is large, execution speed is usually very good and often comparable to that of compiled programs. One of the most interesting features of Proteus is the possibility of running scripts as services or ISAPI scripts.

Running a Proteus script as a service, started as soon as the operating system has finished loading, gives many advantages:

- No user needs to login to start the script.
- A service can be run with different privileges so that it cannot be stopped by a user.

This is very useful to protect critical processes in industrial environments (data collection, device monitoring), or to avoid that the operator inadvertently closes a utility (keyboard emulation). The ISAPI version of Proteus can be used to create scripts run through Internet Information Services and is equipped with specific functions to cooperate with the web server. For intellectual property protection Proteus provides:

- Script encryption.
- Digital signature of the scripts, by using the development key (which is unique).
- The option to enable or disable the execution of a script (or part of it) by using the key of the customer.

Proteus is appreciated because it is relatively easy to write short, powerful and comprehensible scripts; the large number of built-in functions, together with the examples in the manual, keeps low the learning curve. The development environment includes a source code editor with syntax highlighting and a context-sensitive guide. Proteus does not need to be installed: the interpreter is a single executable (below 400 Kb) that does not require additional DLLs to be run on recent Windows systems.
Operation
The power supply for the kit is given using 230/12 v transformer. The four Analog inputs for the controller are given using the four potentiometers respectively. The digital inputs are designed as switches which are connected to microcontroller through opto coupler devices [6]. Initially four analog parameter values are displayed on first line of LCD. By varying the variable resistor the corresponding values are changed. Increasing axial shift (first from controller) value to above 1.75 mm the turbine trip relay will operate. By decreasing the lubricating oil pressure (second from controller), that value goes below 0.6 Kg/cm² AC LOP will start. If any starting problem in AC LOP motor, the lubricating oil pressure further goes to below 0.5 Kg/cm² DC LOP will start. DC source problem or any DC Motor problem DC LOP will not start. In this case lubricating oil pressure further drops to below 0.3 Kg/cm² the turbine will trip on lubricating oil pressure very low. LM35 sensor is directly connected to
microcontroller analog input. Based on the room temperature mV output from LM35 sensor and processed in controller and display the temperature in LCD. Turbine speed increase from corresponding analog input, turbine speed goes to above 3030 RPM (10% of rated speed) turbine over speed will acted and turbine will trip. The power supply for the kit is given using 230/12 v transformer.

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13Nos of Boiler protections and 10 Nos of turbine protections are available in thermal power plant. The simulation done is as shown in Figure 4. The very important 3 turbine protections are studied and tested in this paper. If any boiler protections or other than (except three) turbine protections are simulated in fourth and fifth digital inputs the turbine trip relay will operate.

CONCLUSION
The turbine critical parameters such as axial shift value, Lubricating oil pressure low and very low, Lubricating oil temperature high and turbine over speed values are individually monitored. Condenser vacuum low and Very low
digital inputs are checked and turbine trip relay operation was checked. When the parameters exceed the set point, preferred actions will be taken with the help of simulation software. The controller used here is PIC 16F877A which is used to overcome the demerits obtained by the relay system. The controller helps to maintain the parameters by instructing with appropriate changes. Thus the disadvantages such as high power consumption, slower operation rate, high maintenance cost, more number of wires, and improper operation at critical stage are eliminated.

FUTURE SCOPE
In this paper only a single microcontroller is used for monitoring and controlling turbine parameters. In future data storage of all parameters and fault messages are stored in external memory. In addition to communicate all process parameters are serial communication with RS232 to computers.

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