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Model Identification and Control of Interacting Level Process using Optimization Algorithm

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Abstract

System identification from the venture data plays a decisive role for model based controller design.In general, real time process off times exhibits non-linear behavior, delays and time variance. Powerful PID controllers are used to regulate and control process variables and gives best solution due to changes in load. By using all three control algorithms together, rapid response to major disturbances with derivative control , setpoint without major fluctuations with proportional control and Elimination of offset with integral control has been achieved. This proposed work solely based on acquisition of transfer function from interacting level process in real time experimental data and objective of supervising with PID controllers like Zn, T-L, ant colony optimization (ACO), particle swarm intelligence (PSO) . The performance indices like ISE, IAE, ITAE, MSE has also undergone scrutiny performance and above all PSO outperformed well correlatively with other controllers. We have simulated and tuned in matlab to arrive our focused and heuristic solution.

Keywords: PID Controller, Z-N method, ACO, PSO, Interacting, Real time

1. Introduction

The process of constructing models from ventured data is known as system identification. It comprises of deriving mathematical model for a system with process parameters. It holds of acquiring, configuring, processing and deriving mathematical model from the real time system. Then it is framed in form of transfer function, series expansions that can be implied to controller design. It is then observed with step input and responses are eventually recorded. We have used SK and 2-point method for finding transfer function. The formulae are as follows:

SK Method:

$T_d=1.3t_{35.3}-0.29t_{85.3}$

$T_p=0.67(t_{85.3}-t_{35.3})$

2 Point Method:

$T_d=t_{63.2}-t_{28.3}$

$T_p=1.5(t_{63.2}-t_{28.3})$

The transfer function we obtained is:

$$G(s) = \frac{5375.3\ e\hat{} - 0.005s}{s^2 + 99.90s + 926.8}$$

Controllers are tuned in an effort to match the characteristics of the control equipment to the process so that two goals are achieved is the foundation of process control measurement in that electricity: The system responds quickly to errors and the system remains stable (PV does not oscillate around the SP).

2. Modeling of The Tank

It is to explain the analyzed system and to study the content of several components and to predict the process behavior. This paper accentuates about an interacting tank, where area and height remains the same due to linear process. The level of the tank can be evolved into proper modeling of tank. The set up of the tank is

Tank 1,

q-q1 = A1 dh1/dt …(1)

Tank 2,

q1-q2 = A2 dh2/dt…(2)

Where,

q1= h1/R1 … (3)

q2= h2/R2 … (4)

Where,

Q1= q1-q1s

Q = q-qs,

$\tau 1$=A1R1

Q1(s)/Q(s) = 1/ (τs+1) …(5)

H2(s)/Q1(s) = R2/($\tau 2s + 1$)…(6)

Where,

H2= h2-h2s

$\tau 2$=A2R2

Overall transfer function of the system,

H2(s)/Q(s) = R2/(τ1s+1)($\tau 2s + 1$)

H(s)/Q(s) = 1/S (R2/(τ1s+1)($\tau 2s + 1$)

Thus, the transfer function obtained by the model is,

$$G(s) = \frac{5375.3\ e^{-0.005s}}{s^2 + 99.90s + 926.8}$$

3. PID Tuning

3.1. PID Controllers

Controller tuning allows for optimization of a process and minimizes the error between the variable of the process and its set point. It includes the trial and error method, and process reaction curve methods. The magnitude of the correction (change in controller output) is determined by the proportional mode of the controller. The duration of the adjustment to the controller output is determined by the integral mode of the controller .The speed at which a correction is made is determined by the derivative mode of the controller. The transfer function of basic PIS controller for continuous system is :

G(s)=Kp+K_i/s+K_d s

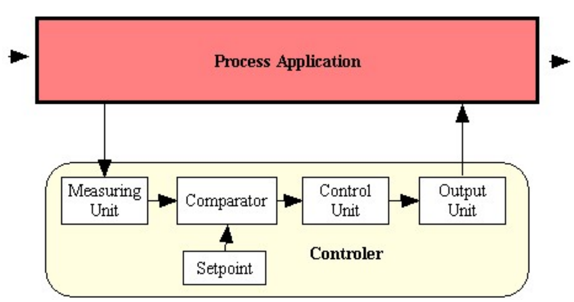

Figure 1. basic control loop

- *Proportional Controller:*

For this mode, the controller output is a function of a change in error. It is responsible for process stability. If stability is low, the process drifts and if it's high, then it begins to oscillate.

