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Performance Analysis of ACO Based PID Controller in AVR System

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Abstract

AVR plays a vital role in generating station. To maintain voltage stability of the generator the terminal voltage should remain constant. In a large interconnected system manual regulation is not feasible and therefore automatic generation and voltage regulation equipment is installed at each generator. So, Automatic voltage regulator (AVR) used to maintain a constant voltage level and it uses an electromechanical mechanism or electronic components depending on its design. The regulators must be designed in such a way that it is insensitive to very small changes; if this is not happened then the system may prone to hunting and result in excessive wear and tear in machine and control equipment. This paper consists of simulation and hardware implementation of Ant Colony Optimization algorithm based PID controller design for automatic voltage regulator. The performance of AVR system with conventional fixed gain PID controller and ACO algorithm based PID is compared in Matlab environment by measuring the settling time, peak overshoot and oscillation. The proposed system is also analyzed by hardware implementation.

***Keywords:** AVR, ACO, PID etc*

INTRODUCTION

In power system it is very much essential that system should operate on steady state condition. Steady state condition means maximum power that can be transmitted without loss of synchronism [44-40]. It is already known that load cycle changes continuously because load is not constant;

as it is peak in the morning, lowers in the afternoon section and again increases in the evening [39]. Load changing requirements can be met with help of Excitation Systems. Excitation of system is done manually or automatically. For large interconnected systems manual excitation is not feasible therefore AVR is installed at each generating station [44]. A good quality of the electric power system requires both the frequency and voltage to remain at standard values during operation. Turbine speed governor system is also choice to maintain speed and excitation of system but this system has disadvantage that it requires another supplementary mechanical system e.g. flywheel ball governor [44].

PID controller is one of the Fix gain system but it is not a best solution for AVR system because of fluctuating load and constant gain, which reduces the performance of AVR system. However, in general PID controller is designed for a specific situation and its effectiveness under these particular conditions. Hence, it is desirable to increase the capability of PID controllers to suit the needs of present day applications [37].

In modern system more than 70% industrial controller is PID controller. In any system fine tuning of PID controller is vital. In various literatures many methods are present for fine tuning PID controller [37]. Also, automatic tuning methods have been developed and some of the PID controllers may possess on-line automatic tuning capabilities. Advance forms of PID control, such as I-PD control are currently used in industries. PID controller is used in most of control system and their applications where plants mathematical model is not known [3].PID controller improves transient response by reducing settling time and overshoots of system results in performance improvement. Traditionally tuning PID by trial and error method is very tedious and time consuming. To reduces this complexity, Evolutionary algorithm technique is used which solves wide range of practical problem. Evolutionary algorithms like Genetic Algorithm (GA), Simulated Annealing (SA), and Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) has been employed in control applications to efficiently search global optimum solutions.

II. LITERATURE SURVEY:

Surya Prakash et al. propose a theory on Load frequency control of interconnected hydro-thermal reheat power system using artificial intelligence and PI controllers. The result reveals that the conventional (PI) and Intelligent control approach improves dynamic response of hydro power station. Combination of most complicated scheme such as hydro electrical and steam power station interconnected obviously increases the non-linearity of system .the performance are simulated by using MATLAB [1].

Mohd. Rozely Kalil, Ismail Musirin (2006) developed Ant Colony Optimization for Voltage control study identify that application of Ant colony algorithm for searching optimal point for maximum load ability point at load bus and shows that Ant colony optimization technique reduce computational burden on in optimization process [2].

Hamid Boubertakh, Mohamed Tadjine, Pierre-Yves Glorennec and Salim Labiod (2009) in Tuning fuzzy PID controllers using Ant colony optimization reveal that in addition to the conventional tuning methods, the nature inspired algorithms become actually an alternative for tuning PID controllers. Ant colony algorithm finds optimum parameters which minimization of cost of function coding and efficiency illustrated by simulation result [3].

