CHAPTER ONE

INTRODUCTION

1.1 General Review

Automatic control system is situated among different aspect of applied branches of knowledge since it controls the production units in different industries. It controls different types of vehicles and equipments. Steam turbine owners are being confronted with complex operating processes brought on by deregulation. In order to compete in today's electrical power market place and meet these complex operating conditions. Steam turbine owners have begun to retrofit their steam turbine control systems with modern control platforms. Because these modern control platforms provide better control of the steam turbine, the flexibility to meet the demands of the market can be obtained. The control system design is critical to optimize availability and reliability while minimizing impact on maintenance and capital budgets. Issues such as turbine performance, controls integration and future upgrades are sometimes overlooked when implementing a turbine control system modification. This project presents examples of steam turbine control system design and integration and offers recommendations for a successful steam turbine control upgrade [1].

1.2 Problem Statement

The steam temperature must not exceed above $530C^0$ to achieve peak turbine efficiency and reduce fatigue in the turbine blades. If the temperature become above $530C^0$, the steam will be recycling or the turbine run on no load for a period of 3 minutes.

1.3 Objective

The primary objective in the steam turbine operation is to maintain a constant speed of relation irrespective of the varying load. This can be achieved by names of governing in a steam turbine.

1.4 Methodology

(1) Study the previous works.

(2) Study and understand the turbine.

(3) Study microcontroller.

(4) Study the PROTUS software.

(5) Evaluate performance of system based on simulation results.

1.5 Thesis Outline

This research consists of five chapters as follows:

Chapter two: Presents the previous study and general overview about the techniques used to control steam turbine temperature. Chapter three: presents definition of control system and microcontroller specification, the main steam turbine part and desuperheating system. Chapter four gives Simulation results under different values of temperature. Chapter five consists of conclusion and proposes recommendations for future work.

CHAPTER TWO
TURBINE AND CONTROL SYSTEM

2.1 Previous Study

Several research works recently have discussed the control steam turbine temperature by using different types of control systems .This study [2] is about recovery boiler reheat steam cycle. High electricity costs and incentives for renewable energy are driving pulp companies to improve the power generating potential of their mills. In Japan, where energy costs have traditionally been high, recovery boilers have been built that run superheat cycles with pressures and temperatures as high as 1915 psig (132 bar) and 960 F (515C). In north america there are boilers that have operating conditions of 1550 psig (107 bar) and 925F (496C), but approximately 60% of the recovery boilers in North America operate at or below 900 psig (62 bar). Since the 1960s, electrical generating utilities have operated natural circulation boilers in excess of 2600 psig (180 bar) at the superheater outlet. These utility boilers operate with superheater and reheater temperatures from 1000 to 1055 F (538 to 568C). The reheat cycle greatly improves thermal efficiency of the power generation cycle. Utility boiler experience applied to a pulp mill steam cycle would greatly improve the electrical power generation potential of a pulp mill steam cycle. Babcock and Wilcox Power Generation Group has made developments in the recovery boiler design that will allow a recovery boiler to operate at utility pressures and with reheat steam cycles. This study [3] is about reheat steam temperature control concept in once -through boilers - a review. In once through boilers, superheated steam temperature is controlled by means of coordinated feed water flow and spray attemperation. For reheat (RH) steam temperature control, many methods are being adopted namely burner tilt, gas recirculation, divided back pass dampers, excess air and steam bypass as primary control and feed water attemperation is envisaged as emergency control. When the boiler is operated in sliding pressure mode the cold reheat steam temperature is higher compared to constant pressure operation. The adjustment required for maintaining constant reheat outlet temperature is larger in constant pressure operation mode. In general spray is not used for RH steam temperature control for boilers designed for constant pressure operation since the spray quantity required will be large and its impact on plant heat rate. In Europe utility boilers are operated under sliding pressure mode and hence RH steam temperature control by spray is a common practice especially for once-through boilers. This paper deals with the benefits and losses of using spray for RH steam temperature control in lieu of other control mechanisms .

This study [4] about advanced control of Steam superheat temperature on a utility boiler**.** Steam superheat temperature control is critical to the efficient operation of utility boiler steam turbines. Traditional Proportional-Integral-Derivative (PID) controllers are difficult to apply in this application due to significant time delay and changing process dynamics as a function of turbine load. This paper describes the application of a predictive adaptive model based controller (Brain Wave) on a 430 MW Utility Boiler to control steam superheat temperature.

2.2 A Steam Turbine

A steam turbine is a rotary type of steam engine, having a rotating wheel to which is secured a series of buckets, blades or vanes, uniformly spaced on its periphery. Steam from nozzles or a guide passage is directed continuously against these buckets, blades or vanes, thus causing their rotation. Expansion of steam in the nozzles or buckets converts its heat energy into energy of motion and gives it a high velocity which is expended on the moving wheel or buckets. The difference in the various types of steam turbines is due to different methods of using the steam. depending upon the construction and arrangement of the nozzles, steam passages and buckets. The steam turbine is essentially a high speed machine. It is used to advantage with direct connection to electric generators, centrifugal pumps and compressors and with geared connections to rolling mills, fans and other machinery which are run at low speed.The advantages of steam turbines are: comparatively low initial cost, low expense for maintenance small floor space, large overload capacity, and exhaust steam is free of oil contamination as no internal lubrication is needed and high efficiency over a wide range of load conditions. The steam turbine can be built in a unit of much greater capacity than is practical with the reciprocating steam engines [5].

2.3 Classification of Steam Turbines

According to action of the steam turbine there are two type of turbine classification which is impulse types and reaction types.

2.3.1 The Impulse Type Steam Turbine

In the impulse type steam turbine, the expansion and consequent change in the pressure of the steam occurs entirely within the nozzles which direct the steam in jets against the moving buckets. In as much as the expansion of steam takes place in the nozzles, the clearance between the rotating and stationary surfaces is greater than in the reaction type steam turbine [5].

2.3.2 The Reaction Type Steam Turbine

In the reaction type steam turbine, the expansion and consequent change in pressure of the steam occurs entirely in the blading where the steam is directed against the moving buckets or blading by guide valves or orifices. The expansion of the steam takes place through both the stationary and moving guide vanes, and therefore the clearance space between the stationary and moving surfaces is very small to cut down on the pressure drop by leakage between stages to a minimum [5].

2.4 Steam Turbine Parts

All steam turbines have the same basic parts, though there is a lot of variation in how they are arranged.

2.4.1 Thrust Bearings and Squealer Rings

Thrust bearings should be checked for wear and clearance. The smaller impulse turbines have roller thrust bearings with specially hardened steel washers. These should be very carefully inspected as the clearance is close. Any bearings of this type which show even minute pitting or roughness of the rollers or any cutting or galling on the hardened washers should be replaced. In reality these are not thrust bearings, but only serve to maintain shaft position since there is not axial thrust transmitted to the shaft on impulse turbines [6].

2.4.2 Shaft Couplings

Shaft couplings connecting steam turbines to driven machines are usually of the flexible type. Turbine manufacturers use several designs of flexible couplings, usually of the jaw, pin or gear type. Lubrication is a matter of extreme importance with all flexible couplings, as lack of sufficient and proper lubricant will cause excessive wear. Wear and the lubrication of couplings should be checked at each inspection and in no case less than once each year [6].

2.4.3 Turbine Bleeder

Steam turbines are often designed to extract steam at definite pressures from one or more points along the expansion cycle. This is done on either the impulse or the reaction machine with the turbine acting as a reducing valve and at the same time driving a machine. Where steam is taken off from the turbine for process work non return valves are required at the turbine just in case that there may be a live steam connection somewhere in the plant to prevent a backup of steam into the turbine, which would allow it to over speed, and being beyond the main steam inlet the governor would have no control over the speed and a runaway would result [6].

