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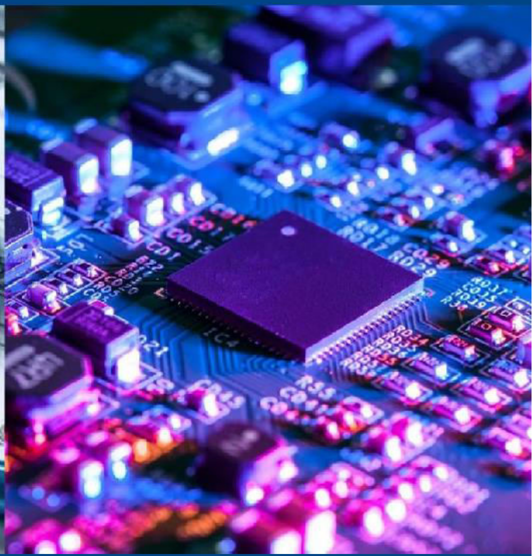

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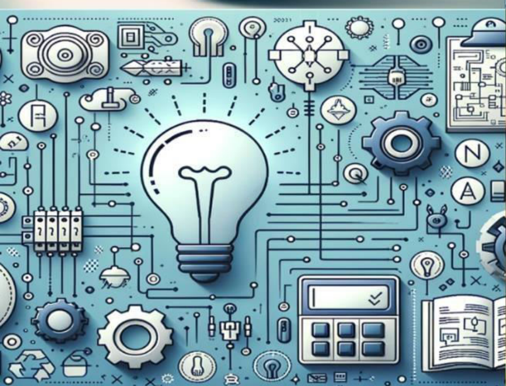

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Intelligent Control of DC-DC Converter based on PID-Neural Network

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ABSTRACT: This paper introduced a "PID-NN" based on Particle Swarm Optimization control that was applied to a boost converter operating in large-signal domains. Simulation results have shown that the proposed "PID-NN controller" could enhance the (boost converter) startup response with the use of fewer on-off switch operations compared to the Conventional "PID controllers". This result has been of high importance in practice for reducing the number of on-off switches can effectively decrease the transient disturbances and losses due to switching. Simulations also prove that the proposed "PID-NN controller" is capable of efficiently, improving rejecting potential disturbances that could happen in the input voltage. Moreover, it has been noticed that the output voltage is more efficiently controlled when applying "PID-NN controller". The results of the simulation show the efficiency of the suggested algorithm compared with other well-known learning methods.

I. INTRODUCTION

By way of the industrial development, control objects keep getting more complicated, particularly for the unknown parameters or slow variations in large delay, time-changing, non-linear complicated systems, with random interference or delay. However, The Proportional Integral Derivative (PID) control has simple structure and linear behaviour. Moreover, it gives acceptable performance for several industrial applications [1]. The "PID controller" is one of the traditional controllers which are usually used in many drive systems. However, it is sluggish response due to sudden change in power and the sensitivity to controller gains [2] the conventional "PID control" parameters will not change post completion, which will result in parameter changes of controlled objects that can't be traced in real time, cannot satisfy growing needs of control quality in the process of production, this is why, scholars improved a range of enhancements for Conventional "PID controller", especially in 2 aspects: one of them is improving structure, which is, variable structure control [3]. Recently, the use of intelligent control like Neural Network, Neuro Fuzzy and fuzzy control, the fuzzy logic control can answer the uncertainty problem and sudden disturbance, on the other hand its design depends on the experience which sometimes is not available for some systems [1]. In addition, it can add control non-linear systems, which would be hard or not possible to model mathematically. An artificial neural network could be applied to a wide range of tasks like signal processing, pattern recognition, function approximation, and classification. Usually, there are two operations when utilizing neural networks for control, those operations are [4], System identification and Control design [4]. The PSO algorithm can lead to a higher quality solution with time and secure convergence in comparison with other stochastic methods [5]. In addition, Meta Heuristic methods have had a profound effect on optimization in modified engineering streams. The efficiency of these algorithms is important as the hardware application of these algorithms for various engineering applications is to be carried out [6]. PSO, as one of the meta-heuristic methods of optimization, relies on the thorough search area's ideal solution based on the exchange of experiences among the population's particles. [7]. Moreover, PSO is a swarm-based meta- heuristic algorithm with some intrinsic inconveniences that weak local search and slow convergence rate and trapping in local optimum when solving complicated multi-modal issues [8]. Also, one of the most problem a range of DC-voltage of these sources have low output levels, unstable, the settling time is too tall moreover. There are also many situations where loss may be either unnoticeable or acceptable [9] compare with other techniques like (PID-NN), therefore the suggested new configurations of the intelligent (PID-NN) and optimized by using PSO method applied to the "Boost converter" due to several reasons and will be implemented to better optimize boost converter stability compared to the conventional "PID". High voltage increases and decreased steady-state error are the advantages of the proposed scheme [10].