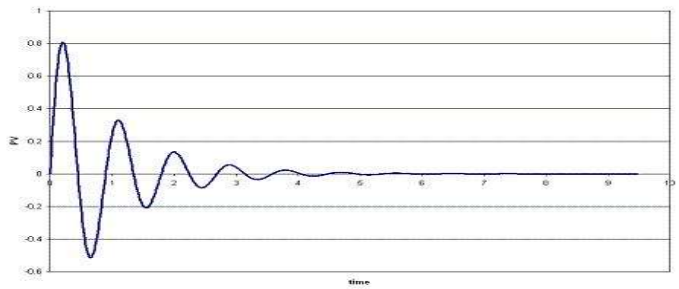

Figure 1: Kp1 value for finding sustained oscillation

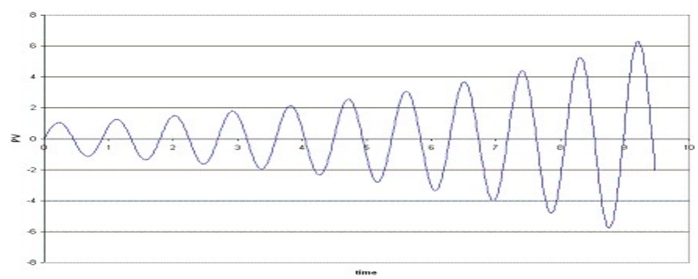

Figure 2: Kp2 value for finding sustained oscillation

PB = (ΔInput, % / ΔOutput, %) x 100 = 100/Gain

Δ Controller Output = (Change in Error) (Gain)

It reduces PB (increase gain) until the process cycles following a disturbance, then double the PB (reduce gain by 50%).

- *Integral Controller:*

It is a function of the duration of the error because output is a repeat of the proportional action as long as error exists. It eliminates steady state deviation but with sluggish response of larger oscillations

- *Derivative Controller:*

It is the rate of change of the PV and expressed in terms of minutes. It also anticipates future error. It has stabilizing effect in closed loop response. It is responsible for system response. The rate of change of error multiplied by a gain, K_d.

3.2.Tuning Methods

i). Z-n Method

It was introduced in the 1940s, had a large impact in making PID feedback controls acceptable to control engineers. It determines the dynamic characteristics of the control loop. It is also known as online-tuning

method or closed loop method. It works well in linear and monotonic system. Given the magnitude and phase, we can determine gain parameter of the model, frequency F_u through pi-radians, plant gain K_c and gain margin Ku.The method is robust.

Table 1. Tuning Formula

Controllers	K_p	K_i	K_d
P	$0.5K_u$	-	-
PI	$0.45\ K_u$	$P_{u/1.2}$	-
PID	$0.6\ K_u$	$P_{u/2}$	$P_u/8$

ii). Tyreus-Luyben Method:

Its procedure is quite similar to the Zn method but the final controller settings are different .This method is applicable for PI and PID Controller. As Z-N is based on a quarter decay ratio, the Z- N settings tend to produce oscillatory responses and large overshoots for set point changes. Consequently, more conservative controller settings are preferable such as T-L settings. This method is based on ultimate gain period and period.

Table 2. Tuning Formula

Controllers	K_p	t_i	t_d
PI	$K_u/3.2$	$2.2P_u$	-
PID	$K_u/2.2$	$2.2P_u$	$P_u/6.3$

3.3. Swarm Techniques

A) Ant Colony Optimization

It was proposed by Marco Dorigo in 1992, based on the behavior of ants seeking for their own food and shelter. It is a probabilistic technique for solving computational and tedious problems. It is a metaheuristic. Its ant's foraging behavior and how they tend to reach their food in shortest path. When searching for food, ants initially explore the area surrounding their nest in a random manner. While moving, ants leave a chemical pheromone trail on the ground. Ants can smell pheromone. When choosing their way, they tend to choose, in probability, paths marked by strong pheromone concentrations.

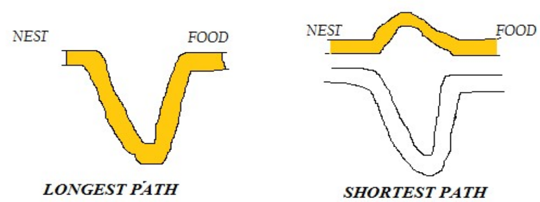

Figure 3. ACO process

B) Particle Swarm Optimization

PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms. It applies the concept of social interaction to problem solving and was developed in 1995 by James Kennedy (social-psychologist) and Russell Eberhart (electrical engineer).It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. Each particle is treated as a point in a N-dimensional space which adjusts its "flying" according to its own flying experience as well as the flying experience of other particles. It gives best solution for multi system, unimodel and non-linear system.