2.4.4 The Governor

Only a relatively short period of time is required to dangerously accelerate the rotor of a steam turbine. Therefore when the governor fails, the rotor is subject to the danger of a "run away" or in other words instant over speeding. To guard against this hazard the turbine is provided with an emergency governor which shuts off the steam to the turbine when normal speed is exceeded by 10% most emergency governors (also referred to as over speed trip) consist of a small piston located in a recessed opening in a collar mounted on the main shaft of the turbine .Centrifugal force of the turbine over speeding causes the piston to move outward where it contacts a trip lever as it emerges from the recess which in turn actuates the quick closing emergency valve shutting off the steam supply to the turbine. Movement of the piston is opposed by a spring the tension of which is adjustable to obtain the desired tripping speed [6].

2.4.5 Gland Seal

Regardless of whether a steam turbine utilizes carbon rings or the labyrinth metallic packing to seal the shaft there is going to be some degree of leakage past these seals depending upon the clearance between the shaft and the seal. On a condensing turbine this gland seal leak-off is piped to the condenser during normal operation and vented to atmosphere during startups and shutdowns to prevent it from escaping into the turbine room.

Non condensing impulse turbines normally have very little steam seal leak-off, so it is usually allowed to emit from the carbon packing cases and into the turbine room. This is usually only a wisp of steam and allows the turbine operator to visually determine the degree of wear on the carbon rings. This is the usual mode with an impulse type turbine exhausting into very low pressures such as a deaerator or low pressure heating system [6].

2.4.6 The Steam Strainer

A steam strainer should be installed in the main steam line to the turbine to prevent foreign particles from being carried into the turbine with the steam. It is therefore an important accessory steam strainers are normally installed ahead of and close to the throttle valve some are an integral part of the governor/throttle valve assembly. When installed as a separate part of the unit, the grid is usually accessible for cleaning without breaking any piping connections [6].

Figure 2.1 show explain main part of turbine [6].

2.4.7 Main stop valve

It is valve through which steam passes to the turbine blades, by controlling this valve steam flow can be controlled. Each main stop valve consists of valve disk, valve steam and hydraulic actuator. The hydraulic actuator contains a piston and a compression spring. Since the valve disk and steam are connected to the piston, movement of the piston causes movement of the valve disk. During normal turbine operation, hydraulic oil is directed into or out of the hydraulic actuator. Directing oil into the actuator opens the valve and compresses the spring. As long as amount of oil in actuator is held constant, the valve will remain in the same position. Bleeding oil from the actuator allows the spring to push on the piston, closing the valve. Tripping the turbine causes hydraulic oil to be bled quickly from beneath the piston, allowing the spring to quickly shut the valve. Steam pressure also helps to close the valve by forcing the disc back toward the seat. When the valve is closed the flow of steam toward the High Pressure (HP) turbine is shut off [6].

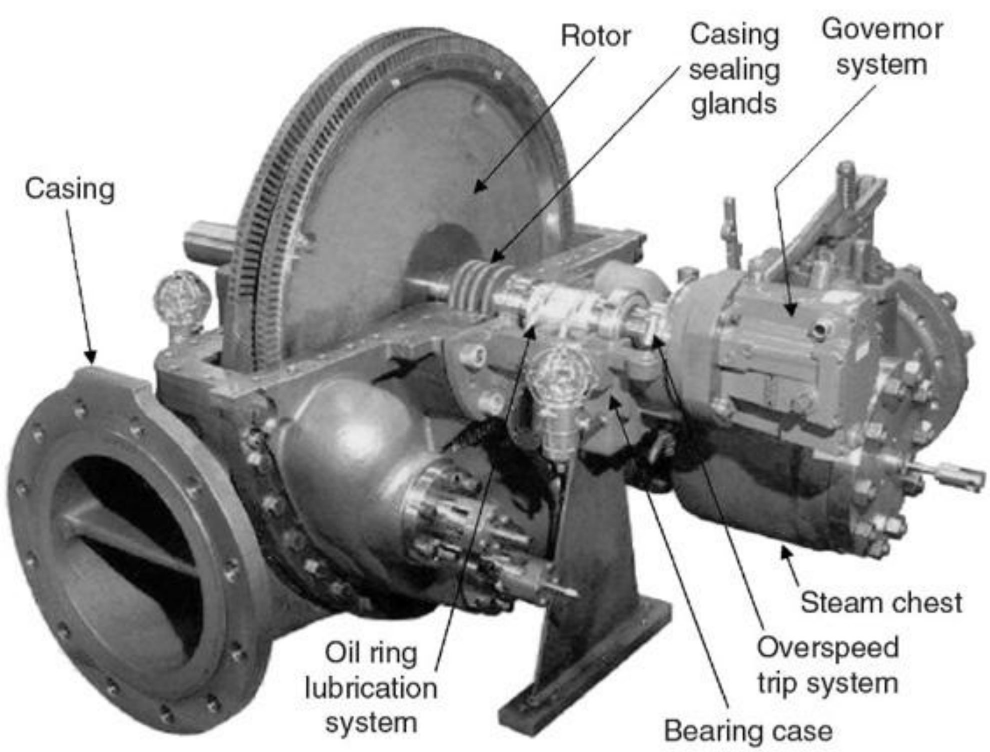

Figure 2.1: The main parts of steam turbine cutaway

2.5 Control System

Control system is an interdisciplinary field covering many areas of engineering and sciences. Control system is an interconnection of components forming a system configuration that will provide a desired system response. Hence, a control system is an arrangement of physical component connected or related in such a manner as to govern itself or another system. An efficient control system enhances the productivity of components by providing fine control over the desired range. In the nature everything is controlled or otherwise leads to catastrophic manner which creates a huge damage. In the same way in and around you everything is controlled by some component to ensure the stability. For example a light in a room is controlled by an electric switch. When a switch is on electricity flows and the light will be on, same for the reverse operation. The basic of control system consists of three components:

1. Input.
2. Logic operation.
3. Output or decision device.

Input is the cause parameter on which the control system acts, the logic operation is the intended or desired operation to perform on the input for generating a new output state, and the output is drive parameter which actuates the end component to perform the desired task. These can be open loop or closed loop control system depends on output feedback. Block diagram reduction helps in analysis and simplification of control system [7].

2.5.1 Open Loop and Closed Loop System

There are two common classes of control systems, open loop control systems and closed loop control systems. In open loop control systems output is generated based on inputs. An open-loop control system utilizes an actuating device to control the process directly without using feedback as shown in Figure 2.2.

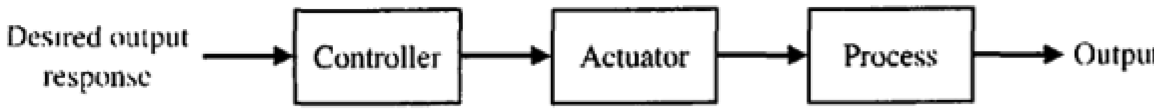

Figure 2.2: Open loop control system

In closed loop control systems current output is taken into consideration and corrections are made based on feedback. A closed loop system is also called a feedback control system. The human body is a classic example of feedback systems**.** A closed-loop control system uses a measurement of the output as feedback of this signal to compare it with the reference or command signal as illustrated in Figure 2.3.

In the case of linear feedback systems, a control loop, including sensors, control algorithms and actuators, is arranged in such a fashion as to try to regulate a variable at a set point or reference value. An example of this may increase the fuel supply to a furnace when a measured temperature drops. Control systems that include some sensing of the results they are trying to achieve are making use of feedback and so can, to some extent, adapt to varying circumstances. Open-loop control systems do not make use of feedback, and run only in pre-arranged ways [7].