Nazli Madinehi, Kiarash Shaloudegi, Mehrdad Abedi, Hossein Askarian Abyaneh (2011) in optimum design of PID controller in AVR system using intelligent methods in that study two optimization algoritm are used namely shuffled frog leaping and particle swarm optimization this two algoritm are used to determine optimal PID controller in AVR system and also shows that for tuning PID controller using various optimization technique reduces complexity and find more realistic result than trial and error method [5].

Hany M. Hasanien(2013) propose optimization of PID controller in AVR system shows that minimize the maximum percentage overshoot, the rise time, the settling time and oscillation and step response of AVR system can be changed[5].

Narendra Kumar Yegireddy and Sidhartha Panda (2014) on their study of design of PID controller in AVR system this design in this shows that high degree of fine tuning is first priority so that got best result for PID controller and electronic control system for synchronous generator for stable operation [7].

S. Dadvandipour, N. Khalili Dizaji, S. Rosshan Entezar (2015) propose an approach, based on the imperialist competitive algorithm (ICA) and fuzzy logic to optimize the coefficients of PID controller so that more stability and controllability obtain [9].

Haluk Gozde (2010) in performance analysis of artificial bee colony algorithm for AVR system realize that AVR system with better dynamic response, a number of different control strategies such as optimal, adaptive, robust control, etc. have been reported by researchers so far that fine tuning and robustness of control system are extensively investigated [8-11].

S. Panda (2012) on design of PID controller in by using AVR system by overshoot and settling time reduces effectively by using PSO. And PSO also know as Many Optimizing Liaisons (MOL) [13].

Yinggan Tang(2012) in design of fractional order PID controller for AVR system using chaotic ant swarm shows that reduce nonlinear behavior of objective such as settling time, peak overshoot, oscillations[15].

III. ACO-PID CONTROLLER

In control system PID control system is more popular for parameter tuning purpose. The Conventional fixed gain PID controller, this is well known technique for most of industrial control process. The design of this controller requires the three main parameters, namely Proportional gain (Kp), Integral time constant (Ki) and derivative time constant (Kd). This gain of the controller is tuned by trial and error method based on the experience and plant behavior. This process will consume require more time and will be suitable only for particular operating condition means that where fix gain is present or in the other word error value is always remain same at that condition this is used. In this project, ACO algorithm is used to optimize the gains, and the values are transferred to the PID controller of the plant representing AVR of the power generating system as shown in Figure.

The proportional gain makes the controller respond to the error value while the integral gain help to eliminate steady state error and derivative gain to prevent overshoot. The plant is replaced by AVR models developed using Simulink in MATLAB.

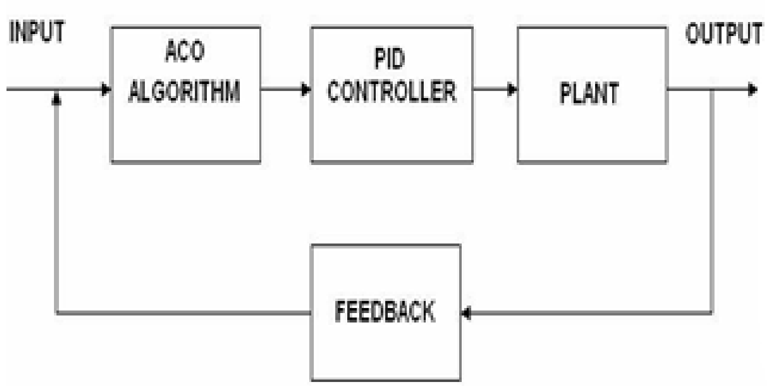

Figure 1: ACO-PID Controller [45]

IV SIMULATION RESULT

1) Firstly, initialize algorithm parameters like number of iterations and decay rate. Then set the value of Kp, Ki and Kd for further operation randomly from 0.1 to 10 with gradual increment of 1 in its array. Initially all arrays remain blank.

