Optimization In Recent Aspects Of Power Converter

Agalya V, Sumathi S

Abstract: In this paper, a detailed literature review is given pertaining to Artificial intelligence (AI) emerges in Power Electronics field. Switch mode pulse width modulation technique based dc-dc converter plays a vital role while designing hardware parts in computer industries and the speed of the processor used in converter has increased drastically. The processor families have improved their performances in speed and functionality. Many optimization techniques have been studied related to AI, finally immune system is more robust and adaptable system for converter application.

Index Terms: AI, converter, robust, adaptable, optimization, immune system, pulse width modulation

1. INTRODUCTION

The converter parameter with respect to the load and supply voltage fluctuation is the main task in designing voltage regulator module. AIS offer an alternative to the traditional computational approach on immune-computing. This paper deals with the investigation of AI controllers. It can reduces the dynamic error.

2. OPTIMIZATION TECHNIQUES

Optimized electronic regulators are depends on output voltage regulation for line and load variation. To improve the performance of the converter many controllers such as Proportional Integral and Derivative (PID) controller, Sliding Mode Controller (SMC), Fuzzy Logic Controller (FLC) and Neural Network Controller (NNC) [5],[15]are used. Conventionally many closed loop application depends on PD, PI and PID controllers [6],[11] Literature exhibits a few works for controller optimization initially, various classical methods like Ziegler-Nichols are used to tune the PID parameters. In this tuning method, mathematical computation is complex and gives poor performance structures. Many specialists in their studies have exhibited the new advances in tuning the PID parameter. Artificial Immune System (AIS) is one of the easiest algorithms to get the best PID parameters. As computerized AIS-PID possess substantial measure of controller parameters, a large portion of the optimization is centered on the converter that uproots consequential data safeguarding all the significant and essential data.

A powerful method of control is digital control like PID control. Here, selection of PID parameters is very tough because of parasitic components. Therefore, gain of PID parameters must be designed by robust control techniques. PID controller optimization technique can be implemented using soft computing. Fuzzy PID [18] is an optimum control. It associated with tuning the controller parameters. When compared with the analog controller, the control gain is high in this case. Based on gain the controller performance gets stable under BIBO stability. In order to improve the transient performance of PID an overview of modern tuning method can be analyzed [3]. Also, [8] have capably advanced the controller design expected for engineering problem. In this, it is inferred that fuzzy logic is a mathematical addition to Boolean logics. This work gives an overview of pattern recognition and design of controller. To interpret the data, a Self-Adaptive Neuro --Fuzzy Inference System (SANFIS) can be implemented by clustering algorithm [17]. The criticisms of storage space and program time are the two most important riding factors in controller optimization for converter. Keeping this in view, an investigation of nonlinear PI controller was offered [16]. The dynamic performance was better than the linear PI controller.

Proportional Integral Derivative (PID) controller tuning is a territory of enthusiasm for analysts in numerous orders of science and engineering. This work introduces another calculation for PID controller tuning taking into account a blend of the scavenging conduct of genetic algorithm(GA) and Particle Swarm Optimization (PSO).[13] has proposed an optimal tuning the PID with random time delay by utilizing stochastic algorithm. Here, the integral time has minimized. In converter applications, to achieve fast transient response a few logical exploration studies have been performed to decide the level of controller behavior that keeps up the unproductive trial and error [9].In recent years, various research have been carried out on PID optimization through artificial intelligence such as Fuzzy Logic(FL) [7], Genetic Algorithm(GA)[12], Artificial Bee Colony[20], Particle Swarm Optimization(PSO),[1]and Bacterial Foraging Optimization(BFO) [10],[14]. Conventional controllers are not fit for nonlinear converter like dc-dc converter. In order to take up such constraints AIS optimization is used in the buck converter topology. [2] have phenomenally proved the simple closed loop control strategy using Ant Colony(ACO) system. Here, type III and PI controllers are tuned by ACO. The outcome of all energy elements in buck and boost mode were studied and the transfer function is obtained for further research. Comparative strategies are propelled, which have been profoundly viable in perspective of their improvement in closed loop system. The present study is carried out with MATLAB software package for the model development.

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3 FUZZY LOGIC CONTROLLER

Fig. 1. shows the second phase involved in the controller design of PID-FLC that plays an important role in the advanced control techniques. The actual voltage \( U(t) \) is verified with the reference input and it has obtained the error level of voltage signal.

Fig. 2. Simulation diagram of FLC controller

FLC rules for the gain of PID parameters are adjusted with the help of \( K_p \), \( K_i \) and \( K_d \). The output voltage, current and error in voltage were shown in fig. 3.

Fig. 3. FLC-PID controller performance characteristics of voltage, current and error in voltage

From this performance analysis FLC-PID controller [22], the voltage error is more due to random selection of PID parameter. It will be replaced with help of optimization techniques.

The dc-dc converter with FUZZY is the control method discussed by Dinesh Kumar A and Agalya V (2016). This controller has variable gain when compared to normal PID controller.

The major drawback of this FLC as follows
- Need of acceleration
- Terms are inaccurate
- Difficulty in implementing

4 ANFIS CONTROLLER

[4] discussed that, ANFIS structure consists of different layers like, fuzzification, inferences process, defuzzification and cumulative output is mentioned in fig. 4.

Fig. 4. Layout Diagram of ANFIS controller
5 NON DOMINATED SORTING GENETIC ALGORITHM(NSGA-II)

Non dominated Sorting Genetic algorithms-II is a probabilistic search approach which is based on the ideas of evolutionary processes. The GA procedure is based on the Darwinian principle of survival of the fittest. The initial population is created as in the base work.

