Effectiveness of Error Recursion Technique on Real Time Closed Loop Pressure Process using validated model by NARX- Recurrent Neural Network tool

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Abstract- Analysis of process parameter in a plant is very much essential for the operation in process industries. In this article the real time pressure process is taken into account and process parameters are identified as first order plus dead time (FOPDT) transfer function. System identification of the process is done by Nonlinear Autoregressive exogenous (NARX) Recurrent Neural Network and is validated, proposed for controller design. The work aims to development and implementation of fine tuning of closed loop control response, by Error Recursion Reduction Computational (ERRC) method. Initially, optimization technique Particle Swarm Optimization (PSO) is used to find closed loop control parameter settings. The efficacy of the controller is assessed by the basics of time domain and stability analysis. The durability of the controller is approved by exposing it with both servo and regulatory process. Hence the results demonstrate that the proposed method, which gives least time domain specifications than PSO based PID control settings and also reduces the error much faster.

Keywords: Error Recursion, ERRC, NARX, Neural Network, PID Control.

1. Introduction

Pressure is one of the most important parameter that has to be controlled in the process industries. It is defined as the force per unit area. The force is applied opposite to the surface of a protest for every unit zone over which the force is dispersed. Measured pressure is the pressure in respect to the atmospheric or surrounding pressure.

The presence of pressure in the closed surface changes dynamically which must be taken care of its functional behavior. A controller is designed for controlling the system parameter, which can be carried out different tuning process. Tuning a PID control settings for a pneumatic process is an essential which generally will make a basic condition for bubbling, compound (chemical) reaction, refining, expulsion, and vacuuming, aerating, cooling and different reactions at advanced end. Then again poor pneumatic control can cause significant security, quality, and profitability issues. On expansion to this high weight inside a shut framework can cause a blast. In this manner, it is profoundly desirable over keep the pressure inside the shut circle framework in charge and to keep up it inside its wellbeing limits which turns into the essential of pneumatic control. A corresponding essential subsidiary controller (PID) is an ordinarily utilized shut circle criticism controller [1,2] utilized as a part of process station that screens the blunder flag which is the contrast between the present yield process variable and the genuine set point. Day by day a research on obtaining best fitted PID control for process is boomed out in research community. Many researchers were focused to develop control algorithms based on [15,16,17] human thinking ability and neuron structure, and now a days more research work are coming out on developing optimization algorithms [9,10] for improving the results. A few research communities are working on iterative algorithm and recitative control techniques [3,6]. And researchers are testing their developed and designed controller on various linear and non linear, single and multi variable systems [8, 9, 10]. On considering the objectives of all research works carried out on closed loop control system is to minimize the error nearly to zero is faster and smoother means. By considering, the same error tracking mechanism has been proposed here and is tested on transducer interfaced real time pressure process station.

The works has been carried as starting from obtaining process model as first order plus dead time transfer function by bump test method and validated by NARX recurrent neural network tool. Secondly, PI control settings are obtained using PSO technique in offline mode and implemented in closed loop process, and a proposed ERRC technique is also implemented in process station. In lastly, conclusion will be made on effectiveness under considering time domain analysis, stability analysis.

2. Process Setup

The physical experimental system consisting of various components which are listed below and (National Instruments- Educational Laboratory Virtual Instrumentation Suite) NI-ELVIS interface module, using LabVIEW, which goes about as a controller, frames a closed loop framework. The instrumentation diagram of the framework [18] is appeared in Figure.3 process particulars are mentioned.

