Optimal Tuning of PI Controller Using Genetic Algorithm for Power Electronic Converter

B. Achiammal
Asst. Professor
Department of Instrumentation Engg.
Annamalai University

Dr. R. Kayalvizhi
Professor
Department of Instrumentation Engg.
Annamalai University

Abstract

DC-DC converters are widely used in application such as computer peripheral power supplies, car auxiliary power supplies and medical equipment's. Positive output element Luo converter performs the conversion from positive source voltage to positive load voltage. Due to the time- varying and switching nature of the power electronic converters, their dynamic behaviour is highly non-linear. Conventional controllers are incapable of providing good dynamic performance and hence optimized techniques have been developed to tune the PI parameter. In this work, genetic (GA) algorithms are developed for PI optimization. Simulation results show that the performances of GA-PI controllers are better than those obtained by the classical ZN-PI controller.

Keywords: PID controller, DC-DC converter, positive elementary Luo converter, Genetic Algorithm

I. Introduction

Many industrial applications require power from variable DC voltage sources. DC-DC converters convert fixed DC input voltage to a variable DC output voltage for use in such applications. DC-DC converters are also used as interface between DC systems of different voltages levels. Positive output Luo converter is a recently developed subset of the DC-DC converters. This converter provides positive load voltage for positive supply voltage. Luo converters overcome the effects of the parasitic elements that limit the voltage conversion ratio. These converters in general have complex non-linear modes with parameter variation problems. PI controllers do not provide satisfactory response for these converters which are time varying systems. Hence optimized techniques are used for regulating the positive Luo converter. In this work, PI controller, GA based PI controller is designed and simulated for the above Luo converter. The performance indices used is Integral Squared Error (ISE) and Integral Absolute Error (IAE).

II. Modelling of positive output elementary luo converter

A positive output elementary Luo converter (Fig.1) performs step-up/step-down conversions from positive input DC voltage to positive output DC voltage. The voltage transfer ratio of the above converter is (k/(1-k)) where k is the duty ratio. The circuits (Fig.2 and Fig.3) for the switch-on and switch-off modes of the chosen converter are developed using a state-space approach. At this point, these two models are averaged over a single switching period T using a state-space averaging technique. The state variables are:

$$X_1 = i_{L1}, X_2 = i_{L2}, X_3 = V_o, X_4 = V_{co} \qquad (1)$$

Using the above state variables, the system matrices A_1 and A_2, input matrices B_1 and B_2 and output matrices C_1 and C_2 are obtained.

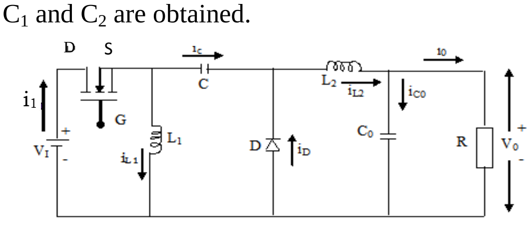

Fig.1 positive output elementary Luo converter

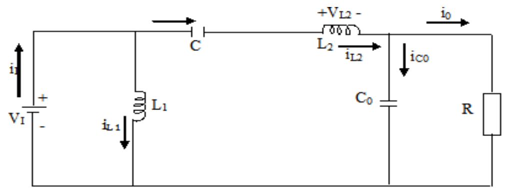

Fig.2 Positive output elementaryLuo converter on mode

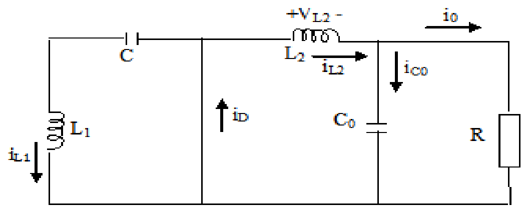

Fig.3 Positive output elementaryLuo converter off mode

IV. Genetic algorithm

III. Design of PI Controller

The function of a controller is to receive the measured process variable (PV) and compare it with the set point (sp) to produce the actuating signal (m) so as to drive the process variable to the desired value. Therefore the inputs to the controller are the error (sp-pv).It is also known as proportional plus reset controller. The actuating signal m(t) is related to the error e(t) by the equation.

$$m(t) = K_c e(t) + (K_c / T_i)\int_0^1 e(t)dt + ms \qquad (2)$$

where T_i is the integral time constant or reset time and I/Ti is called repeats per minute.