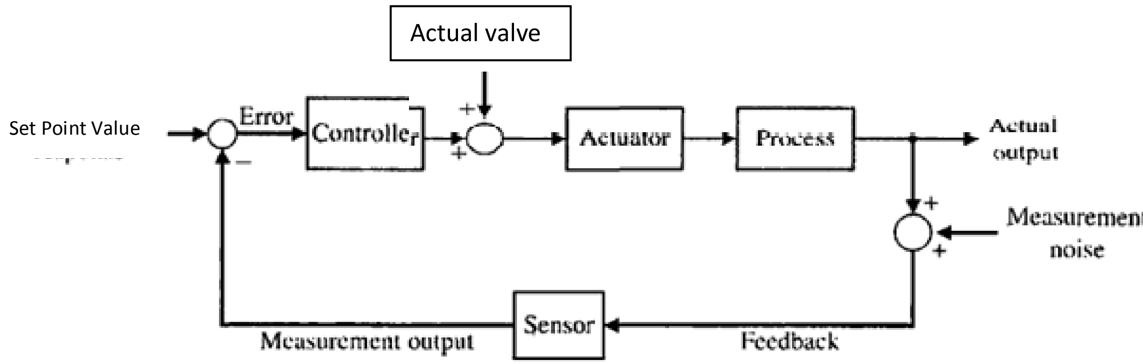

Figure 2.3: Closed-loop feedback system with external disturbances and measurement noise

2.5.2 Classical and Modern Control System

There are essentially two methods to approach the problem of designing a new control system: the classical approach, and the modern approach. Classical and Modern control methodologies are named in a misleading way, because the groups of techniques called “Classical” were actually developed later than the techniques labeled "Modern". However, in terms of developing control systems, Modern methods have been used to great effect more recently, while the classical methods have been gradually falling out of favor. Most recently, it has been shown that classical and Modern methods can be combined to highlight their respective strengths and weaknesses.

Classical Methods are methods involving the Laplace Transform domain. Physical systems are modeled in the so-called time domain, where the response of a given system is a function of the various inputs, the previous system values, and time. As time progresses, the state of the system and its response change. However, time-domain models for systems are frequently modeled using highorder differential equations which can become impossibly difficult for humans to solve and some of which can even become impossible for modern computer systems to solve efficiently. To counteract this problem, integral transforms, such as the Laplace Transform and the Fourier Transform, can be employed to change an Ordinary Differential Equation (ODE) in the time domain into a regular algebraic polynomial in the transform domain. Once a given system has been converted into the transform domain it can be manipulated with greater ease and analyzed quickly by humans and computers like. Modern control methods, instead of changing domains to avoid the complexities of time-domain ODE mathematics, converts the differential equations into a system of lower order time domain equations called state equations, which can then be manipulated using techniques from linear algebra [8].

2.6 Microcontroller

A microcontroller (sometimes abbreviated µC, uC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of ferroelectric Random Access Memory (RAM), flash or Read Only Memory (ROM) is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to microprocessors used in personal computers or other general purpose applications. Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, band input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems. Some microcontrollers may use four-bit words and operate at clock rate frequencies as low as 4 kHz, for low power consumption (single-digit milliwatts or microwatts). They will generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping Central Processing Unit (CPU) clock and most peripherals off may be just nanowatts, making many of them well suited for long lasting battery applications. Other microcontrollers may serve performance-critical roles, where they may need to act more like a Digital Signal Processor (DSP), with higher clock speeds and power consumption [9].

2.6.1 Higher Integration

Microcontrollers may not implement an external address or data bus as they integrate RAM and non-volatile memory on the same chip as the CPU. Using fewer pins the chip can be placed in a much smaller, cheaper package. Integrating the memory and other peripherals on a single chip and testing them as a unit increases the cost of that chip, but often results in decreased net cost of the embedded system as a whole. Even if the cost of a CPU that has integrated peripherals is slightly more than the cost of a CPU and external peripherals, having fewer chips typically allows a smaller and cheaper circuit board, and reduces the labor required to assemble and test the circuit board, in addition to tending to decrease the defect rate for the finished assembly. A micro-controller is a single integrated circuit, commonly with the following features:

central processing unit - ranging from small and simple 4 bit processors to complex 32- or 64-bit processors volatile memory (RAM) for data storage ROM, EPROM, EEPROM or Flash memory for program and operation parameter storage discrete input and output bits, allowing control or detection of the logic state of an individual package pin serial input/output such as serial ports Universal Asynchronous Receiver/Transmitter (UARTs) other serial communication sinter faces like integrated circuit, Serial peripheral interface and controller area network for system interconnect peripherals such as timers, event counters, pulse width modulation generators, and watchdog clock generator - often an oscillator for a quartz timing crystal, resonator or resistor-capacitor circuit (RC) many include analog-to-digital converters, some include digital-to-analog converters in-circuit programming and debugging support , This integration drastically reduces the number of chips and the amount of wiring and circuit board space that would be needed to produce equivalent systems using separate chips. Furthermore, on low pin count devices in particular, each pin may interface to several internal peripherals, with the pin function selected by software. This allows a part to be used in a wider variety of applications than if pins had dedicated functions. Micro-controllers have proved to be highly popular in embedded systems since their introduction in the 1970s.

Some microcontrollers use a Harvard architecture: separate memory buses for instructions and data, allowing accesses to take place concurrently. Where a harvard architecture is used, instruction words for the processor may be a different bit size than the length of internal memory and registers. The decision of which peripheral to integrate is often difficult. The microcontroller vendors often trade operating frequencies and system design flexibility against time-to-market requirements from their customers and overall lower system cost. Manufacturers have to balance the need to minimize the chip size against additional functionality. Microcontroller architectures vary widely. Some designs include general-purpose microprocessor cores, with one or more ROM, RAM, or input/output functions integrated onto the package. Other designs are purpose built for control applications. A micro-controller instruction set usually has many instructions intended for bit-wise operations to make control programs more compact. For example, a general purpose processor might require several instructions to test a bit in a register and branch if the bit is set, where a micro-controller could have a single instruction to provide that commonly required function. Microcontrollers typically do not have a math coprocessor, so floating point arithmetic is performed by software [10].

2.6.2 Atmel Microcontrollers

Atmel microcontrollers deliver a rich blend of efficient integrated designs, proven technology, and groundbreaking innovation that is ideal for today's smart, connected products. In this era of the Internet of Things microcontrollers comprise a key technology that fuels machine to machine communications. Building on decades of experience and industry leadership, Atmel offers proven architectures that are optimized for low power, high-speed connectivity, optimal data bandwidth, and rich interface support. By using our wide variety of configuration options, developers can devise complete system solutions for all kinds of applications.Atmel microcontrollers can also support seamless integration of capacitive touch technology to implement buttons, sliders, and wheels . In addition, Atmel microcontrollers deliver wireless and security support. No matter what your market or device, atmel offers a compelling solution that is tailored to your needs today and tomorrow [11].

2.6.3 Applications for Atmel Microcontrollers

- Automotive
- Building Automation
- Home Appliances
- Home Entertainment
- Industrial Automation
- Lighting
- Smart Energy
- Mobile Electronics
- PC Peripherals
- Internet-of-Things

Figure 2.4 and Figure 2.5 show the microcontroller and its pin configuration, respectively [11].