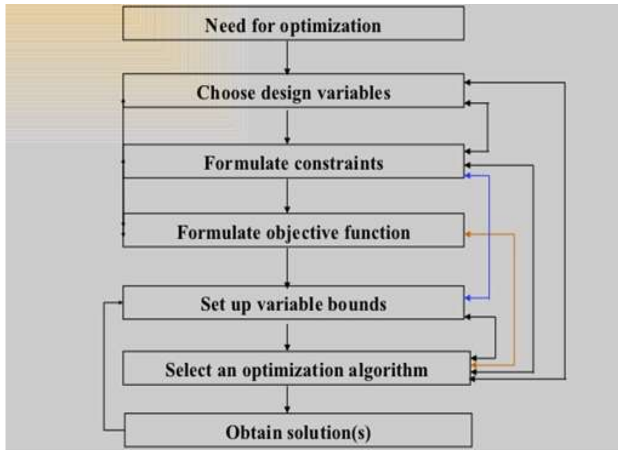

Figure 4. Flow chat for PSO is as follows

4. REAL-TIME EXPERIMENTAL SETUP

Figure 5. Process Setup

Specifications

- Diameter of the tank= 92mm
- Initial flow rate = 30LPH
- Final flow rate = 40LPH

Course of Action

- Start the setup an partially close tank 2 & 3
- Rotameter is set to 30 LPH and initial steady
- State of both the tanks are obtained
- A step change is given(40LPH) & for every 10sec tank 2 levels is noted

4.1 Tuning Parameters

The real time interacting level process is tuned with traditional controllers like Zn,T-L and compared with swarm intelligence techniques like ACO and PSO.The tuned parameters were analyzed and the corresponding response curves were observed and plotted. The tunings are tabulated below.

Table 3. PID Gain Values

Methods	K_p	K_i	K_d
Z-n	2.37	100	0.014092
T-L	1.234	11.797	0.0093167
ACO	3.0591	93.0485	0.0247
PSO	3.1347	83.5257	0.0183

4.2 Response Curve

Tuning controllers like Zn and T-L has been evaluated and graphed and Zn proved to be the best.

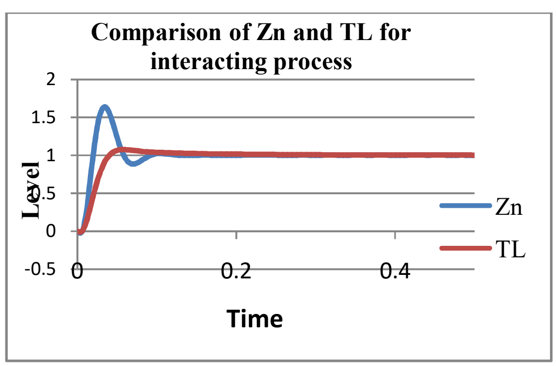

Figure 6. Closed loop comparison conventional Controllers

It is then compared with ACO and PSO, and PSO attains the best heuristic solution of all by the assessment of time domain specifications.

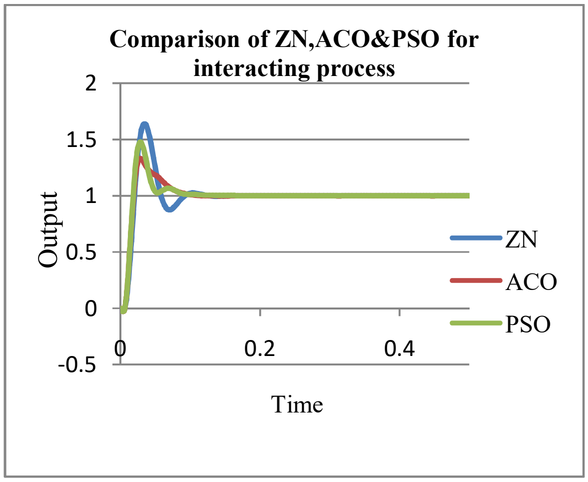

Figure 7. Closed loop comparison Optimzation alogorithms based Controllers

4.3 Performance Indices

At times, system responds with some error which is inevitable and it becomes smaller as time goes on, as long as the system performance is well and stable. The common Performance indices are used in practice is as below,

1) Integral Square Error (ISE) $=\int e^2 (t)\, dt$

2) Integral of the absolute magnitude of error (IAE) $=\int | e (t) | dt$

3) Integral Time-absolute error (ITAE) $=\int t. | e (t) | dt$

Table 4. Performance index

Methods	ISE	IAE	ITAE	MSE
Zn	1.002	1.037	0.0038	0.0109
T-L	1.00	1.008	9.7407e^005	0.0196
ACO	1.00	1.000	2.3269e^006	0.0477
PSO	1.00	1.000	1.8763e^005	0.090

4.4 Time domain Specifications

From the response curve: specifications like rise time, peak time, overshoot and settling time has been calculated.