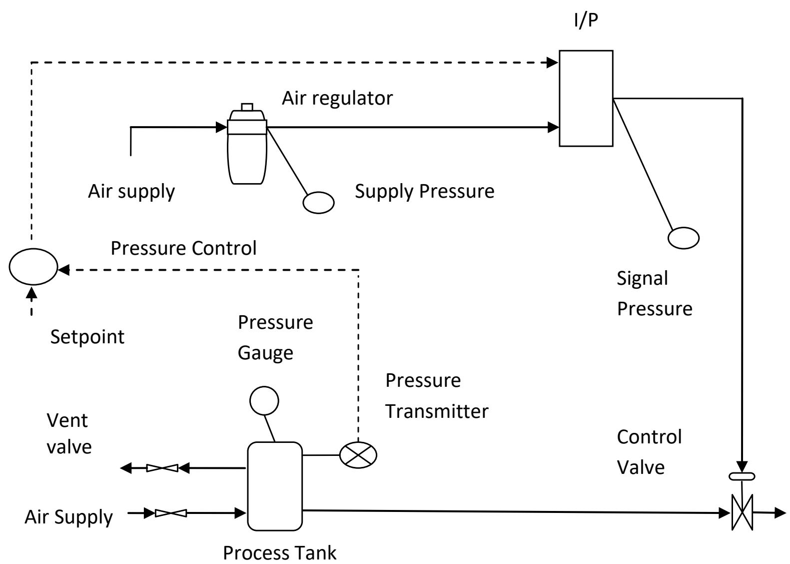

Figure 1. Schematic of Pressure process station

The operating parameters of the process station are process tank is an opaque vessel, pressure transmitter with operating range of 3 to 15 psi corresponding output range of 4 to 20 mA, Air filter regulator of range of 0-0.25 kg/cm^2, Pneumatic type Control valve of quarter size with Input range of 3-15 psi, Normally open and Linear type, Pneumatic gauge is vary from 0 to 2.5kg/cm^2 [1] and from 0 to 7 kg/ cm^2 [2], I to P converter with input varies from 4 to 20 mA to correspondingly output varies from 3 to 15 psi respectively, and RS232 communication cable used for computer interface. The inflow rate to the progressive tank is controlled by adjusting the stem spot of the pneumatic valve, passing a control signal the current to pneumatic converter through the NI-ELVIS analog channel. The working current range is 4-20 mA, is utilized to control the valve position. 4-20-mA is changed over to 3-15 psi by utilizing compacted pneumatic stress. The pressure level in the tank is measured by capacitance type electronic two wire sensor which is calibrated to give an output current range of 4-20 mA for full operating condition. The output current signal, from pressure sensor is passed through nominal value of resistor and converted to range of 1.21-2.02 V, is given through analog input channel of NI-ELVIS. The NI-ELVIS module is used to connect personal computer and sensor/final control instruments. Signal [1-7] V, from the computer is mapped to [3-15] psi pressure to operate the control valve. A process model is obtained by step test method; A little advance change has been presented with the assistance of manual control action. For each change in input, the response is noted and which mirrors the open the loop response of the plant, is appeared in figure 2.

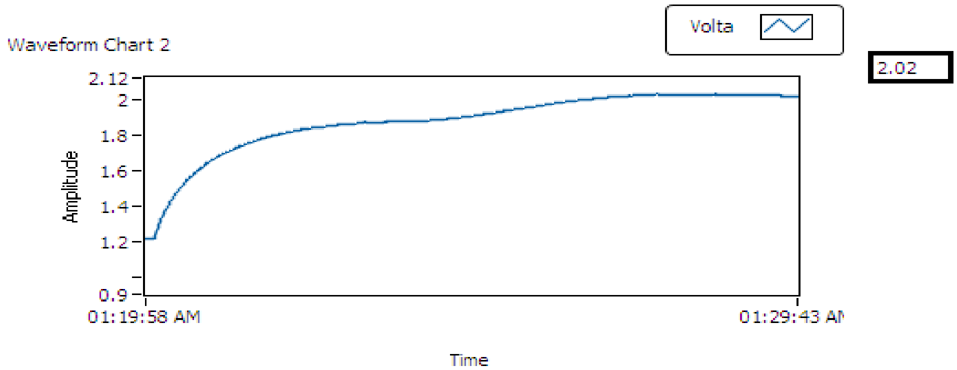

Figure 2. Open loop response

3. System Identification

In this work, system identification is the process done by Nonlinear Autoregressive exogenous (NARX) Recurrent Neural Network. A open loop readings are noted by conducting step test and the model identification is performed using neural networks tool. Neural networks have become a accepted tool for system identification of linear and nonlinear dynamic systems. System identification for a system, which is based on measured experimental data and artificial neural network (ANN), can be utilized to identify dynamic systems keeping in mind the end goal to outline a compelling controller based on the framework model. Where, the obtained model is fitted with FOPDT model and is given by Equation (1),

$$G(s) = \frac{K_p e^{-t_d s}}{\tau s + 1} \qquad (1)$$

Where,

k_p is the process gain,
τ_d is the dead time and
τ is the time constant [19].

