CHAPTER 1

INTRODUCTION

1.1 GENERAL

A heat exchanger is a heat transfer device that is used to transfer the internal heat energy between two or more fluids available at different temperatures. In many existing heat exchangers, fluids are alienated by a heat transfer surface, and ideally they do not mix with each other. Heat exchangers are primarily employed in the process, power, petroleum, transportation, air-conditioning, refrigeration, cryogenic, heat recovery, alternate fuels and in many other related domains. Familiar examples of heat exchangers falling under some day-to-day use are automobile radiators, condensers, evaporators, air pre-heaters and oil coolers. A heat exchanger constitutes elements like core or matrix containing the heat surface, fluid distribution elements such as headers or tank and inlet/outlet nozzles or pipes. Typically there is no mobile part in a heat exchanger, there are exceptions, like a rotary regenerator in which the matrix is driven to rotate at some specified speed and the scraped surface heat exchanger in which a rotary element with scraper blades incessantly rotates inside the heat transfer tube. The heat transfer surface is in straight contact with fluids through which heat is transferred by conduction. The section of the surface that separates the two is generously referred as the primary or direct contact surface. To augment the heat transfer area, secondary transfer surface known as fins are attached to the primary surface.
In common, industrial heat exchangers have been classified on the basis of construction, transfer processes, degree of compactness, flow arrangements, pass arrangements and heat transfer mechanism. According to the construction it classified as tubular, plate and extended surface heat exchangers. The valuable heat exchanger found applicable in current years, is the shell and tube heat exchanger which abides under tubular heat exchanger. Shell and tube heat exchanger in their diverse constructional modifications are perhaps the most widespread and regularly used basic heat exchanger configuration in the process industries. They offer comparatively, a larger ratio of heat transfer area to volume/weight and are effortless to manufacture in huge variety of flow configurations. They can function at high pressure and their construction facilitates disassembly for intervallic maintenance and cleaning.

A shell and tube heat exchanger consists of a bundle of tubes enclosed within a cylindrical shell. One fluid flows through the tubes and the second fluid flows through the space between the tube and the shell. Heat is thus transferred from one fluid to the other through the tube walls, whichever from tube side to shell side or vice versa. They can be additionally classified according to their flow arrangement, into co-current heat exchangers and shell-and-tube heat exchangers. The former facilitates the two fluids to enter the exchangers as the fluids enter the exchanger from opposite ends and the latter might be of 1, 2, or 4 pass designs on the tube side depending upon the number of times the fluid in the tubes passes through the fluid in the shell.

Shell and tube heat exchangers fall short with confusing pieces of equipments for process control engineers. The principle of operation is straightforward enough: two fluids of different temperatures are conveyed into close contact but are disallowed from addition by a
physical barrier. The temperature of both the fluids will be likely to
equalize. By arranging counter-current flow, it becomes probable for the
temperature at the outlet of each fluid to come up to the temperature at
the inlet of the other. The heat contents are merely exchanged from one
fluid to the other and no energy is added or removed. Being the heat
necessities of the process and the heat content of the two fluids are not
constant, the heat exchanger ought to be designed for the worst case and
also be controlled to craft it to function at the particular rate required by
the process at each moment of time. The heat exchanger itself is not
steady and its characteristic varies with time. The most widespread
change is the decrease in the heat transfer rate due to fouling at the
surfaces. Exchangers are originally oversized to permit fouling which
steadily builds up all through the usage until the exchanger is no longer
capable of performing its duty. Again, as it is cleaned it becomes
oversized.

A heat exchanger system control is mandatory to control the
outlet temperature of the shell side stream or tube side stream in the shell
and tube heat exchanger. Generally the shell side stream is controlled and
the conventional PID controller contributes to this satisfactory operation
of the heat exchanger system by maintaining these parameters within the
satisfactory limits. The PID controllers are practically exploited in most
engineering applications because of its simplicity, easy implementation
and lofty robustness. The PID controller has the capability to cope up
with a variety of load changes and various disturbance effects on the
dynamic performance of the heat exchanger system. The gains of the PID
controllers ought to be properly tuned to promise security, dynamic
performance and sustainable exploitation of the plants. The conventional
PID tuning methods such as Ziegler-Nichols, Simplex method etc., needs an
absolute set of plant information and prerequisite knowledge towards the
problem. In conventional controllers the gain values are tuned manually and it is designed for a specific operation condition. Hence, it fails to yield an effective control, when there is a change in operating condition. In this eloquent thesis, high-quality advancements have been carried out to moderate the requirements of ultimate ends users.

In modern engineering control domain, the application of intelligent computing techniques like Neural Network, Fuzzy Logic, Genetic Algorithm and Evolutionary Algorithm effectively solves the problems associated with the design of controllers. The imperative advantage of using evolutionary search lies in the gain of flexibility and adaptability to the task at hand, in grouping with robust performance and global search characteristics (Thomas Back 1997). The artificial intelligence paradigms are more appropriate to model the uncertainties established in the process plant. So that it improves the performance of the controller. The present research focuses on the optimum tuning of PID gain parameters with the application of intelligent computing techniques.