In this study, controller of buck converter is simulated using NSGA-II-PID algorithm. A basic NSGA-II-PID control model of buck converter is shown in figure 6.11(a). \( K_p, K_i, K_d \) and \( u(t) \) is the output control variable. The parameters are optimally controlled and converter becomes stable and achieves robust transient response than FLC-PID. By using this algorithm, it is used to determine the PID parameter optimally. In usual NSGA-II boundary possibility assumed as 0.9 and mutation probability \( P_m \) calculated by using \( 1/n \), where \( n \) is the number of decision variable assigned as 8. The distribution indicates for crossover \( \eta_c = 20 \) and mutation operator \( \eta_m = 20 \). The optimization process run upto 100 iteration with population size is 20. Simulation results are output voltage waveform using NSGA-II as shown in figure 8. The output voltage gives dynamic response when compared to the advanced algorithm like AIS and DE. The value of voltage is increased 7 to 7.5V at the duration of 1.5s to 3s.
Disadvantages of NSGA II

- Not easy to find a suitable constraints.

6 DIFFERENTIAL EVOLUTION (DE)

DE is an evolutionary process. This contains chromosomal algorithms, strategies and evolutionary programming [19] is shown fig. 8. To optimize the parameters of PID, it is used to select the size of population (N). The parameters are arranged in a vector form with the help of generation number (G) and N. All the inhabitants’ constraints go to mutation, recombination and selection. At this instant mutation factor (F) is constant.

**Fig. 8. Evolutionary algorithm steps**

The core objective of this process is to find the approximate solution for the non-linearity created by PID. In converter system, the PID tuning design is to reduce the static and dynamic error and it have small overshoot and long settling time. The DE evolutionary algorithm is stochastic and it includes GA. The target value of PID parameters is obtained by trial and error such as mutation, recombination and selection until the best value of PID parameter is reached. DE algorithm has simple mechanism to implement than the other computational algorithm. The waveforms of performance metrics are shown in Fig 9.

The DE based control is more robust than the FLC and NSGA-II.

4 ARTIFICIAL IMMUNE SYSTEM BASED CONTROLLER

In general, AIS framework is used to construct computational model and cross domain modeling and have discussed computational algorithm. Technologically advanced system is increasing over last five years. [21] Has carried out detailed research in Artificial Immune System (AIS). The disadvantages of GA are eliminated by AIS algorithm. In GA the population variable size is fixed, whereas AIS not concerned about the population. AIS architecture is based on network but in ANN it is fixed. When compared to ANN and GA, AIS memory depends on network models. Detailed analysis of research framework is shown in figure 5. From this figure, solutions are derived from state space model. By using this model the algorithm is framed. Algorithms are considered as bone marrow models, clonal selection, negative selection, positive selection and immune network models in AIS. For this work the clonal selection procedure is used to enhance the constraints of PID. Hence affinity layer is used to evaluate the data sets of PID. The representation layer is used to identify the best fit value of PID. This best fit value is used in converter application.

**Fig. 10. AIS research framework**
The simulation illustration of buck converter as shown in Fig. 11

**Fig. 11. Simulation of AIS-PID**

Simulations are performed for AIS-PID and existing controllers. The performance metrics are measured to prove the PID controller for converter application. Detailed result analyses of these metrics are discussed. The AIS-PID voltage ripple value is measured based on four developed existing methods namely PID-FLC, ANFIS, NSGA-II and DE. The comparison is shown in table 1.

Table 1. Voltage-Ripple (in volts)

<table>
<thead>
<tr>
<th>Voltage-Ripple (in volts)</th>
<th>FLC-PID</th>
<th>NSGA-II-PID</th>
<th>DE-PID</th>
<th>AIS-PID</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.0045</td>
<td>0.0032</td>
<td>0.0038</td>
<td>0.0024</td>
</tr>
<tr>
<td>10</td>
<td>0.0025</td>
<td>0.0018</td>
<td>0.0014</td>
<td>0.0011</td>
</tr>
<tr>
<td>15</td>
<td>0.0020</td>
<td>0.0015</td>
<td>0.0011</td>
<td>0.0009</td>
</tr>
<tr>
<td>20</td>
<td>0.0018</td>
<td>0.0011</td>
<td>0.0009</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

The fig. 13. Illustrates the voltage ripple measurement with respect to the converter voltage. The voltage ripple is one of the significant parameters to be measured based on voltage being applied when designing a converter. The value of voltage ripple decreases with increase in the input voltage. Figure 12 describes the voltage ripple value on the controller used in dc-dc converter. The ripple values are reduced in AIS-PID controller when compared with other controllers. In addition, the AIS-PID controller reduced the ripple value by 97% when compared to other AI controllers. The rise time ($t_r$), settling time ($t_s$) and peak overshoot values are measured based on developed methods is shown in table 2.

**Table 2 TRANSIENT RESPONSE COMPARISON OF AI CONTROLLER**

<table>
<thead>
<tr>
<th>Controller</th>
<th>FLC-PID</th>
<th>NSGA-II-PID</th>
<th>AIS-PID</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_r$</td>
<td>0.0069</td>
<td>0.0050</td>
<td>0.0045</td>
</tr>
</tbody>
</table>

The fig. 12. Output of AIS-PID a) voltage b) current c) error

**Fig. 12. Output of AIS-PID a) voltage b) current c) error**
Simulation is performed for proposed FLC-PID, NSGA-II-PID and AIS-PID controller. The performance metrics such as, voltage ripple value, rise time, settling time and peak overshoot are measured to prove the PID controller for converter application.

5 CONCLUSION
The detailed discussion of the literature indicates the characteristics, advantages and disadvantages of various intelligence optimization techniques for dc-dc converter analysis in power electronics industries. Among all the methods, AIS becomes robust algorithm for controller parameters optimization.

REFERENCES