Table 5. Servo Regulatory Performance

Methods	Rise time	Peak time	Peak overshoot	Settling time
Zn	8.68	0.035	63.8	0.5
T-L	0.0294	0.06	7.2	1.5
ACO	7.9	0.0276	32.38	0.2
PSO	2.3	0.0276	17.53	0.1707

From the above parameters ZN is the best method compared to Tl. Hence, ZN is compared with ACO and PSO. The following figure indicates the servo and regulatory performance

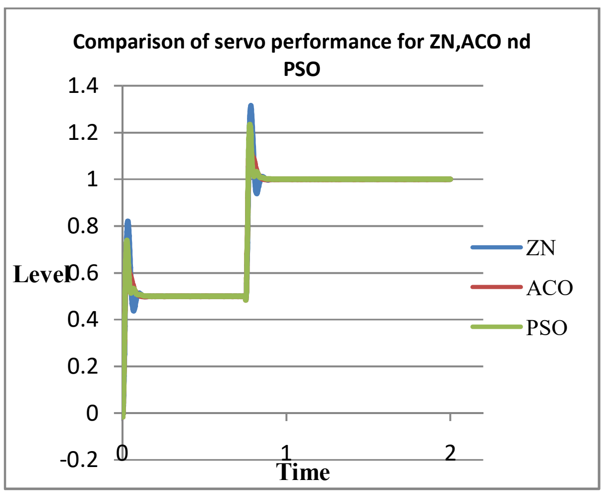

Figure 8. Comparison of Conventional Controller Response

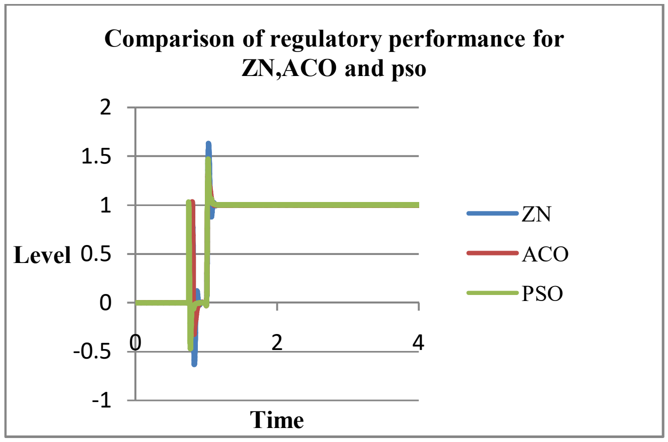

Figure 9. Comparison of Conventional Optimization based Controller Response

5. Conclusion

Thus, this paper proved that PSO is best when correlated with Zn, T-L, and ACO. Since PSO doesn't evolve into tedious process. It has been implemented in many areas like power system optimization, killing tumors, ANN, hybrid vehicles etc. The future evolutions known as improved PSO is highly applicable for hydrothermal power system. The performance indices were also reduced by PSO. From the simulation results, it is proved that the performance of PSO is better for interacting level process.

REFERENCES

[1] A.Ganesh Ram & S. Abraham Lincoln, "A Model Reference-Based Fuzzy Adaptive Pi Controller For Non-Linear Level Process System", International Journal of Research and Reviews in Applied Sciences, Volume 14, Issue 2, February-2013.

[2] P.Aravind, M.Valluvan, S.Ranganathan," Modelling and Simulation of Non Linear Tank", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 2, February 2013.

[3] Pushpaveni, S.Srinivasulu Raju, N.Archana, M.Chandana, "Modeling and Controlling of Conical Tank System Using Adaptive Controllers and Performance Comparison with Conventional PID", International T Journal of Scientific & Engineering Research, Volume 4, Issue 5, May-2013.

[4] M.Lavanya, P.Aravind, M.Valluvan, Dr.B.ElizabethCaroline,"Model Based Control for Interacting And Non-Interacting Level Process Using Labview", International Journal of Advanced Research In Electrical, Electronics And Instrumentation Engineering, Vol. 2, Issue 7, July 2013.

[5] Abhishek Sharma and NithyaVenkatesan," Comparing PI controller Performance for Non Linear Process Model", International Journal of Engineering Trends and Technology- Volume 4, Issue 3- 2013.

[6] D.Mercy , S.M.Girirajkumar "Tuning of controllers for non linear process using intelligent techniques'', International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization) Vol. 2, Issue 9, September 2013.

[7] L. M. Gambardella and M. Dorigo, "An ant colony system hybridized with a new local search for the sequential ordering problem," INFORMS Journal on Computing, vol. 12, no. 3, pp. 237–255, 2000

[8] M. Dorigo and G. Di Caro, "The ant colony optimization meta-heuristic," in New Ideas in Optimization, D. Corne, M. Dorigo, and F. Glover, Eds., pp. 11–32, McGraw Hill, London, UK, 1999.

[9] V. Selvi Sowmya, S. Priya dharsini, R.Priya Dharshini, P Aravind, "Application of Various PID Controller Tuning Techniques for a Temperature System", International Journal of Computer Applications, Volume 103, No 14, pages 32 - 34, ISSN: 0975 – 8887, October – 2014.