2) Load all the values such as output array, global array and error array which are initially blank

3) When loop is initiated at that juncture iterations start building solution incrementally. The values start updating and every time results are stored in the output array and finally all the data is stored in global array.

4) After storing these results in the array, now generate error value. Error values are calculated by subtracting output values from set value which are stored in array at every iteration. This loop continues till minimum error value is detected.

5) If maximum iteration is not satisfied then loop repeats itself from the stages 2, 3 and 4 till minimum error value is detected.

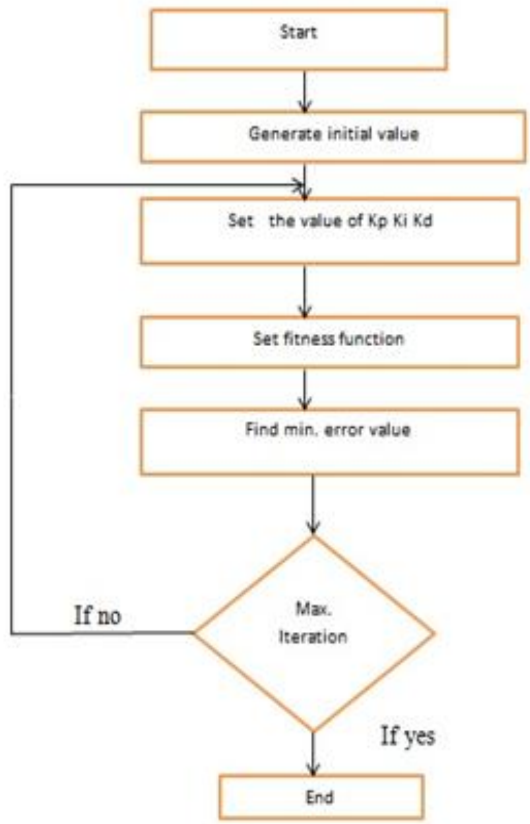

Figure 2: Flow chart of PID Controller

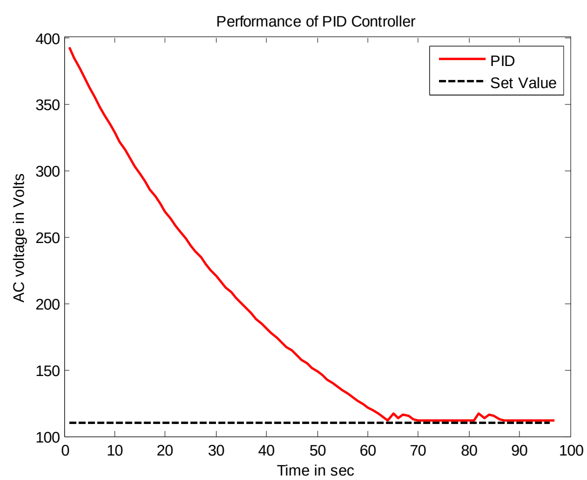

Figure 3: Simulation result of PID controller

This is result of MATLAB simulation of PID controller in AVR system. Every time the output result is compared with set point value. When minimum error value is reached, the cycle stops repeating and declares that value as final result.This value in tabular form as follow

Table 1: Performance of PID controller

Parameters	Only PID
Peak overshoot	274.4675
Settling time	64
oscillation	288.2353

