Chapter 8

Conclusion & Future Scope

The comprehensive literature survey on ongoing research work in the area of tuning controller parameters for the problem of multiobjective optimization results in possibilities of comparing multiobjective evolutionary(NSGA-II and NSGA-III) and swarm (MOPSO) based algorithms. The main objective of research work is to optimize five parameters of 2DOF controller for the problem of shell and tube heat exchanger system using multi-objective evolutionary (NSGA-II and NSGA-III) and swarm (MOPSO) based algorithms enhanced with TOPSIS. MATLAB software tool is used to implement algorithms.
As a result of the research work, we arrive at the following conclusions and remarks regarding tuning 2DOF controller parameters for the problem of shell and tube heat exchanger systems.
1. The drawback of 1DOF control structure is that, it can't optimize both the objective functions i.e. set point tracking and disturbance rejections simultaneously. 2DOF control structure is used to attain both the objectives set point tracking and disturbance rejections simultaneously. Here, feed forward type (FF type) of 2DOF Controller optimization for the problem of shell and tube heat exchanger system is selected because; it is easy to convert the conventional PID controller structure already built in to the FF type of 2DOF structure. The mathematical proof is given in the chapter 3.
2. Heat exchanger system has conflicting objectives set point tracking and disturbance(two conflicting disturbances one is due to flow variation of input fluid and second is due to temperature variation of input fluid) rejections. The prime goal in the process of heat exchanger is to keep outlet temperature of process fluid flowing through it at desire value in the presence of two major conflicting disturbances. The step input of magnitude 0.1

and 0.01 is applied as disturbance for both flow and temperature disturbances. Here, feed forward type 2DOF control structure is employed for the multiobjective optimization problem of shell and tube heat exchanger systems to satisfy conflicting objectives simultaneously; set point tracking and disturbance rejections. The detail is provided in chapter 3.

3. The process of optimizing simultaneously collection of objective functions is called multiobjective optimization. The problem of multiple objective optimization gives rise to set of multiple optimal solutions (known as Pareto optimal, or non-inferior, or non-dominated solutions), instead of single optimal solution. In the absence of information related to the problem it's difficult to determine which Pareto optimal solution is better than other. This demands as many Pareto optimal solutions as possible. Controller tuning is a broad research area in which tuning rules are derived from the mathematical model of the system. Classical computational methods fail in tuning controller for the multiobjective optimization problems discussed in chapter 4. The controller parameter optimization using evolutionary and swarm intelligence in multiobjective optimization problem is one of the emerging topic at present. The literature survey on controller parameter optimization using evolutionary and swarm intelligence has motivated to work in the direction to optimize parameters of 2DOF controller using evolutionary(NSGA-II, NSGA-III) and swarm(MOPSO) based algorithms for the problem of shell and tube heat exchanger system.

4. Three test criteria Integral of Absolute Error (IAE), Integral Squared of Error (ISE), and Integral of Time-weighted Absolute Error (ITAE) function of error (set point tracking and disturbance rejection) and time are used for evaluation of objective functions. Vector of three objective functions are supplied for optimization of 2DOF controller parameters discussed in chapter 4.

5. TOPSIS is applied as a multiple criteria decision making method to rank the set of Pareto optimal solutions for reducing these to a single solution discussed in chapter 7.

6. Performance criteria used for comparison of results are: (1) Minimization of peak overshoot of step response. (2) Reduction in flow and temperature disturbance. (3) Reduction of set point tracking error. (4) Reduction in settling time. (5) The percentage of solutions obtained from optimization algorithms under all three evaluation criteria IAE, ISE, and ITAE.

7. Initially, 2DOF controller parameters are tuned using single objective optimization

of GA and PSO by assigning equal weights(unity) to all three objective functions under three separate evaluation criteria. From the Figure 5.2 ,5.3, 5.4 and parameters tabulated in Table 5.1, it is concluded that IAE criterion for optimizing simultaneously all the five parameters of 2DOF controller using GA method has minimum peak overshoot of step response(20.75%). The maximum reductions of flow(58.2%) and temperature (86%) disturbances are obtained under the criterion of ISE compared to other two criteria IAE and ITAE discussed in chapter 5. From the Figure 6.1 ,6.2, 6.3 and parameters tabulated in Table 6.1, it is concluded that ITAE criterion for optimizing simultaneously all the five parameters of 2DOF controller using PSO method has minimum peak overshoot of step response(1.22%) and maximum reduction of flow disturbance(21.6%). The maximum reductions of temperature (75%) disturbances is obtained under the criterion of ISE compared to other two criteria IAE and ITAE discussed in chapter 6.