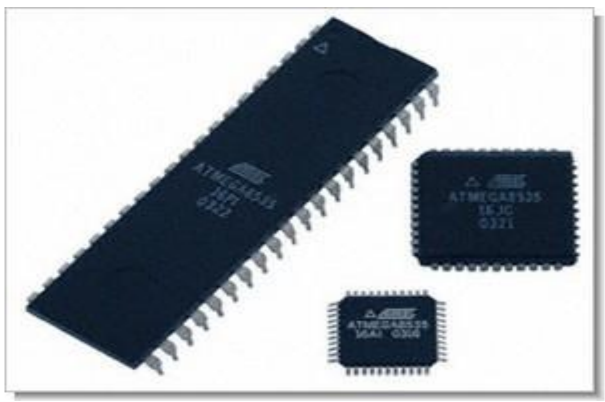

Figure 2.4: Microcontroller

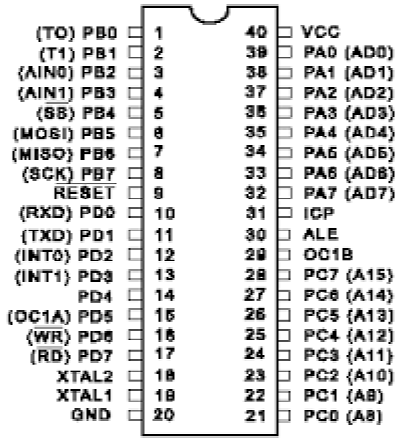

Figure 2.5 : Microcontroller pin configuration

CHAPTER THREE

THERMAL SYSTEM

3.1 Introduction

Temperature control system is found in a host of commercial products and many environments. The concepts of temperature and heat are encountered in almost all engineering systems. Thermal systems transfer or store thermal energy by virtue of temperature and heat flow rate. The thermal effects are conduction, convection, radiation and heat storage capacity. Thermal systems have a static and dynamic behavior similar to mechanical, electrical and fluid systems, but in some ways they are quite different. A thermodynamic system is the part of the physical world that the observer selects to analyze separately from the rest; in between a frontier is defined through which mass and energy exchanges are precisely identified: an isolated system has no interaction with the rest, a closed system may only exchange heat and work and an open system may also exchange mass, fluids are frequently used to transfer heat from one location to another. A thermal system, on the contrary, is a complex assembly of coupled components (some of them thermal), showing a common structured behavior. Thermal systems usually demand some services as electrical supply (for power or at least for control), water intake and exit, air intake and exit, fuel supply and flue stack, etc. Thermal systems exhibit resistance and capacitance effects can be analyzed by circuit analysis and have dynamic responses that can be characterized by time constant. The analyses of thermal systems often require combination of three technologies which is thermodynamics, heat transfer and fluid mechanics [12].

3.2 Steam Superheat Temperature Control

Steam superheat temperature control is a textbook problem for the operators of utility boilers. Steam temperature must be stable to achieve peak turbine efficiency and reduce fatigue in the turbine blades. Adjusting the amount of water that is sprayed into the steam header after the steam has passed through the super heater controls the steam temperature.

3.3 Process Description

After diverted out from drum, saturated steam enters back-end shaft cage front wall header, flows through cage front wall, cage side wall (left wall and right wall) and rear wall, concentrates into inlet header of low temp. super heater and cools down its pipe group, enters platen super heater from two sides, then return to high temp. super heater of back-end shaft. Finally eligible steam is diverted out from one side of high temp. Super heater outlet header. Flexible spray attemperator is adopted by super heater system as a measure of steam temperature modulation and heating surface tubes protection. The whole super heater system is furnished with two-level spray: attemperator I (one for each side) is configured in the pipe between low temperatures. Super heater outlet and platen super heater inlet as the first adjustment; attemperator II (one for each side) is configured in the pipe between high temperatures. Super heater and platen super heater as the second adjustment. Both of the two-level spray attemperators above can eliminate steam temperature difference of two sides (left and right) by adjusting spray water flow of two sides as shown in Figure 3.1 [13].

3.3.1 Open-Loop Control

- Interlocking close following valve when Main Fuel Trip (MFT) occurs boiler spray water header motor-operated valve.
- Steam vent valves and drain valves adopt automatic mode [13].

3.3.2 Closed-Loop Control

Main steam temperature control is based on a cascaded scheme where the primary controller gives the remote set point to the secondary controller. The secondary controller's output sets the position of the spraying control valve.

Two-level attemperators are configured at two sides (left and right), so there are four independent steam temperature control system:

- Left main steam temperature control system.
- Right main steam temperature control system.
- Left platen super heater outlet temperature control system.
- Right platen super heater outlet temperature control system.

In left (right) main steam temperature control system, measured value of main controller is left (right) main steam temperature measured value of sub controller is the temperature behind left (right) attemperator II. In left(right) platen super heater outlet temperature control system, measured value of main controller is left (right) platen super heater outlet temperature measured value of sub controller is the temperature of left (right) attemperator I [13].

3.4 Desuperheating System

Temperature control system includes temperature sensor, temperature transmitter, controller, a current to pressure converter, temperature gauges, etc. Spray water quantity required for the temperature reduction of the steam is controlled by separate spray water valve. The spray water control-element turndown requirement is influenced by variations in supply water pressure, steam pressure, and nozzle backpressure, which in combined-cycle power plants can be extreme. The last varies with flow demand the variation in differential pressure across the operating range may require a spray water flow-control element with extremely high turndown capability. A heat exchanger used to lower the temperature of superheated steam in a boiler unit or before a turbine. Changes in a boiler unit's operation may lead to wide variations in the temperature of the superheated steam; a desuperheater then becomes necessary to prevent excessive superheating of the steam super heater or to maintain the steam turbines normal working conditions. A desuperheater is usually installed either in the intermediate header, which receives partially superheated steam, or at the point where the steam leaves the super heater. The steam is cooled by a water feed that removes heat from the steam. The water feed passes through the tubes of the heat exchanger in shell-and-tube-type desuperheaters, whereas in other desuperheaters it is directly injected [13].

3.5 Desuperheater Type

There are basically two type of desuperheater :

3.5.1 Indirect Type

The medium used to cool the superheated steam does not come into direct contact with it. cooler liquid or gas may be employed as the cooling medium, this type of desuperheater consists of a heat exchanger typically a shell and tube, here the superheated steam is supplied to one side of the heat exchanger and a cooler medium is supplied to the other side. As the superheated steam passes through the heat exchanger, heat is lost from the steam and gained by the cooling medium. The indirect desuperheater type as shown in Figure 3.2 [14].