The model is ascertained with the process parameters as

$$G(s) = \frac{0.113 e^{-2s}}{16s + 1} \qquad (2)$$

From the data history, for random input and output information the network is trained and the proposed process model is designed. The NARX neural network (NARX 1990) is one of the recurrent network types. In this type, the network nodes are partially interconnected [13, 14].

4. Controller Design

This paper addresses the implementation and analysis of ERRC technique with PSO based PID control settings.

4.1. Particle Swarm Intelligence

PSO is the strong and effective method, in finding PID control settings for process systems applies the idea of social cooperation to critical thinking. In the year 1995, James Kennedy (social-clinician) and Russell Eberhart this technique and it was utilized by most researchers for finding PID Controller settings. Here, selection parameters are chosen as follows.

4.1.1. Selection of PSO parameters

To fire up with PSO, certain parameters should be characterized. Choice of these parameters chooses, as it were, (19) the capacity of global minimization. Design Operating parameters are, Population size of 100, Number of iterations is 100 , Velocity constants, C_1=1.2 and C_2=2.

$$velocity = w \times velocity\_old + C_1(r_1 \times localbest - current\_position) + C_2(r_2 \times globalbest - current\_position) \qquad (3)$$

Where,

C_1 and C_2 are sure constants, address the scholarly and social parameter separately; r_1 and r_2 are discretionary numbers reliably passed on and w is idleness weight to adjust the worldwide and neighborhood seek capacity.

4.2. Error Recursion - Reduction Computational technique

In the error recursion reduction computation (ERRC) approach, consider a closed loop negative feedback control system with typical block diagram in Figure 3.

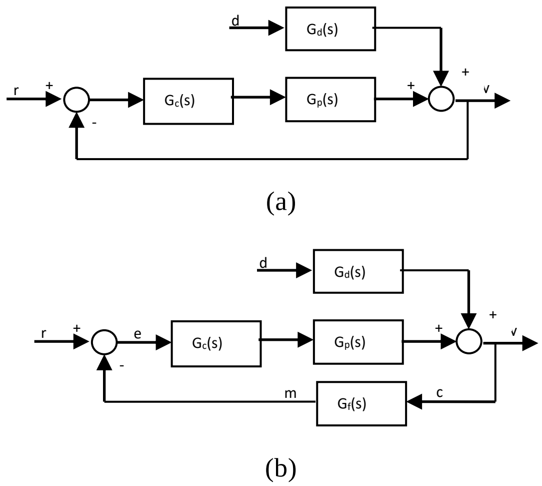

Figure 3. Feedback control strategies. (a) Classical feedback control. (b) Error recursion reduction approach.

Consider $G_p(s)$ is model of a plant, sensor and final control element. The closed loop transfer function of a setpoint change is derived as,

$$\frac{y}{r} = \frac{G_p(s)G_c(s)}{(1+G_p(s)G_c(s)G_f(s))}$$
(4)

$G_f(s)$ is a parameter estimator; the output is estimated by considering following two cases. Generally, the target of outlining closed loop framework is to keep up the controlled variable at required set-point i.e. $y = r$ and here the controlled variable is referred as c, i.e. sensor output. Here, the objective of the work is to make the output from the sensor equal to the value '*m*' given to comparator.

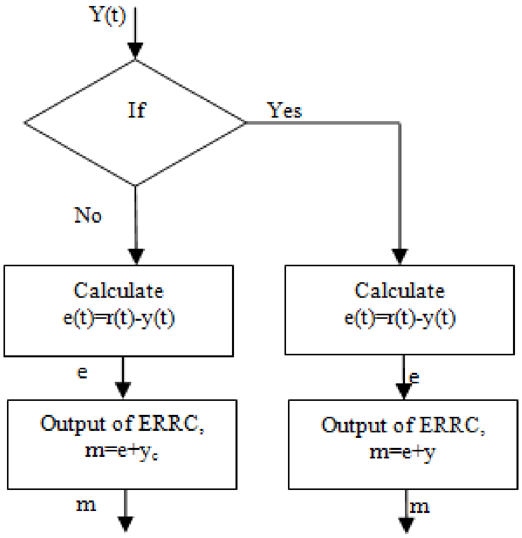

Figure 4. Flow chart of computational progress

5. Result and Discussion

The following section deals with the analysis of PI control settings is found using PSO for the pressure processes are Proportional gain, K_p= 49.5665 and Integral gain, K_i= 2.2230.