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II. BOOST CONVERTER

Recent electronic systems involve highly efficient resources. By replacing diode with MOSFET [11], the effectiveness of (DC to DC converters) such as the energy source of electronic equipment can be improved. (DC / DC converter) can be used for different applications such as voltage output control, electric vehicle energy storage system, renewable power storage system, [12] a "DC-DC boost" Converter switching was intended to show the scheme proposed. The boost energy phase output current is either constant or non- pulsing. [13] Considering the "DC–DC boost" as converter circuit which is depicted in Figure 1. Through the interval, when the Q switch is off, (diode) D conducts the current i_L of inductor L on the way to the capacitor C and the load R_O. For the duration of the interval, when the Q switch is on the diode D opens and the C discharges through the R_c as shown in Figure 1. The converter transmits the energy between the input and the output with the use of the inductor. A "DC-DC Boost" converter design instance is available to achieve the efficiency needed for the implementation listed below. The simulation package MATLAB / Simulink was used to check the theoretical projections [13].

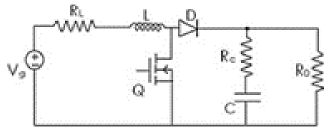

Figure 1. Boost converter.

In Figure 1, transfer function that is derived with useing of the approach of standard state space averaging, where the circuits for the two a operational mode ON and OFF mode for the converter are modelled in the following way:

$x^{\cdot} = A_x + B_u$

$y = C_x + D_u$ (1)

where: u, y input, output voltage (Vin, Vo) and x state variable.

The post is modelled, the average of those two modes over one switching period T is calculated [14].

III. THE PROPORTIONAL INTEGRAL DERIVATIVE (PID) CONTROL PRINCIPLE

"Controller PID " is one of the traditional controllers of many drive systems. [2]. The Conventional "controller PID" which is depicted in Figure 2 includes 3 distinct action parameters, which are the Integral, Derivative and Proportional. Those 3 parameters from the computation of "PID" [15]. Conventional "PID controller" in the process of production is the most often utilized control approach, commonly implemented in chemical, machinery, metallurgy and extra industries [16]. In other side, the simulated of control system is Conventional "PID controller" based on the deviation differential (D), proportion (P) and integral (I) are the most commonly implemented controller automatic [3].

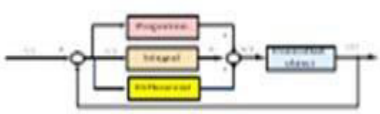

Figure 2. Conventional controller PID principle.

The proportional value regulates the reaction to the instantaneous error; the integral value regulates the reaction according to the summation of recent errors and the derivative value regulates the reaction according to the rate of the error changes. By through them, y(t) is the effective output value while, r(t) is the given value. Then, e(t)=r(t)-y(t), Conventional "PID controller" when the equation is:

$$(t) = ((t) + \frac{1}{T_i}\int_0^t (t) + T_d \frac{d}{dt} e(t))\, k_p \quad (2)$$

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where, T_i and T_d are the integral and derivative time constants respectively [15].
(18)

IV. SIMULINK MODEL AND RESULTS

For the sake of verifying the performance of the proposed design we have developed a model of the converter in (MATLAB–Simulink), and the most important results will be presented here. Figure 5 present the model for this controller for "Boost converter".

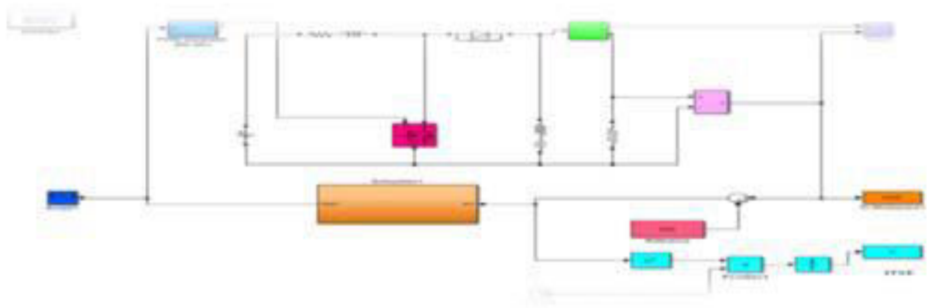

Figure 5. Boost converter model.

To design the suitable controller and adjusting the controller parameters, it's required to employ suitable model. The proposed intelligent model can be used efficiently in this work to design and optimize the controller parameters. The performance of the optimization algorithm, by using the optimizing coefficients C1=C2=1.3 and W=0.9, gives the optimum values of the "PID-NN controller" in 10 iterations as the following: V1= 1.6901e-05, V2=2.9139e-06, V3= 9.2440e-06, V4= 1.21579e-05. The control signal system input is the ranged from 0 to 40V and limited within this range. The optimization performances are shown in Figures 6, 7 and 8.