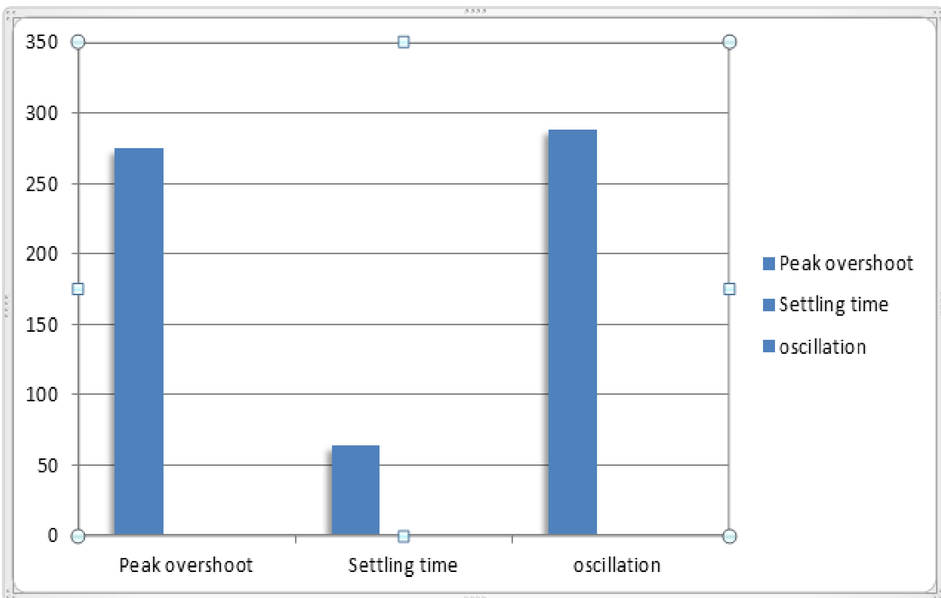

Figure 4: chart of PID controller in AVR system

First section underlines the performance of PID only and second section portrays the performance results of PID with ACO. The performance results are stored subsequently in ‘Output array_1’ and ‘Output array_2’. Then error values are set. Error value changes at every iteration.

Later on as loop is cycled, error value is settled at minimum value. The initialization process of simulation of ACO with PID controller is similar to only PID controller in AVR system expect the absolution of pheromone distinctiveness.

Simulation of PID with ACO in AVR system Algorithm of ACO with PID controller

1. Initialize the parameters. Set initial values of Kp Ki Kd
2. Load all the values and array such as output array, global array, error array and pheromone, which are initially blank.
3. When loop is initiated at that juncture iterations start building solution incrementally. The values start updating and every time results are stored in the output array and finally all the data is stored in global array.
4. 4After storing these results in the array, now generate error value. Error values are calculated by subtracting output values from set value which are stored in array at every iteration. This loop continues till minimum error value is detected.
5. At initial stage pheromone is set blank.
6. When maximum intensity of pheromone is reached, the system stops computing further iterations.
7. All the results are stored in global array.
8. After that tuning of the control parameter with the help of ACO is done. This loop continues till minimum error value is detected.
9. Finally performance of the simulation system is shown graphically.

