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Implementable Self-Learning PID Controller Using Least Mean Square Adaptive Algorithm

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Abstract:
More than 95% of the industrial controllers in use today are PID or modified PID controllers. However, the PID is manually tuning to be responsive so that the Process Variable is rapidly and steady moved to track the set point with minimize overshoot and stable output. The paper presents generic teal-time PID controller architecture. The developed architecture is based on the adaption of each of the three controller parameters (PID) to be self- learning using individual least mean square algorithm (LMS). The adaptive PID is verified and compared with the classical PID. The rapid realization of the adaptive PID architecture allows the readily fabrication into a hardware version either ASIC or reconfigurable.

Keywords: Adaptive PID Controller, Component, LMS Algorithm, Parameters, PID Control **.**

Introduction:

Currently, most of the control system applications are utilizing PID controllers or modified PID controllers [1]. The most important industrial applications of PID controller are in power control, the loss power in wireless communication is sensitive problem need to be solve, therefore a real-time self-tuned controller developed. The control parameters (P, I and D) are adjustable according to the system requirements. The benefits of power control that in communication link used to send and receive signal in high power to increase SNR and decrease BER in link. In wireless communication used to decrease fading in signal. The traditional PID controller most utilize because their good performance in a widely range of operating conditions and can be operated in a simple, straightforward manner using PID tuning (manual PID tuning) [2]. The contribution of this paper is the creation of digital adaptive PID controller that is efficiently operated in real time to produce an optimum response and may be readily fabricated into a generic architecture.

Existing Related work

There are no shortage of publications to PID controller using different techniques for Varity of advanced and modern applications. In 2017 IEEE published a paper [3] to report Firefly algorithm with PID (FFA-PID that optimized PID controller based on Genetic Algorithm (GA) (GAPID) and Particle Swarm Optimization (PSO) technique (PSOPID). The FFA, GA and PSO algorithms choose the gain parameter of PID controller. FFA outperformed the other optimization algorithms by least settling time, peak overshoot/undershoot. In 2016, a paper [4] discussed effect of PID controller in a magnetic levitation system (MLS) by employing fractional order proportional integral derivative (FO-PID) and integer order PID controller to control the position of the levitated object, where the system is nonlinear and unstable. Control's parameters tuning by use dynamic particle swarm optimization (DPSO).

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In [5] design and simulation of a Fuzzy PID for Hydro Power Plant compared to the conventional. The gain of the PID are tuned by Ziegler-Nichols method to produce faster Fuzzy-PID and smaller time of fault. An adaptive controller is developed by introduced the Transmission Power Control (TPC) [6] into PID controller in Wireless Body Area Networks (WBANs) to save energy by adjust adaptively the transmission power, and enhance energy efficiency and link reliability. The scheme of adaptive power controller increased TPL when deteriorating channel conditions and decreased when channel condition improve.

In [6], an adaptive filtering techniques are developed to resolve the wireless channel Non-idealities that cause distortion to the mobile signal such as long distance, multipath and the noise that the channel added to the transmitted signal. Consequently, an adaptive FIR blind identification architecture is developed using four adaptive algorithms to estimate wireless time invariant as well as time varying channels. The four adaptive algorithms are least mean square (LMS), normalized least square (NLMS), recursive least square (RLS) and affine projection algorithm (AFP). The results shows that the RLS outperforms other algorithm in wireless time-invariant channel with least mean square error of (0.0116), and AFA outperforms other algorithms in wireless time-variant channel with least square error of (0.433) and fastest convergence rate.

Background

The mathematical model of the developed adaptive PID controller. The analog model may be expressed as:

$$u(t)=KP\,e(t)+KI\int_0^t e(t)\,dt+KD\,\frac{de(t)}{dt} \quad \ldots(1)$$

Where KP, KI and KD are proportional, integral and derivative gains respectively. The digital mathematical model of the integral part is

$$\int_0^t e(t)\,dt=\sum_0^n e(n)T \quad \ldots(2)$$

Where, T is sampling time.

The derivative part may be formulated as

$$\frac{de(t)}{dt}=\frac{e(n)+e(n-1)}{T} \quad \ldots(3)$$

The total PID control equation is [7]:

$$u(n)=KP\,e(n)+KI\sum_0^n e(n)T+KD\,\frac{e(n)+e(n-1)}{T} \quad \ldots(4)$$

The Least Mean Square algorithm (LMS) is distinguishably proposed for its low complexity operations, minimum convergence time and high efficiency. Working principle to find $[e(n)]2$ depend on filter coefficients h(n) , input signal x(n), μ step-size and set-point d(n). LMS mathematical model represent in equation [5]