After a period of T_i minutes for a constant error E, the contribution of integral term is

$$K_c / T\int_0^{T1} e(t)dt = (K_c / T_i)ET_i = K_c E \quad (3)$$

The integral action has repeated the response of the proportional action. Reset time is the time needed to repeat the initial proportional action change in its output.

The integral action causes the controller output m(t) to change as long as an error exists the process output.

The transfer function of a PI controller

$$G_c(s)=K_c[1+1/T_is] \qquad (4)$$

The basic principles of GA were first proposed by Holland.This technique was inspired by themechanism of naturalselection, a biological process in which stronger individual islikely to be the winners in a competing environment. GA uses adirect analogy of such natural evolution to do globaloptimization in order to solve highly complex problems. Itpresumes that the potential solution of a problem is anindividual and can be represented by a set of parameters. Theseparameters are regarded as the genes of a chromosome and canbe structured by a string of concatenated values. The form ofvariables representation is defined by the encoding scheme.The variables can be represented by binary, real numbers, orother forms, depending on the application data. Its range, thesearch space, is usually defined by the problem.

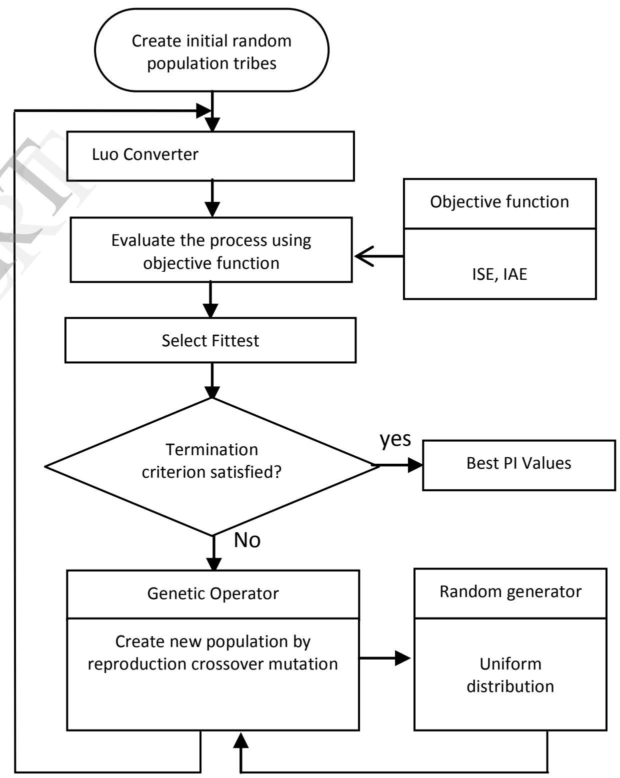

Fig. 4 Flow chart of the general genetic algorithm

GA has been successfully applied to many different problems, such as: traveling salesman, graph partitioning problem, filters design, power electronics, etc. It has also been applied to machine learning, dynamic control system using learning rules and adaptive control. An illustrative flowchart of the GA algorithm implementation is presented in Figure 4. In the beginning an initial chromosome population is randomly generated. Thechromosomes are candidate solutions to the problem. Then, the fitness values of all chromosomes are evaluated by calculating the objective function in a decoded form. So, based on the fitness of each individual, a group of the best chromosomes is selected through the selection process. The genetic operators, crossover and mutation, are applied to this "surviving" population in order to improve the next generation solution. Crossover is a recombination operator that combines subparts of two parent chromosomes to produce offspring. This operator extracts common features from different chromosomes in order to achieve even better solutions. Mutation is an operator that introduces variations into the chromosome. This operation occurs occasionally with a small probability. It randomly alters the value of a bit, in case of binary coding. In real coding it changes the entire value of a chromosome. Through the mutation operator the search space is explored by looking for better points. The process continues until the population converges to the global maximum or another stop criterion is reached

.