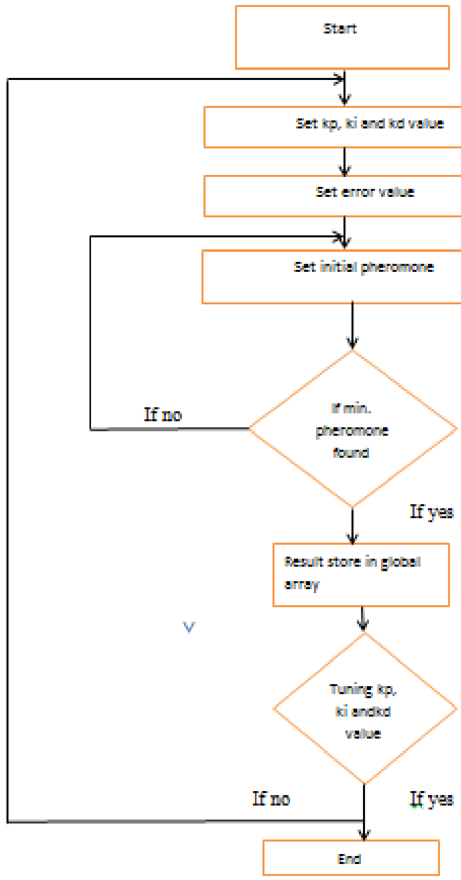

Figure 5: Flow chart of ACO with PID

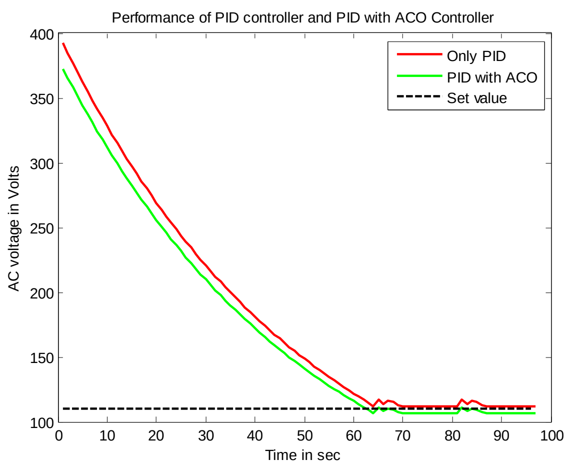

Figure 6: PID WITH ACO

The above fig shows result of only PID and ACO with PID controller in AVR. Here green line indicates result of ACO with PID controller in AVR system and red line shows PID controller in AVR system. The graph is started from calibrated values of servo motor. Output values of iteration are compared with set point value. Iteration stops when minimum error value is detected.

From above performance curves it is understood that by using Ant colony system and PID controller for AVR improves settling time, peak overshoot and oscillation of system. The optimum result is encountered due to pheromone concept of finding shortest possible path to get desired results.

Table: 2 Performance of PID controller with ACO

Parameter	PID WITH ACO	Only PID
Peak overshoot	255.2441	274.4675
Settling time	62	64
oscillation	259.5635	288.2353

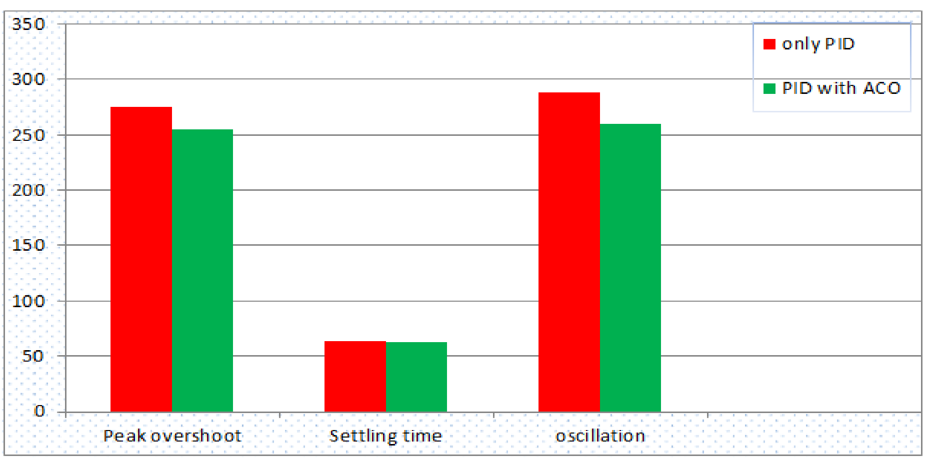

Figure 7: comparison chart of parameter

Comparison of output results of both systems sows that all the parameter of control system such as peak overshoot, settling time and oscillation are improved. Hence it proves that by using ANT COLONY ALGORITHM with PID controller in AVR system, performance gets improved. This is graphically represented as below. This gives clear idea of about reduction in performance hindering parameters by using ACO in PID controller.

V. HARDWARE IMPLEMENTATION

This chapter introduces Ant colony optimization for PID controller in AVR system. In this prototype two step-down transformers are used. Signal conditioning unit requires small voltage level therefore 230V is converted into 5V.

The prominence of ACO is that it gives fine tuning to PID controller in AVR system. ACO gives shortest possible path to get optimum tuning the gain of PID controller. In prototype design the autotransformer connects to servo motor by coupling. Autotransformer is used for buck and boost system. When system voltage is reduced then servo motor senses the error value and it increases the system voltage with the help of autotransformer by changing the angle of autotransformer. When system voltage is increased transformer changes its angle and reduces the voltage level; every time system has to maintain output voltage constant. Servo motor is used for feedback purpose; it gives feedback or senses the error value and accordingly changes their angle. The PWM technique is used to send information to servo motor as servo motor understand the PWM signal.

