SYNOPSIS

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Thesis Title: **MULTIOBJECTIVE OPTIMIZATION OF 2DOF CONTROLLER USING EVOLUTIONARY AND SWARM INTELLIGENCE**

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In control, the degree of freedom is defined as the number of closed loop transfer functions that can be adjusted individually. Hence, two degree of freedom (2DOF) control structure possesses benefits over one degree of freedom (1DOF) control structure. The drawback with 1DOF control structure is that when the disturbance response is optimized, the set point response is found to be poor, and vice versa. Due to this reason, the classical research on the optimal tuning of PID controllers have shown two tables: one for the "disturbance optimal"parameters, and other for the "set point optimal"parameters [1],[2]. The main advantage of 2DOF control structure is to optimize both set point tracking and disturbance rejections simultaneously [3].
Controller tuning is a broad research area in which tuning rules are derived from the mathematical model of the system [4]. Classical computational methods fail in tuning controller for the multiobjective optimization problems due to following reasons: (1) These methods can generate single solution from single run hence; several runs are required in order to generate Pareto set of solutions. (2) Convergence to optimal solution depends on chosen initial condition. (3) It requires differentiability of both objective functions and constraints. (4) These methods fail when Pareto front is concave or discontinuous

[5]. Evolutionary and swarm based controller tuning is appealing investigators due to its efficiency to optimize parameters based on cost function, without any know-how about the process. Also, these algorithms work based on population of search instead of single search therefore, it provides parallelism [6].

The process of heat exchanger is used at different temperatures and thermal contact to transfer thermal energy between two or more fluids, a solid surface and a fluid, or between solid particles and a fluid [1]. Although, varieties of heat exchangers are available in the market, shell and tube type of heat exchanger system is widely used in industry [2]. Heat exchanger system has two predominant disturbances one is due to flow variation of input fluid and second is due to temperature variation of input fluid. Increase in flow variation of process fluid result in increase in mass flow rate of the fluid causes reduction in mean exit temperature of process fluid. On the contrary, increase in temperature variation of process fluid causes increase in mean exit temperature process fluid. The step input is applied to both the disturbances which are in conflict [7]. 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. Hence, the problem of shell and tube heat exchanger is taken as test bench due to conflicting objectives [8].

In the present study, multiobjective optimization of two degree of freedom (2DOF) controller parameters using evolutionary (NSGA-II, and NSGA-III) and swarm (MOPSO) based algorithms for the problem of shell and tube heat exchanger system is proposed. The objective functions are deployed considering, set point tracking and disturbance rejections. 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. ISE integrates the square of the error over time and it penalizes large errors more than smaller ones. If control objective is to minimize ISE, then it will tend to eliminate large errors quickly, but will tolerate small errors persisting for a long period of time. This results in fast responses, but exhibits low amplitude oscillations. IAE integrates the absolute error over time. As there is no any weight is being added to any error in the system, it produces slower response compared to ISE but has low amplitude oscillations. ITAE integrates the absolute error multiplied by the time over time. This adds weight to error in the system with time. It weights errors which exist after a long time much more heavily than those at start of the response. ITAE tuning produces systems which settle

much more quickly than the IAE and ISE [9].
The Pareto set of solutions were obtained after optimizing all the five parameters of 2DOF controller. 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. Technique for Order of Preference by Similarity to Ideal Solution (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 obtained for 2DOF controller parameters after applying TOPSIS on the set of Pareto optimal solutions using evolutionary (NSGA-II and NSGA-III) algorithms are compared with swarm intelligence (MOPSO) algorithm. 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. MATLAB software tool was used to implement the above algorithms.
The majority of real world problems involve multiple conflicting objectives this results in problem of multiobjective optimization. The solution of multiobjective optimization problem resorts to a number of trade-off optimal solutions. Classical optimization algorithms can obtain single solution in one simulation run hence; those algorithms are not suitable to solve multiobjective optimization problems. 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 has motivated to work in the direction to optimize parameters of 2DOF controller for the problem of shell and tube heat exchanger system.
Hence, motivations behind research work reported in the thesis are:
(i) Application of 2DOF controller to satisfy two conflicting objectives set point tracking and disturbance rejections for the problem of shell and tube heat exchanger system under three performance evaluation criteria IAE, ISE, and ITAE of the objective functions.
(ii) To apply multiobjective evolutionary (NSGA-II and NSGA-III) and swarm based algorithms (MOPSO) to optimize five parameters of 2DOF controller using software tool MATLAB.
(iii) Application of TOPSIS a multiple criteria decision making method to rank the set of Pareto optimal solutions for reducing these to a single solution.

(iv) Comparison of results using following performance criteria: (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.
A brief description of the research work reported in the thesis is given below:

Chapter 1: This chapter provides background on multiobjective optimization of 2DOF controller parameters using evolutionary and swarm intelligence enhanced with TOPSIS for the problem of shell and tube heat exchanger system. Motivation for the research work and organization of thesis is provided at the end.

Chapter 2: It provides brief about parameter optimization of 2DOF controller. The comprehensive survey of algorithms based on evolutionary and swarm intelligence including its methodological issues from the perspective of multiobjective optimization is provided.

Chapter 3: It provides theory of 2DOF controller and heat exchanger system description. Theory of 2DOF controller contains difference between conventional 1DOF and 2DOF control structure, and equivalent transformation of 2DOF control structure. The section of heat exchanger system contains types of heat exchangers available in the market, shell and tube heat exchanger system description, and derivation of system transfer function with 2DOF controller.

Chapter 4: It covers difference between single objective and multiobjective optimization, terminologies used in multiobjective optimization, theory of multiobjective optimization, and approach for solution of multiobjective optimization problem. The next section contains 2DOF controller parameter optimization method, formation of three objective functions, discussion on criteria for evaluation of objective functions, and process applying objective functions for multiobjective optimization problem.

Chapter 5: It contains method optimization of 2DOF controller parameters using multiobjective optimization of evolutionary (NSGA-II and NSGA-III) algorithms.

Chapter 6: It contains method optimization of 2DOF controller parameters using Pareto dominance based multiobjective particle swarm optimization (MOPOS) algorithm.

Chapter 7: This covers application of TOPSIS a multi-criteria decision making technique on Pareto solutions obtained using NSGA-II, NSGA-III, and MOPSO algorithms and comparison of results.

Chapter 8: It provides discussion of the results, conclusions, and scope of future work.

Thesis ends with a complete Bibliography.