8. As being multiobjective optimization problem, it is first required to obtain multiple pareto optimal solutions and select best one using multi-criteria decision. The Pareto set of solutions are obtained after optimizing all the five parameters of 2DOF controller using multiobjective evolutionary (NSGA-II and NSGA-III) and swarm intelligence (MOPSO) algorithms. TOPSIS a multiple criteria decision making method is used to rank the set of Pareto optimal solutions for reducing number of Pareto optimal solutions to a single solution. The best rank solution obtain for 2DOF controller parameters after applying TOPSIS on set of Pareto optimal solutions using evolutionary (NSGA-II and NSGA-III) algorithms are compared with swarm intelligence (MOPSO) algorithm. In order to obtain the comparative analysis of optimization algorithms (NSGA-II, NSGA-III, and MOPSO) all the Pareto optimal solutions are combined under three separate evaluation criteria IAE, ISE, and ITAE. The combined nondominated sets of solutions are 202, 133, and 116 under evaluation criteria IAE, ISE, and ITAE respectively results shown in Table 7.1. TOPSIS is used to obtain top 10 high rank individual solutions from combined set of solution. To evaluate the performance optimization of 2DOF controller tuning, we compared the values of peak overshoot of step response, set point tracking error, disturbance rejection (both flow and temperature), settling time, and the percentage of solutions obtained from optimization algorithms under all three evaluation criteria IAE, ISE, and ITAE.

From the results shown in Table 7.5, 7.6, and 7.7, it is concluded that after merging the solutions of the algorithms, the percentage of solutions from NSGA-II is greater than NSGA-III and MOPSO under all three evaluation criteria IAE, ISE, and ITAE. Also, the best rank of solution is obtained from NSGA-II (under IAE and ISE) and MOPSO (under ITAE) shown in Table 7.8. From the figures (Figure 7.1 to Figure 7.3), it is concluded that IAE criterion of NSGA-II (Solution No-177) algorithm has minimum peak overshoot of step response(4.8%), maximum rejection of flow (33.4%), and temperature (78%) disturbances for nondominated set of solution [1.363,0.052, 6.855,0.601,0.439]. The minimum peak overshoot of step response, maximum rejection of flow, and temperature disturbances are achieved under ISE and ITAE criteria using NSGA-II (Solution No-82) [1.677,0.0454, 4.886,0.619,0.215] and MOPSO (Solution No-115) [1.090,0.035,5.876,0.433,0.40] algorithms respectively. It is derived from Table 7.9, that settling time of the system is minimum under IAE criterion of NSGA-II (Solution No-177). From this, it is concluded that, NSGA-II algorithm outperforms NSGA-III and MOPSO algorithms for this particular test problem discussed in chapter 7.

A shell and tube heat exchanger suited for higher pressure applications. It is widely used in oil refineries and chemical processes. The prime goal in shell and tube heat exchangers system is to keep outlet temperature of process fluid flowing through it at desired temperature in the presence of two major conflicting disturbances (Flow variation of input fluid and temperature variation of input fluid). Application of 2DOF controller is set point tracking and disturbance rejections. The main outcome of the research work reported in this thesis is to design and develop multiobjective evolutionary(NSGA-II and NSGA-III) and swarm intelligence (MOPSO) based algorithms for tuning five parameters of 2DOF controller for the problem of shell and tube heat exchanger systems.Though, our main objective to optimize parameters of 2DOF controller for the problem of shell and tube heat exchanger system by using evolutionary (NSGA-II and NSGA-III) and swarm Intelligence (MOPSO) based algorithms is attained, it is felt that still a lot more remains to be done in this important direction. The following recommendations are proposed for future work in tuning of 2DOF controller parameters:

1. The constrained may be applied to the performance measures and proposed approaches can be applied to solve constrained optimization problem in the system of heat exchanger.

2. The performance of NSGA-II, NSGA-III and MOPSO algorithms may be compared with other class of algorithms like: Ant colony algorithm, Artificial Bee colony algorithm and others.

3. The criteria for evaluation of objective functions can be tried other than used one IAE, ISE and ITAE to see the results.

4. Here, results are tested by applying step inputs of magnitude 1, 0.1 and 0.01 for set point tracking, flow disturbance, and temperature disturbance. The other inputs can be applied to verify the performance of algorithms.

5. The mathematical modeling of the system of heat exchanger is considered to be FOPDT with certain constraint. The nonlinearity in the system modeling can be added by considering more real time situations.

6. No modifications in the standard proposed algorithms NSGA-II, NSGA-III, and MOPSO is done except varying algorithmic parameters for better result like; number of population, crossover, mutation, supplying reference points, repository Size, inertia weight, values of random numbers, number of grids per dimension, and mutation rate. Hence, modification in existing algorithm can be thought to improve the performance of algorithms.

7. Instead of considering just three objective optimization problem, many other objectives can be added and problem can be extended to many-objective optimization instead of multiobjective optimization.

8. In industry still 90 % of control loops are PID controller. The drawback of PID is it can have set point tracking or disturbance rejections. 2DOF controller can satisfy both the objectives set point tracking and disturbance rejections simultaneously. It is easy to convert conventional PID control loops in Feed forward type 2DOF controller. Hence, 2DOF controller can be used in control applications where, two objectives set point tracking and disturbance rejections to be attained simultaneously. Tuning of five parameters of 2DOF controller is a challenging task. Hence, outperformed multiobjective optimization algorithms(NSGA-II, NSGA-III, and MOPSO) are used to tune 2DOF controller. Evolutionary (NSGA-II and NSGA-III) and swarm (MOPSO) based algorithms are very complex. Hence, real time implementation for tuning 2DOF controller parameters in a processor/controller is a challenging task. As tuning algorithms are very complex it requires substantial amount of flash memory in the processor/controller. This in turn required processor/controller with higher flash memory, which will add cost to the design.