V. Genetic operator

In each generation, the genetic operators are applied to selected individuals from the current population in order to create a new population. Generally, the three main genetic operators of reproduction, crossover and mutation are employed. By using different probabilities for applying these operators, the speed of convergence can be controlled. Crossover and mutation operators must be carefully designed, since their choice highly contributes to the performance of the whole genetic algorithm.

A. Reproduction

A part of the new population can be created by simply copying without change selected individuals from the present population. Also new population has the possibility of selection by already developed solutions. There are a number of other selection methods available and it is up to the user to select the appropriate one for each process. All selection methods are based on the same principal i.e. giving fitter chromosomes a larger probability of selection. Four common methods for selection are:

1. Roulette Wheel selection
2. Stochastic Universal sampling
3. Normalized geometric selection
4. Tournament selection

Roulette Wheel selection is used in this work.

B. Crossover

New individuals are generally created as offspring of twoparents (i.e., crossover being a binary operator). One or more socalled crossover points are selected (usually at random) withinthe chromosome of each parent, at the same place in each. Theparts delimited by the crossover points are then interchangedbetween the parents. The individuals resulting in this way arethe offspring. Beyond one point and multiple point crossover, there exist some crossover types. Arithmeticcrossover generates an offspring as a component wise linearcombination of the parents in later phases of evolution it ismore desirable to keep individuals intact, so it is a good idea touse an adaptively changing crossover rate: higher rates in earlyphases and a lower rate at the end of the GA. Sometimes it isalso helpful to use several different types of crossover atdifferent stages of evolution.

C. Mutation

A new individual is created by making modifications to oneselected individual. The modifications can consist of changingone or more values in the representation or adding/deletingparts of the representation. In GA, mutation is a source ofvariability and too great a mutation rate results in less efficientevolution, except in the case of particularly simple problems.

Hence, mutation should be used sparingly because it is arandom search operator; otherwise, with high mutation rates,the algorithm will become little more than a random search.

Moreover, at different stages, one may use different mutationoperators. At the beginning, mutation operators resulting inbigger jumps in the search space might be preferred. Later on,when the solution is close by a mutation operator leading toslighter shifts in the search space could be favoured.

VI. PERFORMANCE INDICES

The performance of a controller is best evaluated in terms of error criterion. In this work, controller performance is evaluated in terms of Integral Square Error (ISE) and Integral Absolute Error (IAE)

$$\text{ISE} = \int_0^t e^2 dt \qquad (12)$$

$$\text{IAE} = \int_0^t |e| dt \qquad (13)$$

The ISE and IAE weight the error with time and hence minimize the error values nearer to zero.

VII. Simulation Result

The circuit parameters of the positive Output elementary Luo Converter are shown in the Table 1. The controller parameter values of the conventional ZN-PI and GA-PI controllers are obtained. The responses of positive output elementary Luo converter using conventional ZN-PI and GA-PI controls are shown in Figures 5, 6, 7 and 8.

Figures show that GA-PI controller will drastically reduce the overshoot, ISE and IAE values as compared to the conventional PI controller. Table 2 shows the performance analysis of positive elementary output Luo converter using conventional ZN-PIand GA-PI controllers.

