ABSTRACT

The on-line tuning of a controller, sensor fault accommodation and sensor noise elimination, particularly in nonlinear multivariable systems have offered rich potential for research since the past few years. Attempts hitherto made have been either too specific or unrealistic to the existing real time environment or severely isolated, as to render them less suited for practical applications. A comprehensive system having an inherent quality of automatically overcoming the above problems with minimum human intervention as and when they occur independently or simultaneously (all at a time) is conspicuously absent at present. Moreover, a majority of the existing works presumes a prior knowledge of all the information about a process, but in actual practice this may not be true; most of them may be severely lacking.

The main aim of the present investigation is to bring about the synthesis of the above three, at present functioning separately with lesser coordination or totally absent. Techniques presented here, may conveniently be used to improve the operational range of a plant with minimum human intervention and at no extra (hardware) costs. The proposed design algorithms focus on providing additional information about a plant, which can be used by the control algorithms for better control and stability. A rule-based intelligent controller with an estimator, designed by coordinating the data from multiple sensors, (that are commonly present in a process plant for monitoring various states and environmental conditions) is used, to handle exceptions such as
sensor faults or extreme situations incorrectly handled by the less sophisticated conventional controllers.

In all the previous analogous studies surveyed so far, some of the factors that should have been given more emphasis in the design of an intelligent system, (particularly for a process plant) have been found to be lacking. For example, most of the real time processes are nonlinear, with mutually interacting process variables having a vast amount of highly correlated data. This good correlation needs to be utilized in the design of an intelligent system algorithm. Similarly, in a real time environment, the measured states are noisy, and only these noisy sensor readings alone, are available for processing. Hence the noise removal algorithms should be designed to effectively remove the sensor noise in the presence of this constraint.

Testing the algorithm on a simulated process does not always reflect the actual system performance and can neglect the effects of model mismatch, modeling uncertainties, sensor noise, etc. Thus, any proposed intelligent control algorithm should be tested for satisfactory performance on a real time nonlinear prototype model.

In the present investigation, the intelligent control algorithms have been designed and tested on a real time plant for satisfactory performance, with due emphasis on factors like model mismatch, modeling uncertainties and sensor noise. A multiple sensor coordination model, integrating the data from two or more independently designed, mutually interacting and separately
located sensors is developed. It can be incorporated into any existing interacting multivariable process control loops with slight modifications in the algorithm, at no extra hardware costs. Since no extra hardware costs are involved implies that with the proposed algorithms, the existing configuration need not be altered, but less sophisticated controllers can be made to perform more complicated tasks. The algorithms presented here can be used to assist existing non-fault-tolerant conventional control strategies. The sensor noise removal algorithm presented in this work is unique and is ideally suited for a real time environment, where no apriori information is available about the nature of the noise entering the measured states.

The algorithms developed in this investigation are tested directly on a nonlinear process, since practical systems are not precisely linear. Even, when represented as linearised models around a nominal operating point, the real system characteristics may not be reflected due to variations in process parameters. A nonlinear (the hopper type tank) multivariable interacting (level and flow) process, with parameters (process gain, process time constant), varying with respect to the process variable level, is considered for real time implementation and study. Even though the process is of the first order and simple, it has the desired severe nonlinearity. A shift in the operating point from the bottom to the top of the tank will alter the process time constant and gain drastically. A deliberate feedback sensor fault is introduced in the sensor used for measuring the process variable level, at random time instants, for a considerably long duration, to test the consistency of the designed estimator. By introducing an artificial sensor noise, the effectiveness of the independent
component analysis (ICA) based sensor noise elimination algorithm is easily observed. Since the requisites for testing the algorithms were present in the chosen model the same was taken up for study.

Keywords: Intelligent controller, Fuzzy logic, Neural Network, Independent Component Analysis, Sensor validation, Sensor noise elimination.