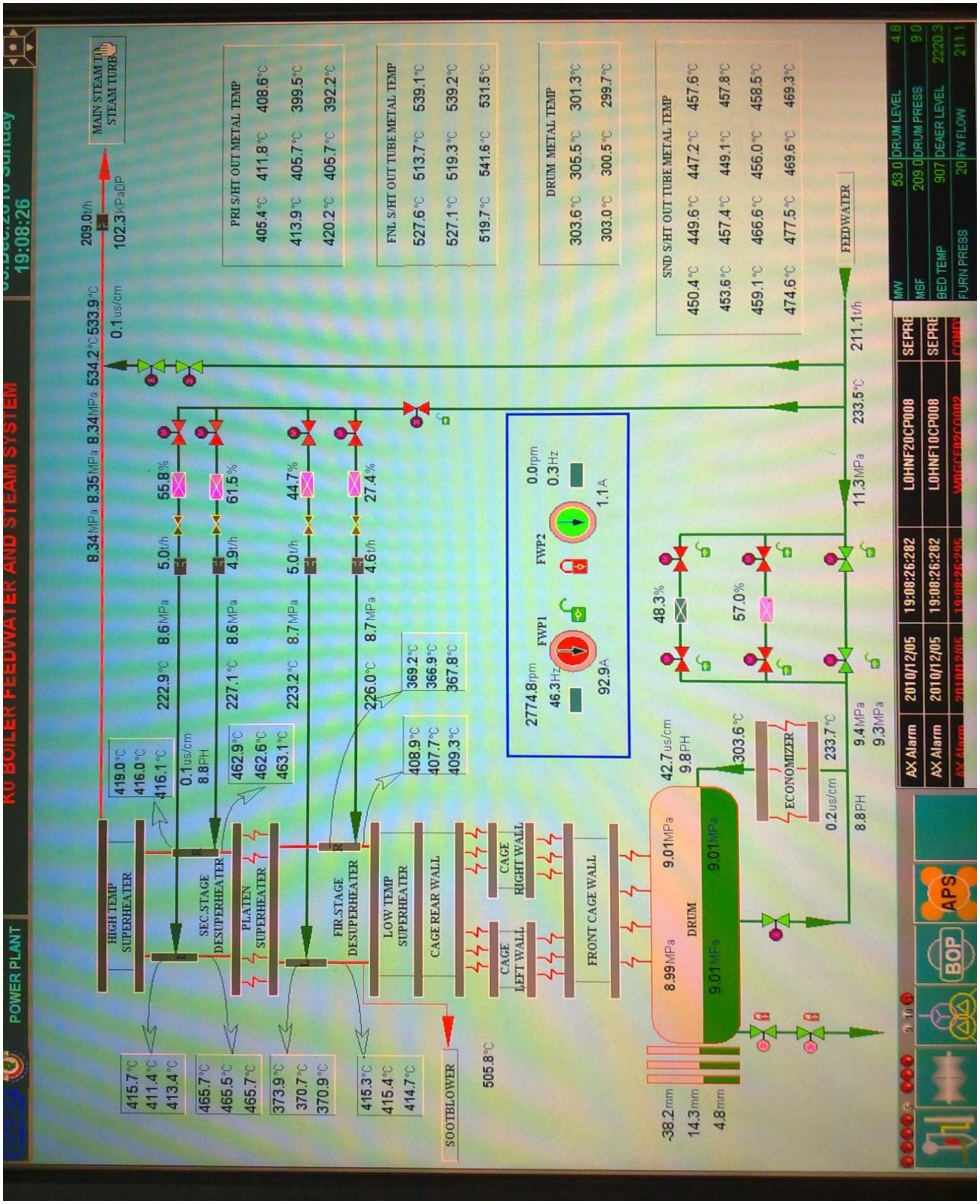

Figure 3.1: Steam superheat temperature control process description

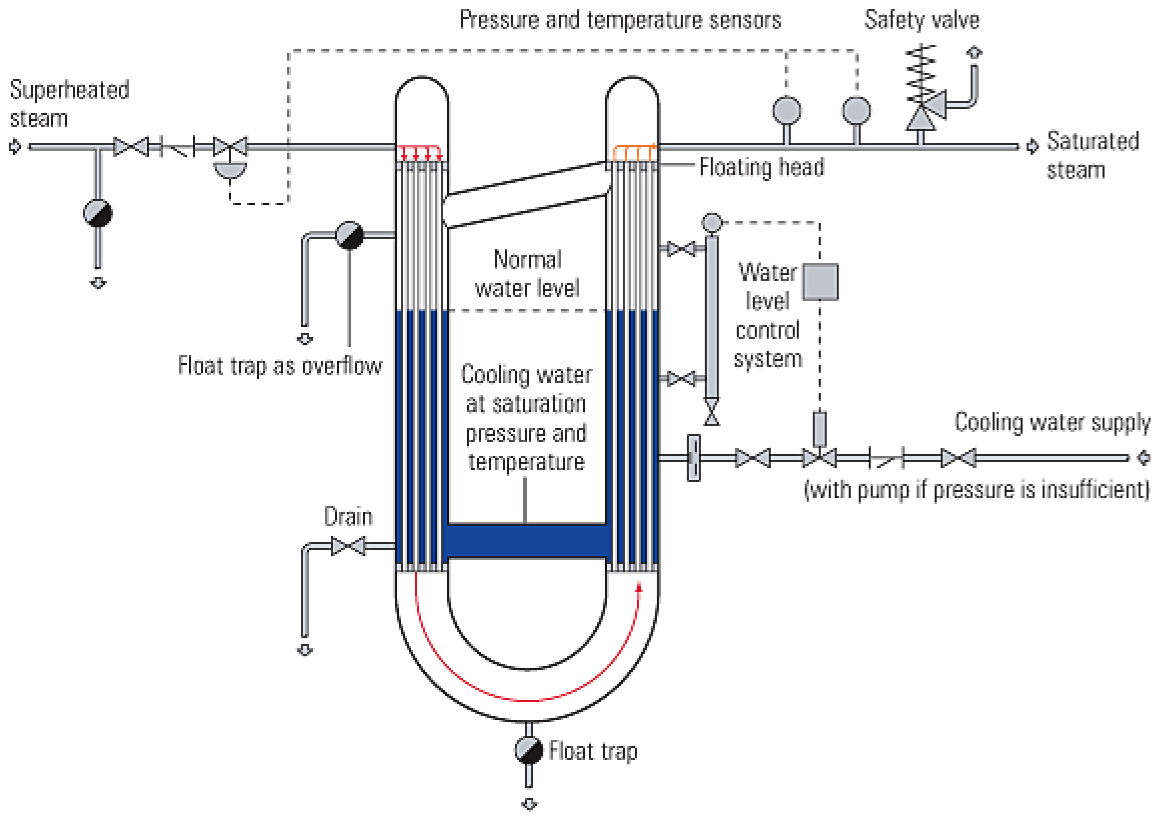

Figure 3.2: A typically indirect shell and tube desuperheating type

3.5.2 Direct Type

The medium used to cool the superheated steam comes into direct contact with it. In most case the cooling medium is the same fluid as the vapour to be desuperheated, but in the liquid state .In the case of steam desuperheaters water is used a measured amount of water is added to the superheated steam via a mixing arrangement within the desuperheater. As it enters the desuperheater, the cooling water evaporates by absorbing heat from the superheated steam, consequently the temperature of the steam is reduced, as shown in Figure 3.2 [14].

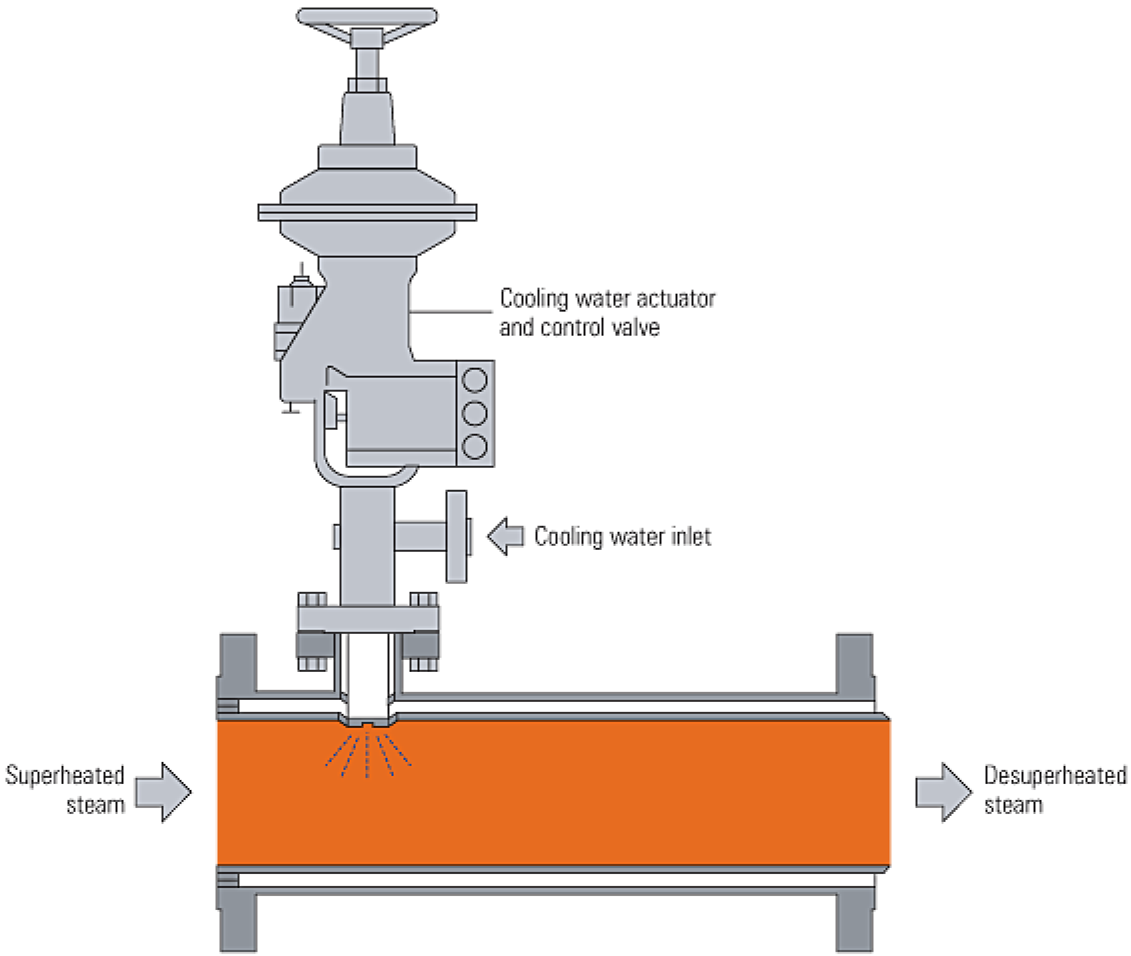

Figure 3.3 A typical direct contact desuperheating type

3.6 Factor affected on the water spray desuperheaters

Water spray desuperheaters are affected by the following factors:

3.6.1 Particle size

The smaller the water particle size, the greater the ratio of surface area to mass, and the higher the rates of heat transfer. Since the water is being directly injected into the moving superheated steam, the smaller the particle size, the shorter the distance required for heat exchange to take place the water is broken into small particles using either a mechanical device (such as a variable or fixed [15].

3.6.2 Pipeline Size

Also important is the size of the pipeline in relationship to the amount of required spray water. Large amounts of spray water in small pipelines can lead to water impingement on the pipe wall and subsequent fallout. Still, desuperheating steam in large pipelines can be challenging because establishing a homogeneous mixture of steam and injected water is difficult. This mixing challenge leads to inaccurate temperature measurements and subsequently, poor temperature control [15].

3.6.3 Turbulence

As the flow within the pipeline becomes more turbulent, the individual entrained water particles reside longer in the desuperheater, allowing for greater heat transfer. In addition, turbulence encourages the mixing of the cooling water and the superheated steam. Increased turbulence results in a shorter distance being required for complete desuperheating to occur [15].

3.6.4 Pressure Drop Across the Nozzle

Subjecting the cooling water to a higher pressure drop will increase its velocity and induce greater turbulence. The amount of pressure differential between the spray water and the steam is very important for both water atomization and the range ability between maximum and minimum water flows. The maximum pressure differential, along with spray water temperature and spray nozzle design, directly affects atomization to the smallest droplet size: the smaller the droplet, the more rapid the vaporization. Additionally the greater the pressure differential the greater the spray nozzle's range ability to reach lower water flow situations through continued acceptable differential levels.

Note also with caution that potential flashing issues exist both in the spray water control valve and at the nozzle. Flashing of the spray water as it exits the nozzle is beneficial. However, flashing upstream in either the valve or just before the nozzle, drastically inhibits performance and may damage both pieces of equipment [15].

3.6.5 Spray Water Temperature

The temperature of the spray water is critical to rapid vaporization and conversion into steam. Hotter water vaporizes faster than cooler water for two reasons. First, the hotter water is closer to its saturation temperature so it requires less heat input from surrounding steam, and therefore, less time to vaporize. Note that an increase in the amount of hot spray water is required compared to cold water and the reduction in evaporation is more favourable than water flow increase. The second, more subtle reason for using hotter water is that at higher temperatures, hot water atomizes into smaller droplets due to less surface tension. Note also with caution that potential flashing issues exist both in the spray water control valve and at the nozzle. Flashing of the spray water as it exits the nozzle is beneficial [15].

3.6.6 Velocity

By increasing the overall velocity of the water and steam mixture, the amount of turbulence is inherently increased. The increase in velocity is usually achieved by creating a restriction in the steam path, which further generates turbulence by vortex shedding. In addition to these high velocities, if poor piping design practices are used, the speed of the superheated steam could in theory approach Mach 1. At such speeds a number of problems would occur (including the generation of shock waves). However, this would be far in excess of the velocities used in good piping design. Typical velocities of steam entering a desuperheater should be around 40 to 60 m/s[15].

(1) Minimum steam velocity

One of the most critical aspects of water vaporization involves minimum steam velocity. For vaporization to occur, water droplets must remain suspended in the steam flow until they can completely evaporate. The type of spray nozzle and the turbulence of the steam flow influence what velocity is required. However, lower velocity are possible when special desuperheater constructions assist in mixing. The optimum situation is to have steam pressure reduction occurring immediately upstream of the desuperheater. Such a situation occurs when a combined function device such as a steam conditioning or turbine bypass valve or a separate pressure reducing valve located within approximately three to five pipe diameters is used. Either arrangement can keep water droplets suspended in average velocities as low as approximately five feet per second because of the turbulence in the steam flow [15].

(2) Maximum steam velocity

Concern about the effect steam velocity has on desuperheating comes from the fact that the faster the velocity, the faster two-phase flow moves in the pipe and the greater the distance required to completely convert the flow to steam. High velocity can be beneficial because its greater overall turbulence enhances the mixing. However, weight the value turbulence against the sheer momentum of the steam, which causes longer distances/time for the spray water to vaporize [15].

3.6.7 Cooling Water Flow Rate

The rate at which cooling water can be added to the superheated steam is affected by a number of factors, which are related by Equation (3.1)

$$qv=CA\sqrt{(2gh)} \quad (3.1)$$

where :

qv = Cooling water volumetric flow rate (m^3/s)

C = Coefficient of discharge for the nozzle

A = Area of the nozzle (m^2)

g = Gravitational constant (9.81 m/s^2)

h = Pressure drop over the orifice (m head)

Bearing in mind that C and g are constants, reviewing equation (3.1) shows that only two factors can be manipulated to alter the cooling water flow rate:

(1)- Changing the pressure drop over the orifice (nozzle)

Expressing flow rate as a function of pressure drop over the nozzle:

$$V \propto \sqrt{h} \qquad (3.2)$$

In addition to affecting the cooling water flow rate, there are two other important considerations when determining the required cooling water pressure:

- The cooling water pressure must be greater than the superheated steam pressure at the point of injection.
- The greater the pressure drop across the nozzle, the better the atomization of the cooling water.

(2)- Changing the area of the orifice

Expressing flow rate as a function of the area of the orifice:

$$V \propto A \qquad (3.3)$$

This direct relationship means that if, for example, flow is to be increased by a factor of 5, the available area must also increase by a factor of 5. This change may simply be achieved by an orifice, which has the ability to change in area or alternatively by altering the number of orifices passing the coolant as shown in Figure 3.4.

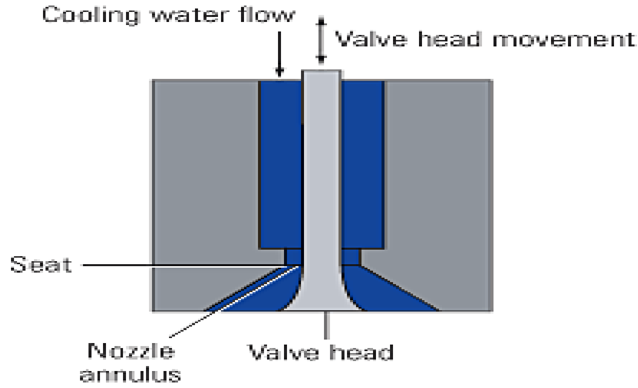

Figure 3.4: Variable area orifice

(3)-Thermal Sleeves

Careful control of the spray is required to ensure that the water does not fall out of suspension as this can result in thermal stresses being generated in the pipeline and cracking may occur. However, in some cases, an inner thermal sleeve can be used to provide protection from this. Figure 3.5 show a thermal sleeve inserted in an in line spray desuperheater.