$y(n) = h(n-1) \times XT(n)$

$e(n) = d(n) – y(n)$

$$h(n) = h(n-1) + \mu \times e(n) \times X(n) \quad \ldots.(5)$$

Method

The adaptive digital PID controller architecture, as shown in Figure-1 depicts the three adaptive proportional, integral and derivative parameters adaptive digital PID controller architecture. The architecture flowchart is outlined in Figure-2. The implementation of the adaptive controller as a fabrication-ready generic architecture has the following steps:

1. The error sequence, e(n), is the previous output subtracted from the set-point that is essential part of algorithm (LMS).
2. The error sequence is individually stimulating the three parameters using the LMS algorithm
3. The adapted (Kp, KI and KD) parameters are added up to produce the optimal real-time correcting control sequence, u(n).
4. The control sequence u(n) actuated the power circuit of any real-time systems.

General wireless communication system:

H(S) = 2S+60

S = Z-1 /T
H(Z) = 2Z – 1 +120T / T
Where T = 0.1 sec.

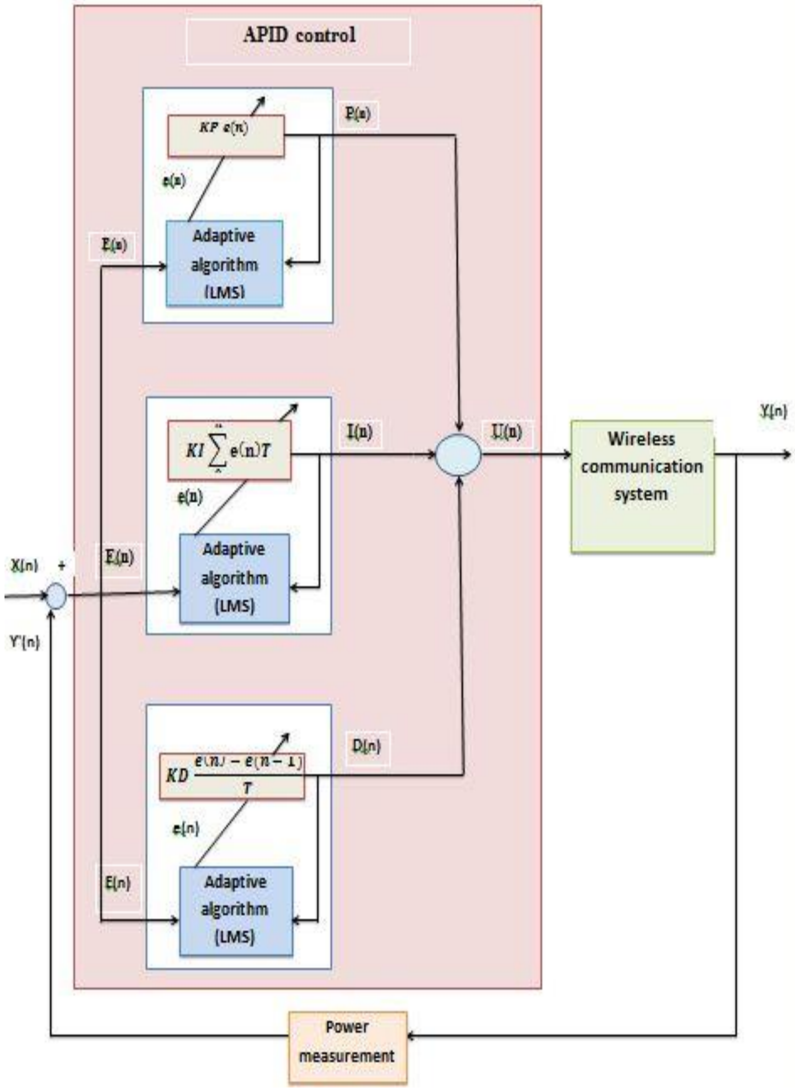

Figure 1-adaptive digital PID controller

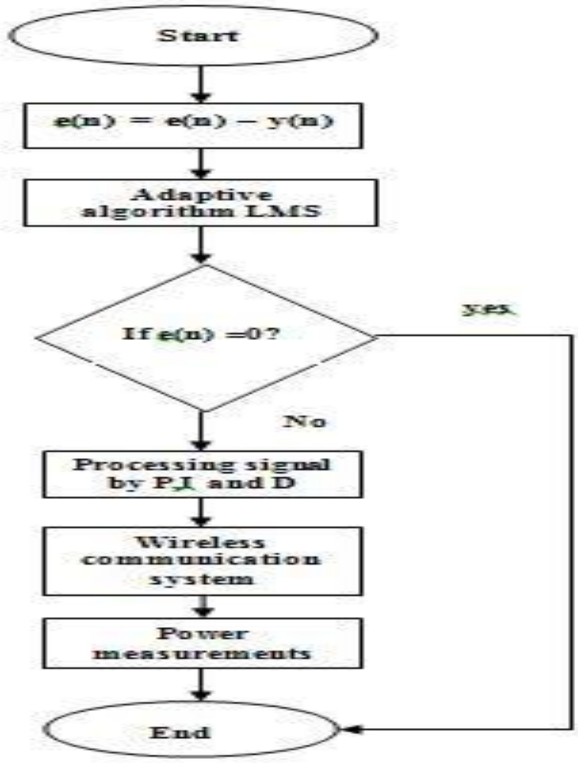

Figure 2-block diagram for implementation system

Results and Discussion

The adaptive PID controller is simulated to produce step response for the proportional, integral and derivative. Then, a comparison step response of a classical PID controller is analyzed.

