ABSTRACT

Multivariable processes make up the majority of industrial and chemical processes. Between measurement signals and control signals, there are frequently complex relationships present. Because of the interplay among input and output variables, developing an efficient controller for Multi Input Multi Output (MIMO) systems is difficult. Cross-coupling between input and output is frequently modest, making it possible to use standard controllers. To attain adequate performance, multivariable controllers should be used if multivariable systems show increased cross-coupling between process input and output.

Although control obstacles such as non-minimal phase behavior, model uncertainties, unmeasured disturbances, and limits on input and output variables, any controller design in control engineering are to stabilize the system to follow the set point and to reject the load disturbances, to achieve this, specific control strategies are presented in this study for the control of a nonlinear multivariable process with a transmission zero. In several control works of literature, the experimental multivariable system known as the Quadruple Tank system (QTS) is utilized for controller synthesis. Depending on where one of its zeros is located, the mathematical model of QTS can be created under two alternative operating conditions, namely minimum phase and non-minimum phase conditions. A relative Gain Array (RGA) is used to study the loops' interactions and pair the input and output.

The PI controller is used in multi-loop control because it is the most popular controller in process industries for level control applications. Auto-tune is used to tune the decentralized PI controllers. Model-based tuning is suggested to improve performance by employing the Decoupled PI Controller, Linear Matrix Inequality based PI Controller, and Iterative Learning Controller based PI Controller principles. Because model-based

design is always based on process models, controller parameter optimization is performed using Simulated Annealing (SA) and Hybrid SA-based ant lion optimization techniques.

LMI works by converting the PI controller design problem to a state feedback controller design problem and then solving it using the convex constraint optimization method. The primary purpose of linear matrix inequalities in control systems is to describe how the interior-point approach emerged from the linear programming optimization tool and to assess the significance of convex optimization theory in control systems. The supplied control issue is then transformed into a collection of LMI constraints that are subsequently stated by an LQR optimal problem. The PI control design issue is primarily turned into a state feedback control design problem in this formulation, which is solved using a convex constraint technique. In general, the interior point LMI solver (MINCX) can solve the convex optimization problem effectively

The ILC technique modifies the control signal's input values. ILC may be used in both single- and multiple-operation industrial applications. Indirect-type ILCs were created by integrating them with classic P, PI, and PID-type controllers. Under various uncertainties, the designs are based on inserting conventional controllers in the feed-forward path of the closed-loop control system in the single-input single-output configuration. Despite limited process expertise, their independent tuning technique ensured the closed-loop system's robust stability and improved system control performance. This research presents ILC-based PI controller parameters suitable for managing levels in a multivariable QTS. The duplication impact of traditional PI, decoupled PI, and LMI-based PI controllers are compared to those of an ILC-based PI controller designed in the MATLAB environment.

This work presents a good selection of ILCPI controller settings for managing levels in a multivariable quadruple tank system using Simulated Annealing (SA) optimization, Ant lion optimization (ALO), and the Hybrid SAALO method. The SA and ALO approaches have stable convergence properties, are easy to implement, have superior features, and are computationally efficient. The simulation results of decoupled PI controllers with optimized parameters ILCSA and ILCSAALO are compared to those of conventional PI, decoupled PI, LMIPI, and ILCPI controllers. This research uses Simulated Annealing optimization, Ant lion optimization, and the Hybrid SAALO method to determine the best ILCPI Level controller parameters for a multivariate quadruple tank system. The SA and ALO approaches are easy to implement, have superior features, and have a high computational performance efficiency. To address the challenges in multivariable industrial processes, a hybrid SAALO-based ILCPI controller is used.

Simulation is performed to validate the efficacy of the proposed quadruple tank controllers. In the suggested model, the Integral absolute error value (IAE value) of the hybrid SAALO-based ILCPI controller in tanks 1 and 2 was derivative. The DIAE (Derivative Integral absolute error value) and actual IAE values are fed into the MATLAB machine learning tool. The multivariable system is more precisely predicted using the regression tree and tree algorithm ensembles. Through studies, it is demonstrated that the suggested controller obtains lower values on different testing data by comparing prediction errors such as Root Mean Square Error (RMSE), R-Squared, Mean Squared Error (MSE), and Mean Absolute Error (MAE). The experimental results reveal that the proposed controllers achieved the regression and ensemble tree algorithm models giving a predicted vs. actual response to check the model performance of the proposed controller after training a machine learning model.