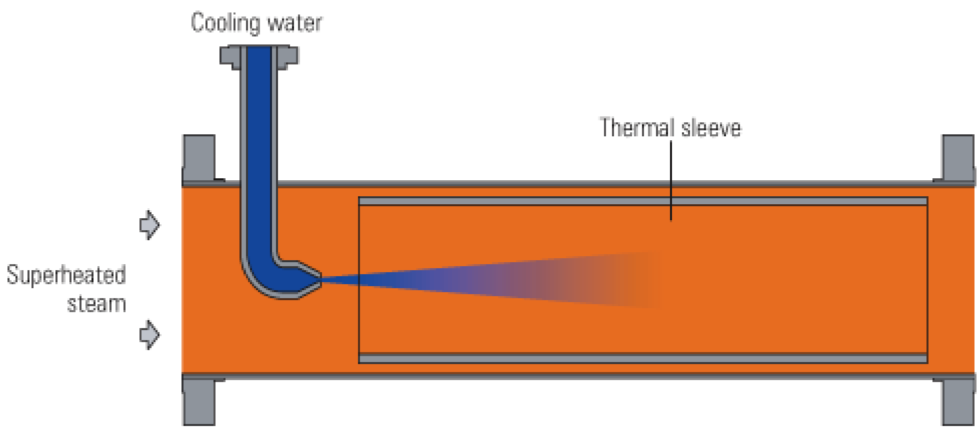

Figure 3.5: A Thermal sleeve inserted in an in line spray desuperheater

The thermal sleeve also allows the circulation of superheated steam around the annular area between the sleeve and the inside diameter of the pipe. This provides a hot surface upon which the injected water can evaporate, as opposed to the walls of the desuperheater, which are inevitably cooler [15].

CHAPTER FOUR

SYSTEM SIMULATION AND RESULTS

4.1 Simulation Modeling

In recent advanced area the temperature measurement and its control has become an integral part of any control system operating in a temperature sensitive environment. For the purpose of controller design to control turbine temperature were modeled in PROTUS program which using for simulation. Another important feature of PROTUS is the ability it provides the user to control the level of accuracy of the simulation. PROTUS is a high performance simulator for multiprocessors. It is fast, accurate and flexible, it is one to two orders of magnitude faster than comparable simulators, it can reproduce results from real multiprocessors and it is easily configured to simulate a wide range of architectures.

4.2. System Identification

An ATMEGA 16 AVR Microcontroller is used for carrying out all the required computations and control. It has an in-built analog to digital converter. Hence an external analog to digital converter is not required for converting the analog temperature input into digital value. An inexpensive temperature sensor is used for sensing the ambient temperature. The system will get the temperature from the sensor and will display the temperature on the LCD. This temperature is compared with the set point temperature declared by the user (also displayed on the LCD) using a keypad. We are implementing open/close control for controlling the temperature. The temperature must be within a certain range otherwise continuous open/close of the controlling elements (motor) will cause damage to adjust the temperature. If the temperature goes beyond the upper limit then the motor will be switched on to desuperheater the steam and if temperature goes below the lower limit then motor of the valve will be stopped. At set point motor of the valve stop. Using motor as function like attemperator which spray the steam, LCD to view temperatures value , microcontroller to make decision if motor will be open or close according to result of comparing the actual temperature value with set point value, Figure 4.1 shows the simulink model of the system.

TT = temperature transmitter

TS = temperature set point

MFB= motor feedback

The main process sequence will scan all stages and start again, there is four stage every stage check the temperature. The procedure for four stage is same, the only different is in stage temperature set point .Procedure start with comparing actual temperature value with set point value then calculating the different which either one of three state:

- The different is more than 50 c°
- The different is less than 50 c°
- The different is equal 0c °

When the different is greater than 50 the controller will check the feedback of the valve and give command to open it 100% with indication in the display show the percentage 100%,when it reach 100% it will stop the valve and the attemperator start spray the steam with specific flow rate. Here there are three feedbacks expected in this state form the valve: If motor feedback percentage is less than 100% then the valve will open

- If motor feedback percentage is greater than 100% then the valve will clos

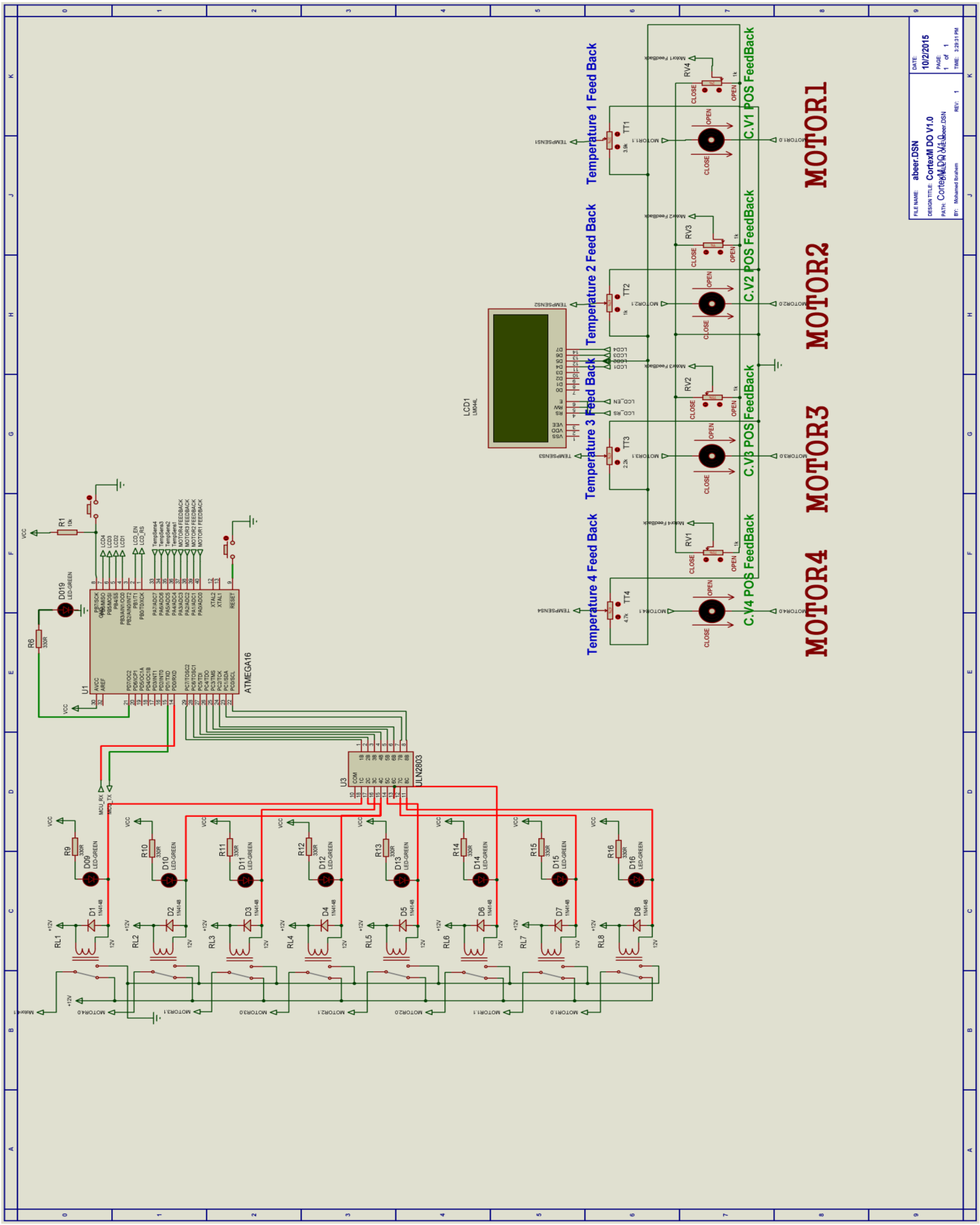

Figure 4.1: PROTUS simulink model for control temperature

- If motor feedback percentage =100% then the valve will stop.