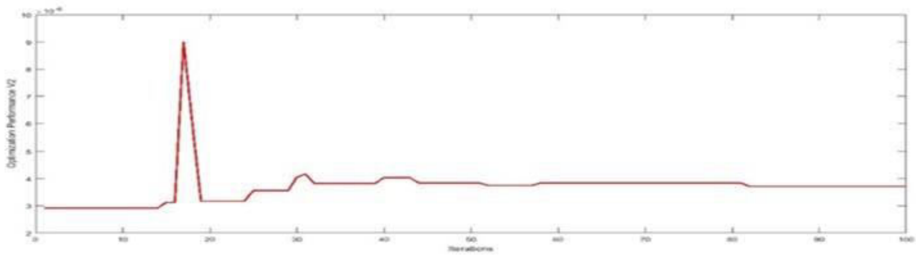

Figure 6. The optimization performance at V2.

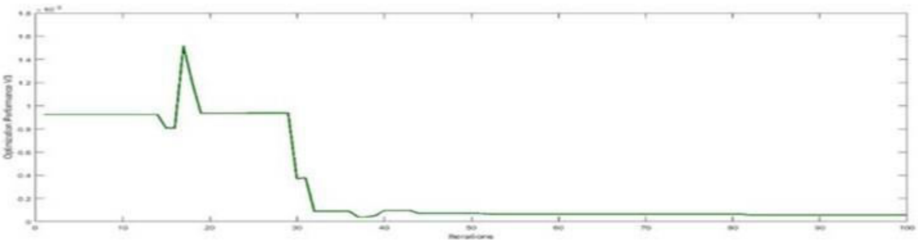

Figure 7. The optimization performance at V3.

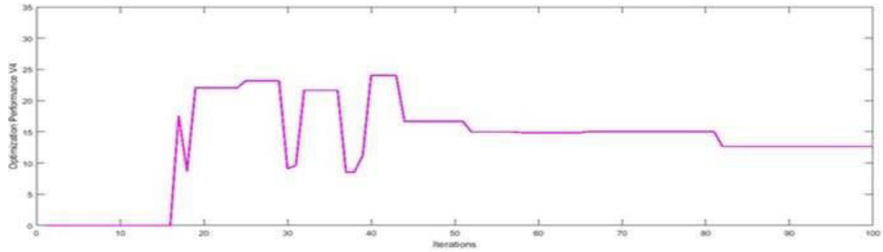

Figure 8. The optimization performance at V4.

From the response it is clear that after 10 ms output voltage is restored to its original value. This segment includes a comparison between the output results obtained by applying Conventional "PID controller" and "PID-NN" Based on Particle Swarm Optimization controllers to the boost converter so the suggested control strategy could brand the "boost converter" functioned in a stable manner under big load transient responses of all the quiescent input DC-voltage range as shown in Figures 10, 11, 12 and 13.

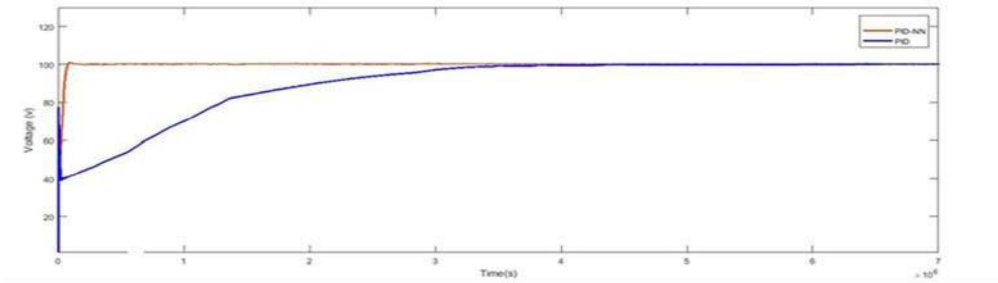

Figure 10. Comparison output voltage of the boost converter with conventional PID and PID-NN controller for 100v - 100Ω.

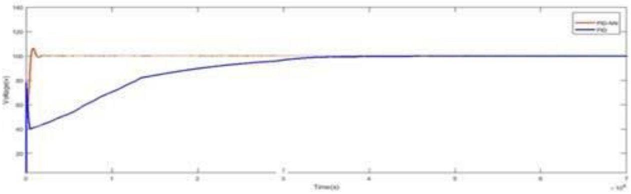

Figure 11. Comparison Vo of the boost converter through conventional PID and PID-NN controllers for 100v -200Ω.