A. Proportional Control Parameter

This part use to make control faster for reduce an error e(n) that never reach zero steady state. Many time use variable gain to produce variable output depend on sensitivity of difference between set-point and variable of controller. Figure-3 represents adaptive proportional control with KP = 9.8.

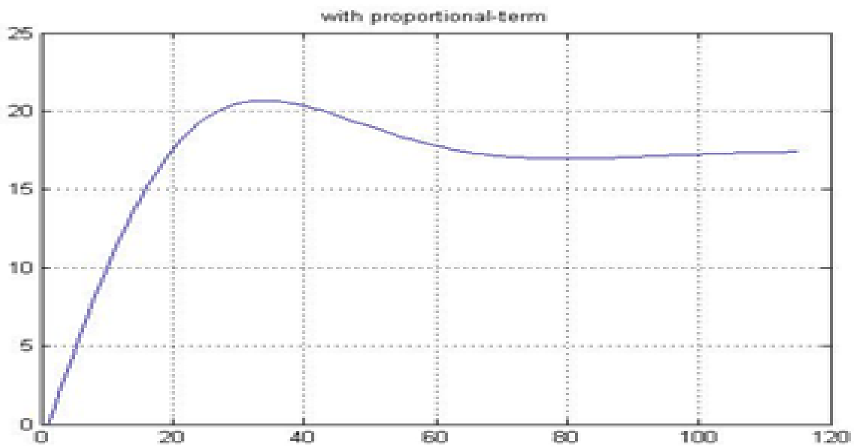

Figure 3-Adaptive proportional control system 1 response with initial value K=9.8.Rise Time: 1.6 sec, Settling Time: 3.9sec.

A. Integral Control Parameter

This control parameter depends on error integration to reach zero study-state. Disadvantage of integral control that decrease stability of feedback controller, also has windup phenomena that produce unstable output variable and if e(n) = 0. In Figure-4, the response of an adaptive integral control is depicted with KI = 25. Rise Time: 1.6sec, Settling Time: 2.96 sec.

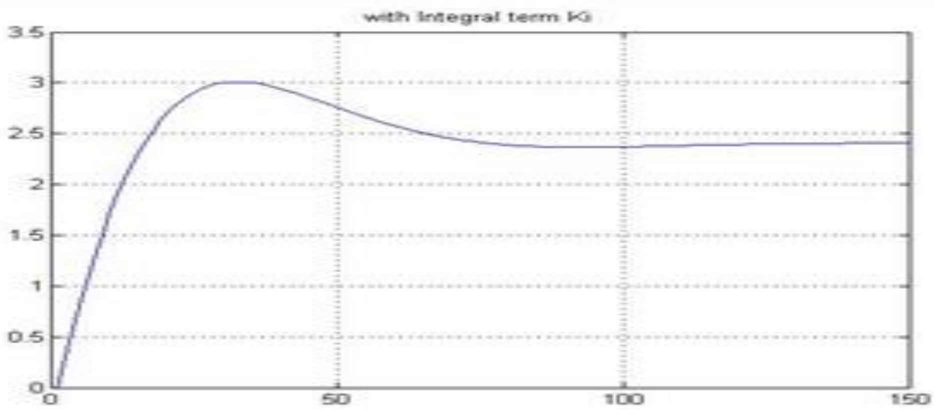

Figure 4-Adaptive Integral control system 1 response with initial value KI =25.

B. Derivative Control parameter

This control parameter is damping the error signal's ripples and estimating future behavior of error signal by considering its rate of change. In Figure-5 represent adaptive Derivative control with KD= 30.