Later in the circuit, analog to digital converter is used because ATMEGA328 IC requires digital signal. ADC converter requires 5V DC supply for that purpose use of signal conditing unit is used. ATMEGA328 IC is used for automatic voltage regulator.

At first PID controller signal is given to coupling system of servomotor and autotransformer. Then signal generated by PID with ACO is given to same coupling system. Output results of both systems are compared.

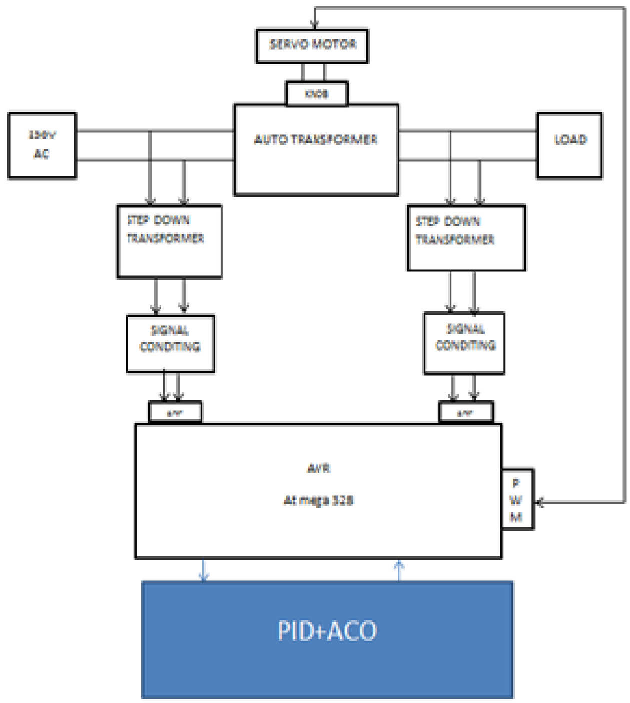

Figure 8: block dig. Of hardware

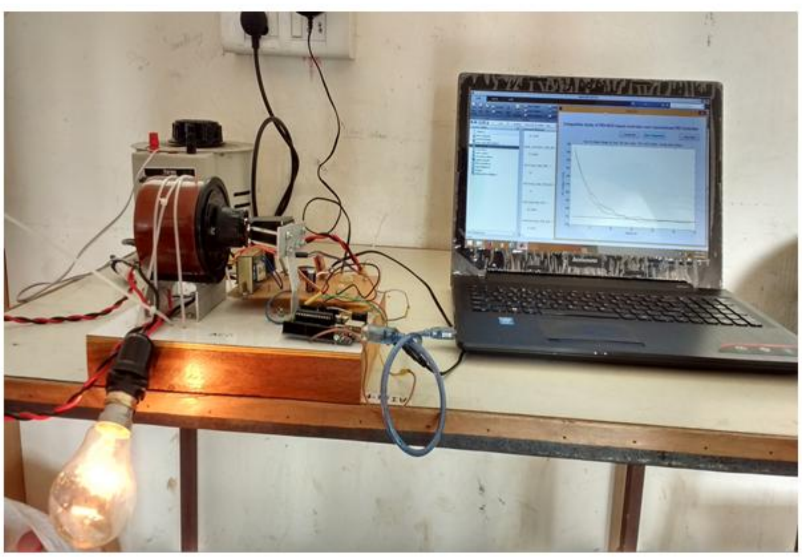

Figure 9: photo of prototype model

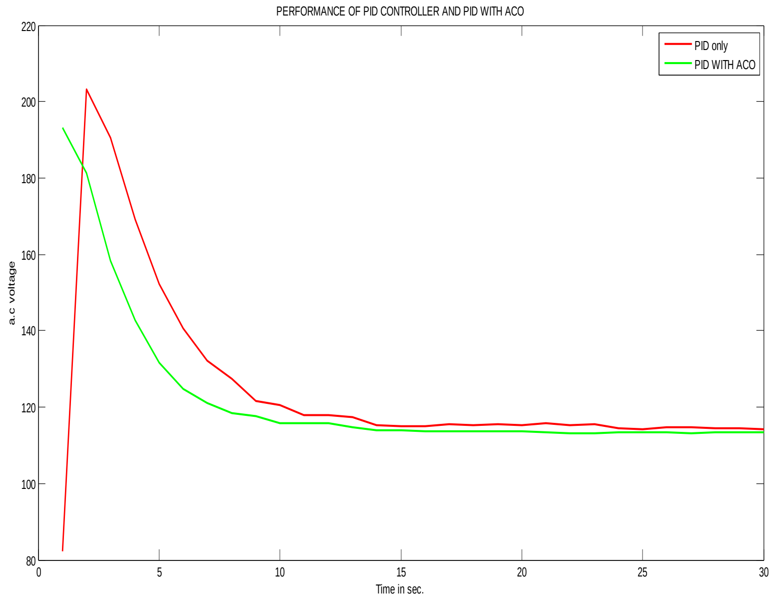

Figure 10: voltage vs. time

Table:3 Hardware result

Parameter	Only PID	PID WITH ACO
Peak overshoot	51.0574	49.5738
Settling time	12	9
oscillation	23.9463	7.4199

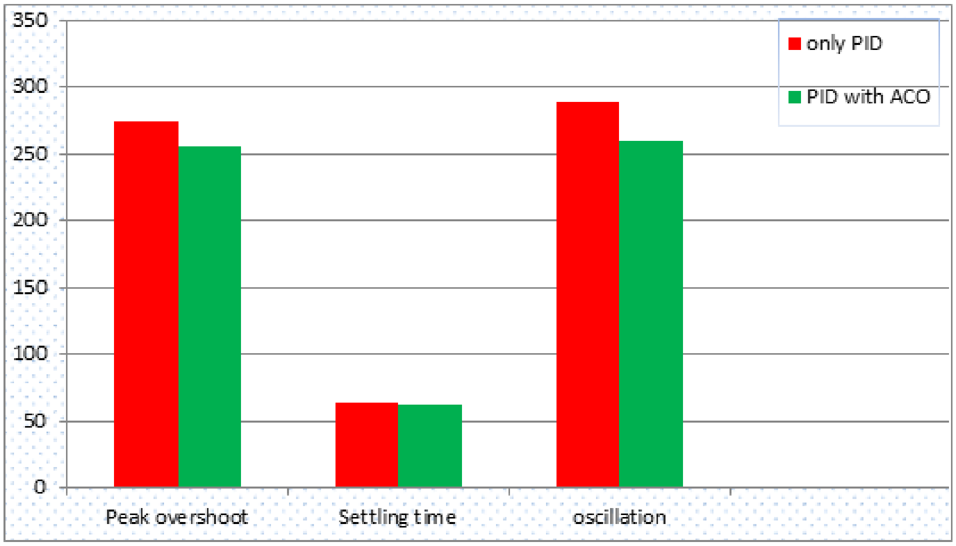

Figure 11: comparison chart of parameter

In hardware implementation the hardware is connected to Matlab by using USB cable which continuously gives signal to servomotor causing the change in angle of autotransformer to buck and boost the system voltage. This helps to maintain terminal voltage at constant value.

FUTURE SCOPE

This project of PID with ACO used in AVR system may be used in generating station for fine tuning. Because PID has fixed gain so if no algorithms are used then it definitely create error so when it use PID with ACO at that time definitely fine tuning takes place. It may be used where load fluctuation takes place. This technique may also be implemented where stable operation is required. This project will be helpful for where constant voltage is required.

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