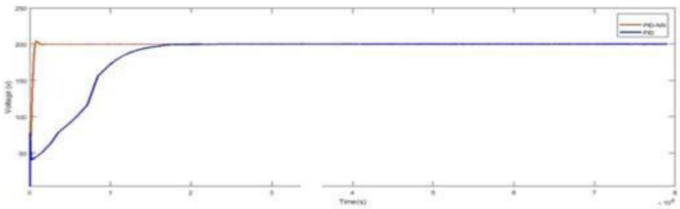

Figure 12. Comparison output voltage of the boost converter with conventional PID and PID-NN controllers for 200v - 100Ω.

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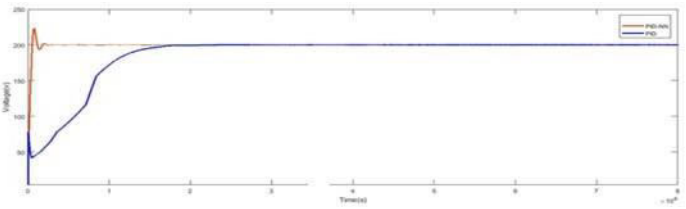

Figure 13. Comparison output voltage of the boost converter with conventional PID and PID-NN controllers for 200v - 200Ω.

V. COMPARISON ANALYSIS AND DISCUSSIONS

The problems can be identified from the previous figures in the Conventional PID controller:
- The settling time is too long.
- During the transient, the converter operates intermittently in discontinuous conduction mode.

In order to make a better comparison between the performance of the Conventional PID and PID-NN controllers, based on PSO controllers, corresponding steady-state, settling time, overshoot, transient responses and the output voltage are more stable and better regulated when the controller PID-NN is applied as shown in Tables 1-4. In addition, the optimal PID-NN controller leads to a feedback system with a considerable faster response, which allows us to ensure continuous conduction operation of the converter at all times, no overshoots and shorter settling times.

Table 1. Performance analysis of PID-NN with the boost converter at different load and V=100.

V=100	R=100	R=200
T_p	0.120*10^-6	0.062*10^-6
Settling time (Sec)$_s$	0.093*10^-6	0.125*10^-6
Overshoot (%)	2.5	7

Table 2. S how analysis of PID-NN with the boost converter at different load and V=200.

V=200	R=100	R=200
T_p	0.118*10^-6	0.110*10^-6
Settling time (Sec)$_s$	0.06*10^-6	0.125*10^-6
Overshoot (%)	3	12.5

Table 3. Performance analysis of conventional PID controller with the boost converter at different load and V=100.

V=100	R=100	R=200
T_p	100	100
Settling time (Sec)T_s	2.7*10^-6	2.2*10^-6
Overshoot (%)	0	0

Table 4. Performance analysis of conventional PID controller with the boost converter at different load and V=200

V=200	R=100	R=200
T_p	200	200
Settling time (Sec)T_s	1.3*10^-6	1.1*10^-6
Overshoot (%)	0	0

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In addition, Table 5 is shown comparison considered the fourth previous works, PID –DOO, Hybrid Adaptive Neuro Fuzzy based speed Controller, Adaptive Neuro-Fuzzy Control Approach for a Single Inverted Pendulum System and GA ANFIS, which have used the same data set. The results show that the "PID-NN with the boost converter" is able to

Table 5. The comparison with previous works

	Reference Article	T_p(Sec)	Settling time (Sec)T_s	Overshoot (%)
PID-NN with the boost converter	-	0.062*10^-6	0.125*10^-6	7
PID –DOO (Comparison of the various buck converter control methods in LED applications) (Shwetha D.V., et al., 2019)	[21]	-	1.07*10^-5	-
PI (Hybrid adaptive Neuro Fuzzy speed controller for Brushless DC engine)2017	[22]	0.025	0.075	12
ANFIS (Adaptive Neuro-Fuzzy Pendulum System Control Approach) 2018	[23]	-	2.2	0.095 rad
GA ANFIS (Intelligent self-tuning GA ANFIS Plastic Extrusion System Temperature Controller design) 2011	[24]	60	1650	0

VI. CONCLUSION

This article suggests an intelligent PID controller based on ANN and optimized by using PSO method applied to the converter Boost. The intelligent model is used efficiently to adapt and optimize the PID-NN controller, Simulation findings have shown that the PID-NN controller provides a smooth reaction to the reference monitoring and retains the boost converter output voltage according to the required voltage comparative with the Conventional PID controller. This controller can provide a much better reaction to start- up than the PID controller for the whole order. The PID-NN controller also has a good dynamic response and an outstanding start-up reaction as shown. Finally, the resulting design was based on the simplicity of this converter, its robustness and its low part count, application in high power high reliability applications. This is especially the case if fast and compact control techniques, like the one presented here, are used that allow for inexpensive and robust controllers use.

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