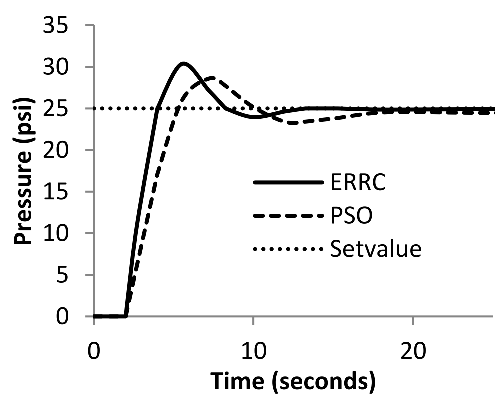

Figure 5. Closed loop response

Analysis results show that the addition of ERRC with the designed controller which disturbs the process variable and helps it to steady state at set point value with minimum rise time, minimum settling time and agreeable over an extensive range of plant operations is shown in Table 1.

Table 1. Comparison of Time Domain Analysis:

Specifications	ERRC	PSO
Peak Time (seconds)	5	7

Peak overshoot(psi)	5	4
Settling time (seconds)	14	17
Rise Time (seconds)	3	4

5.1. Controller Stablity analysis by servo and regulatory response trial

A regulatory control loop is one which reacts to an adjustment in some disturbances, taking the framework back to enduring state. Regulatory means a managerial control action is by a long shot more typical than servo control in the plant. A process is maintained at a set point of 10 psi pressure in the process tank and it has been disturbed at 80 seconds and changes recorded for both Control settings, and from the figure 6 ERRC implementation holds on best compare to PSO based PID control settings.

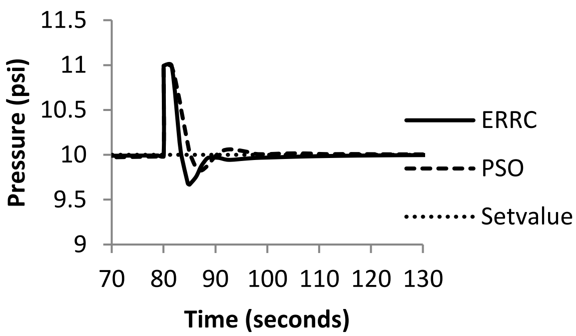

Figure 6. Change in process variable for load distrubance

A servo control loop is one which reacts to an adjustment in set point. The set point might be changed as a component of time and in this way the controlled variable must take after the set point / setpoint tracking. A study carried out process with two control settings for various set-point changes and results shows that ERRC gave a superior result than PSO based PID control settings.

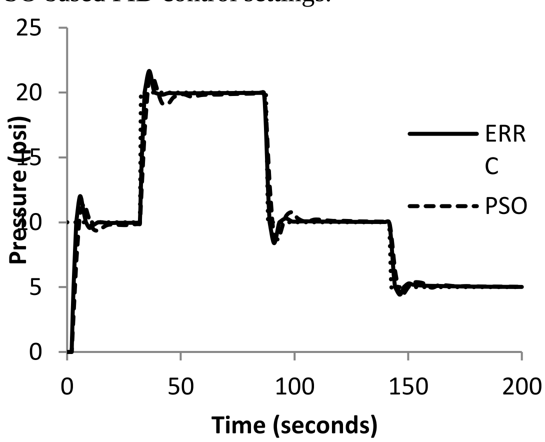

Figure 6. Change in process variable for various set-point values

Regulatory control is by removed more typical than servo control in the process operations . The above is the general description of the servo-regulatory responses. The responses are shown in figure 6 and 7 produced for both two techniques. And it proves that ERRC grasp the best compared with PSO based PID controller.

6. Conclusion

The PSO based PID tuning method has been implemented on real-time pressure process, controller performance is compared with ERRC technique. The analysis was carried on various aspects like closed loop response, servo and load change response and time domain specifications. For the PSO based PID controller the servo response is illustrated by require of soft transition. Additionally it requires much time to reach desired value, Also it takes much but the ERRC control technique tracks the desired value faster and maintains steady state. Outcomes have been given to demonstrate the Performance of the strategy. The projected ERRC control strategy is unbeatable and show great execution in apply with real time implementation.

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