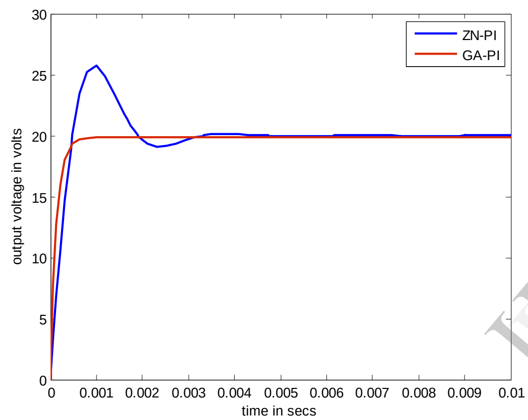

Fig.5 Closed loop responses of Conventional ZN-PI and GA-PI controllers

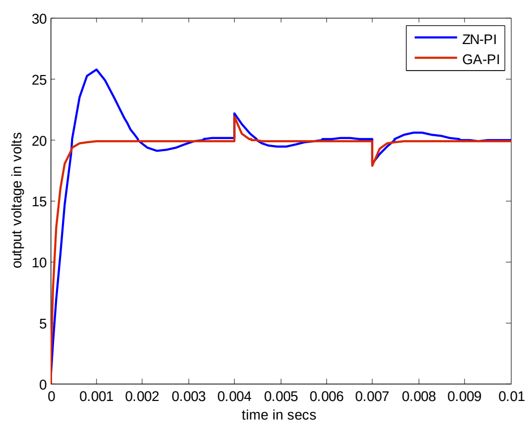

Fig.6 Closed loop responses of Conventional ZN-PI and GA-PI controllers with sudden line disturbance from 10V-11V (10%) at 4 msec. and10V-9V at 7 msec.

Table 1: Circuit parameters of positive output elementary Luo Converter

Parameter	Symbol	Value
Input Voltage	V_{in}	10 V
Output Voltage	V_o	20V
Inductor	L	100µH
Capacitor	C	5µF
Load resistor	R	10Ω
Duty ratio	D	0.70

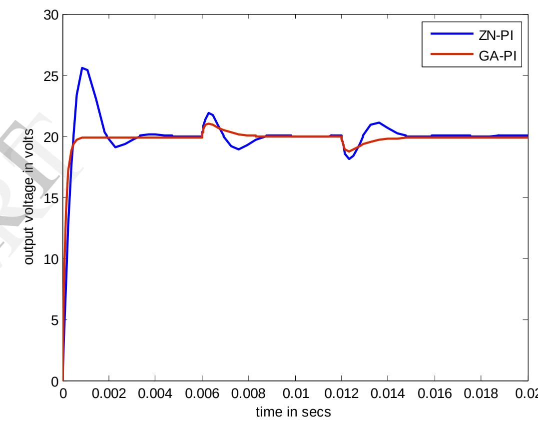

Fig.7 Closed loop responses of Conventional ZN-PI and GA-PI controllers with sudden load disturbance from 10Ω-11Ω (10%) at 6 msec. and10Ω-9Ω (10%) at 1.2 msec.

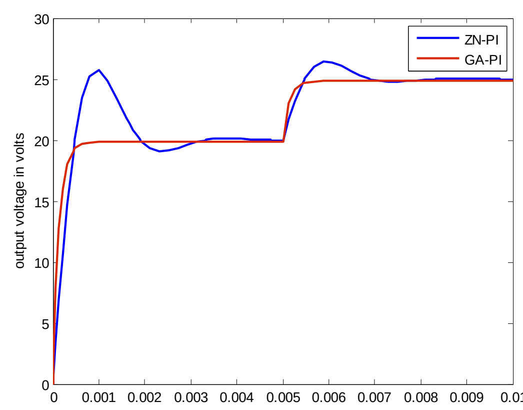

Fig. 8 Servo response of conventional ZN-PI and GA-PI controllers from20V-25V at 5 msec.

Table 2 Performance evaluation of positive output elementary Luo converter

		Tuning parameters	**ZN-PI controller**	**GA-PI controller**
Start up Transient		**Rising time (m.sec.)**	0.5	0.45
		Settling time (m.sec.)	4.7	1.2
		Peak Overshoot %	28.75	0
		ISE	0.0771	0.0272
		IAE	0.0100	0.0039
Line Disturbance	**Supply Increase 10%**	**Settling time (m.sec)**	3	0.7
		Peak Overshoot%	10	9
		ISE	0.0779	0.0274
		IAE	0.0110	0.0040
	Supply Decrease 10%	**Settling time (m. sec)**	2.8	0.8
		Peak Overshoot%	10	10.5
		ISE	0.0780	0.0275
		IAE	0.0110	0.0043
Load Disturbance	**Load Increase 10%**	**Settling time (m. sec)**	4	2.1
		Peak Overshoot%	9.5	5.5
		ISE	0.0796	0.0278
		IAE	0.0123	0.0051
	Load Decrease 10 %	**Settling time (m. sec)**	3.8	2.2
		Peak Overshoot%	9.5	6.5
		ISE	0.0796	0.0288
		IAE	0.0123	0.0069