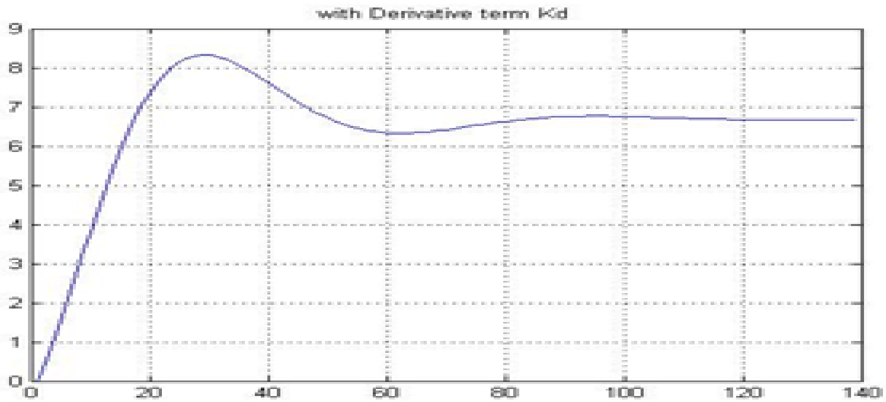

Figure 5-adaptive Derivative control system 1 with initial value KD=30, Rise Time: 0.6sec, Settling Time: 3.93sec.

A comparison of two controller step response with the same initial parameters and same systems find that APID controller make output power nearest to study state at 1.4 second as in Figure-6, and 32.8 second for traditional PID as in Figure-7, the result means system success to make power saving with the 9.8, 25, 30 dB are KP, KI, and KD gain respectively.

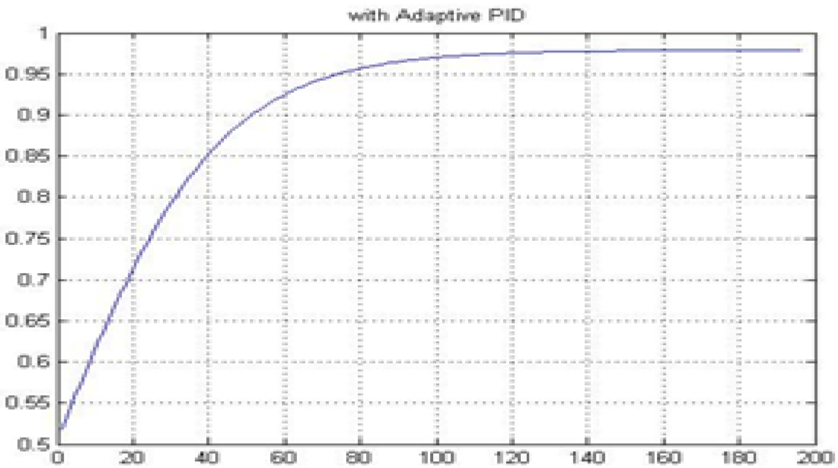

Figure 6-Adaptive digital PID controller

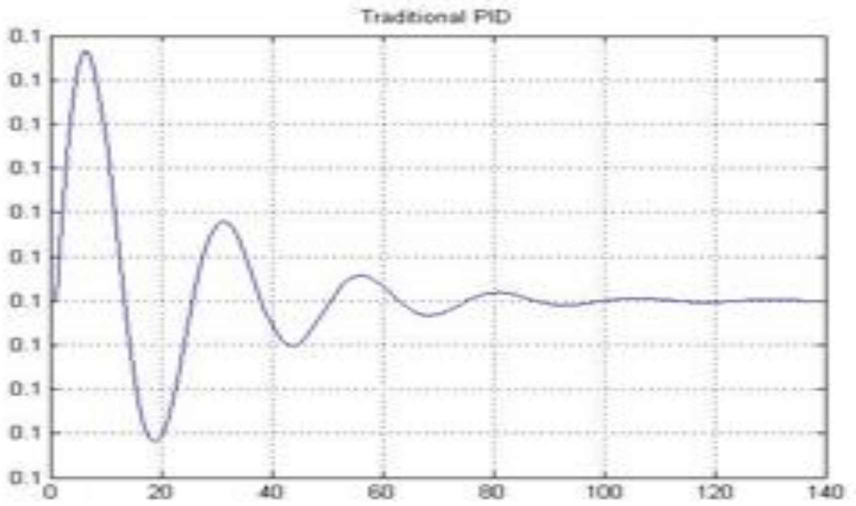

Figure 7-Traditional PID controller

Table 1-A Comparison of Transient Specifications of APID And PID Controller**,**

Control type	**Parameters, the time is in seconds**			
	Settling time	**overshoot**	**peak**	**Peak time**
PID	130	0.0281	1.00	1.411
APID	119	0	0	0

Conclusion

An adaptive PID controller has been efficiently development, as a self-tuning real time controller using LMS algorithm. The results have demonstrated that the developed APID controller has reached steady state faster with no overshoots compared to the traditional PID controller.

FUTURE WORKS

The future work is to implement the developed adaptive controller in a reconfigurable hardware [10-14] as a parallel architecture that may replace complecated and advanced control system applications [15-17].

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