While motor feedback percentage is=0, the normal state in ordinary situation, but controller will check the valve feedback is it 0% , if yes that is means the valve will close .When the different is less than 50 the controller will check the feedback of the valve and give command to open it 25% with indication in the display show the percentage 25%,when it reach 25% it will stop the valve and the attemperator start spray the steam with specific flow rate. Here there are two feedbacks expected in this state form the valve:

- If motor feedback percentage is less than 25% then the valve will open
- If motor feedback percentage is greater than 25% then the valve will close
- If motor feedback percentage equal 25% then the valve will stop.

The controller will scan the analog input value of temperature from temperature sensor and the motor valve feedback, then compare it as above. This two percentage for open motor (25% and 100%) choosed a cording to many calculating applied on equation (3.1), then found the appropriate value of coefficient discharge for the nozzle is equal to 10. So there is recommendation to find an equation to calculate how many temperatures centigrade will be cool down if the valve open at certain percentage.

4.3 System Analysis

control turbine temperature were modeled in PROTUS program and examining on how the system respond to the change in temperature degree, the system have four stages to desuperheat the steam temperature as shown in Figure 3.1.

Figure 4.2 shows the flowchart of control process description.

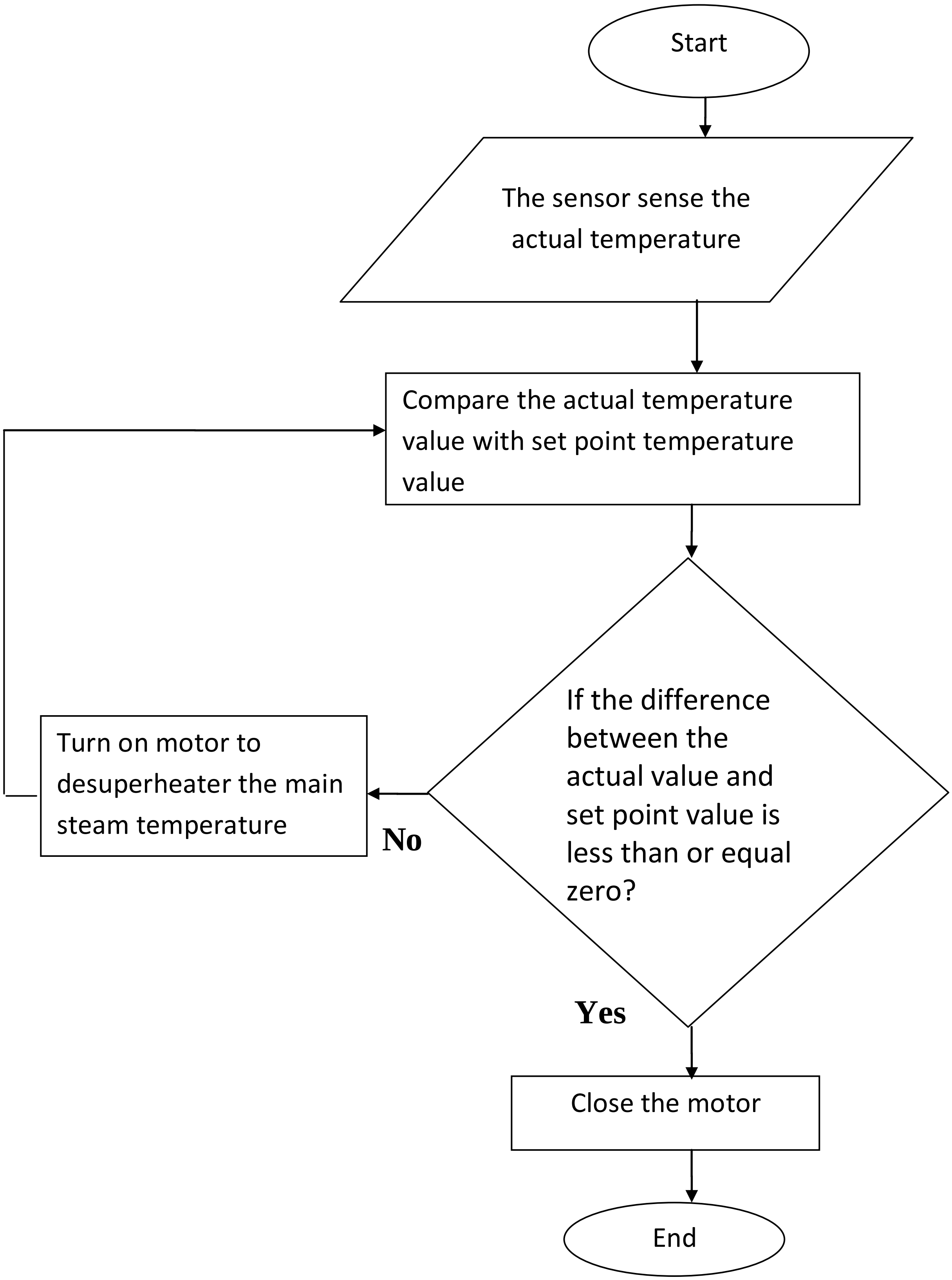

Figure 4.2: The flow chart of control process description

4.3.1 Stage One

Right main steam temperature control system (between platen superheater and low temperature superheater) ,the following results are obtained as shown at the following Table 4.1.

Table 4.1 Stage one desuperheating result

Actual Temperature	Set Point Temperature	Difference	Valve Percentage
308	408	-100	0%
410	408	2	25%
450	408	42	25%
408	408	0	0%
480	408	72	100%
600	408	192	100%

4.3.2 Stage Two

Left main steam temperature control system (between platen superheater and low temperature superheater), the following results are obtained as shown at the following Table 4.2 .

Table 4.2: Stage two desuperheating result

Actual Temperature	Setpoint Temperature	Difference	Valve Percentage
395	415	-20	0%
435	415	20	25%
460	415	45	25%
415	415	0	0%
515	415	100	100%

4.3.3 Stage three

Right platen super heater outlet temperature control system (between high temperature superheater and platen superheater) ,the following results are obtained as shown at the following table 4.3.

Table 4.3: Stage three desuperheating result

Actual Temperature	Set Point Temperature	Difference	Valve Percentage Open
450	462	-12	0%
470	462	8	25%
490	462	28	25%
462	462	0	0%
540	462	78	100%
700	462	283	100%

4.3.4 Stage four

Left platen super heater outlet temperature control system (between high temperature superheater and platen superheater) ,The following results are obtained as shown at the following table 4.4.

Table 4.4 Stage four desuperheating result

Actual Temperature	Setpoint Temperature	Difference	Valve Percentage
460	465	-50	0%
470	465	5	25%
465	465	0	0%
500	465	35	25%
515	465	150	100%

4.4 Discussion

The result as shown in Table 4.1 to 4.4 obtained when actual temperature value is differ from temperature set point .the desuperheater apply at four stage , every one of this stage have specific set point value which the actual temperature value compare with it. when the different is not more than 50C° the steam need small amount of water spray through the valve to cool it down , so the valve open at percentage equal 25% , and if the different is more than 50C° large amount of water require to spray the steam and make the temperature of steam at normal value , so the valve open at percentage equal to 100%.When the valve open become appropriate according to the different of temperature ,the valve stop and starting flow rate the water from nozzle directly to the steam. The coefficient of discharge for the nozzle taken equal to 10 because these values of it make the flow rate more effective to decrease the temperature.

CHAPTER FIVE

CONCULUSION AND RECOMMENDATIONS

5.1 Conclusion

Steam superheat temperature control is very important to avoid the turbine harmful or damage. Adjusting the amount of water that is sprayed into the steam header after the steam has passed through the super heater, controls the steam temperature .Control turbine temperature were modeled in PROTUS program and examining on how the system respond to the change in temperature degree, an ATmega16 AVR Microcontroller is used for carrying out all the required computations and control, it built inside PROTUS simulation.

5.2 Recommendations

- Find an equation to calculate how many temperatures centigrade will cool down if the valve open at certain percentage open.
- Using fuzzy logic control.
- Using PID controller.

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