VIII. Conclusion

In this work, Genetic(GA) algorithm are developed to tune the PI controller parameters which control the performance of positive output elementary Luo converter. The simulation results confirm that PI controller tuned with GA algorithm rejects satisfactorily both the line and load disturbances.Also the results proved that GA-PIcontroller gives the smooth response for the reference tracking and maintains the output voltage of the positive output elementary Luo converter accordingto the desired voltage.

References

[1]. Luo,F.L.: **"Positive output Luo-converter:voltage liftTechnique"**,IEE-EPAprocessdings,146(4),July 1999,pp.415-432.

[2]. J.F.HUANG, F.B.DONG,**"Modelling and Control on Isolated DC-DC Converter",** Power Electronics, voI.44, pp.87-89, April 2010.

[3]. M.Namnabat, M.BayatiPoodeh, S.Eshtehardiha**"Comparison the Control Methods in Improvement the Performance of the DC-DC Converter,"***International Conference on Power Electronics* 2007, (ICPE'07), pp.246-251, 2007.

[4]. Martin Plesnik., **"Use of the State space averaging technique in fast steady state simulation algorithms for switching power converters"***ieeexplore.ieee.org* CCECE'2006.

[5]. J.YOU, S.B.KANG ,**"Generalized State Space Averaging based PWM Rectifier Modeling",** Electrical Measurement &Instrumentation vo1.46, pp.67-70, October 2009.

[6]. T O.Mahony, C J Downing and K Fatla, "**Genetic Algorithm for PID Parameter Optimization: Minimizing Error Criteria,**" *Process Control and Instrumentation 2000 26-28 July 2000,* University of Stracthclyde, pp.148~153

[7]. C. R. Houck, J. Joines. andM.Kay, "**A genetic algorithm for function optimization: A Matlab implementation,**" *ACM Transactions on Mathematical Software*, 1996.

[8]. D. E. Goldberg, "**Genetic Algorithms in Search, Optimization, and Machine Learning**," *Addison-Wesley Publishing Co., Inc.*, 1989.

[9]. Dionisio S. Pereira, "**Genetic Algorithm Based System Identification and PID Tuning for Optimum Adaptive Control,**" *International Conference on Advanced Intelligent Mechatronics*, Monterey, California, USA, 24-28 July, pp.801~806, 2005

[10]. Ian Griffin, "**On-line PID Controller Tuning using Genetic Algorithms**," *Dublin City University*, 2003

[11]. T. K. Teng, J. S. Shieh and C. S. Chen, "**Genetic algorithms applied in online autotuning PID parameters of a liquid-level control system,**" *Transaction of the Institute of Measurement and control* 25, 5 (2003), pp.433~450.

B.ACHIAMMAL received her B.E (Electronics and Instrumentation) and M.E (Process Control) degrees from Annamalai University in 2003 and 2008 respectively. She is presently working as a Assistant Professor in the Department of Instrumentation Engineering, Annamalai University, where she has put in a total service of 10 years. She is presently pursuing Ph.D in the Department of Instrumentation Engineering, Annamalai University. Her areas of interest are: DC-DC converter:modeling, simulation and implementation of optimization techniques for control of power electronic converters.

Dr. R. KAYALVIZHI received her B.E (Electronics and Instrumentation) and M.E(Power Systems) degrees from AnnamalaiUniversity with distinction in 1984 and 1988respectively. She is presently working as aProfessor in the Department ofInstrumentation Engineering, AnnamalaiUniversity where she has put in a totalservice of 28 years. Shehas published 25 National and International journals and attended 15 national and international conferences. Her research interests are inDC-DC converters:modeling, simulation, implementation of intelligent controlstrategies and Digital image processing. She is a life member of Indian society for TechnicalEducation.