The present research spotlights on the application of intelligent computing techniques for optimum tuning of PID gain parameters to advance the efficiency of the controller. The optimized values of gains ($K_p$, $K_i$ and $K_d$) are applied to the PID controller for temperature control of the heat exchanger system. The elementary argument to be justified on the application of evolutionary computing: it is uncomplicated to be implemented, better computational efficiency and permits fine tuning for obtaining predetermined results. EA frequently yield outstanding results when applied to tricky optimization problems whereas other conventional methods are either not applicable or turn out to be unsatisfactory (Back et al 1997). The heat exchanger model is developed using simulink and simulated for diverse flow and temperature disturbance parameters to
confirm the heftiness of the proposed algorithms. The performance measures used to learn the effectiveness of proposed controller model include settling time, overshoot and oscillations. The computational complexity of the projected algorithms is lucidly compared on the basis of program execution time taken by the CPU in engendering best results.

1.2 SCOPE OF THE RESEARCH

The specific objectives of this research are the following:

1) To analyze and model the problems related to heat exchanger in maintaining constant outlet temperature and to recommend appropriate intelligent computing techniques to improve the effectiveness of temperature control of the system.

2) To build up an efficient methodology for explaining these complex problems by using different evolutionary optimization algorithms.

3) To analyze and compare the results obtained using EA with those obtained by conventional PID controllers.

4) To estimate the potential of EA in attaining optimal solutions for dissimilar load and disturbance parameters, related to convergence rate and computational complexity in implementing the proposed algorithm.

5) To present specific recommendations on the type of algorithm, computational efficiency, performance characteristics and the requirements for tuning the control parameters of the algorithm, on the basis of simulation results.
The major contribution of this thesis is to elaborately discuss different intelligent computing techniques for obtaining optimal solution for temperature control problems in heat exchanger system. The ambition of this thesis is to elaborately discuss on different intelligent computing techniques for online temperature stability monitoring. The performance of the heat exchanger is improved with the application of FL, GA, PSO, ACO and Hybrid EA optimization techniques as illustrated below:

1) A fuzzy rule based intelligent controllers is designed to improve the performance and robustness of heat exchanger. The conventional PID controller in the control loop is replaced by fuzzy logic controller. The design is simulated and the performance characteristics of FLC is compared with the conventional PID controller.

2) GA based tuning of PID controller is demonstrated for solving the optimization problem of temperature control of heat exchanger system. The GA based PID controller improves the dynamic performance with reduced settling time, oscillations and overshoot. Subsequently, GA based fuzzy PID controller is designed and its performance characteristics is compared with GA based PID controller.

3) Evolutionary Algorithm is useful and effectual paradigm in finding the optimum solution for the real-time optimization problems. The evolutionary algorithm such as PSO and ACO are proposed to overcome the computational complexities in real time modeling and to improve the performance of the controller. The EA based controller efficiently optimizes the gain parameters of the PID controller and it increases the
computational speed and capabilities. The simulation results have been analyzed and compared with other controllers.

4) To defeat the computational challenges in real-time online modeling, hybrid EA has been proposed to boost the computational capabilities and speed.

In this detailed research, the conventional GA algorithm is united with fuzzy, to obtain hybrid algorithms, to effectively optimize the PID gain parameters.

Currently, researchers are focusing on exploring the possibilities of applying knowledge based systems to augment the efficiency and computational complexity of conventional controllers. This in turn has prompted the development of novel and intelligent algorithms for temperature system control with superior reliability and reduced computational time. The performance measures used to quantify the merits of the proposed intelligent computational techniques includes settling time, oscillations, overshoot and computational time of the controller.

1.3 Thesis Outline

The particulars of the research are organized into six chapters. The overall organization of the research describes the use of intelligent controllers for heat exchanger.

Chapter 1 presents a vivid general information on the heat exchanger and also illustrates few conventional control methods for controlling temperature of heat exchanger.

Chapter 2 gives the detailed literature survey of heat exchanger control
Chapter 3 entails the precise mathematical modeling of simple heat exchanger and, shell and tube heat exchanger. The heat exchanger with PID controller is modeled along with diverse parameters that are affianced in simulation.

Chapter 4 details the architecture and operation of the proposed FLC for intelligent control of heat exchanger system. The model of the plant has been designed and simulated using simulink tool available in MATLAB. The simulation outcome has been compared and analyzed with the conventional PID controller, and improvement is found to occur in settling time, overshoot and oscillation.

Chapter 5 elaborates the proposed GA for efficient selection of gain parameters for the PID controller. To demonstrate the efficiency of GA, step responses of the closed loop system are compared with conventional PID controller. The application of GA for PID gain tuning perks up the computational efficiency with abridged settling time, oscillation and overshoot. Simulation results have been evidently observed and the consequent values are tabulated for analyzing the performance of the proposed controller.

Chapter 6 demonstrates the investigation on the application of the proposed EA for effectual control of heat exchanger system. The design steps and implementation of PSO and ACO algorithm for selecting optimum PID gains for the heat exchanger has been detailed. Simulation results observed on the way towards performance of the controller vividly indicates that the proposed algorithms detains high quality solutions and reveals better control performance. The computational time required to generate optimum solutions has been compared with GA based controller.

Chapter 7 concludes the research investigations profoundly with some valuable ideas for future efforts in the analogous vicinity of research.