Hardware Implementation of PI Controller using Genetic Algorithm for NOEL Converter

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Abstract:

Negative Output Elementary Luo converter (NOELC) is one of the DC-DC Converters. High non-linearity can be observed in the dynamic performance of NOELC for its variation in time and switching character. Genetic Algorithm based PI (GA-PI) controllers have been developed to tune the PI parameters, since conventional PI controllers have unacceptable active performance for such converters. In this paper, design and implementation of ZN-PI controller and Genetic algorithm based PI (GA-PI) controller using TMS320C5420 DSP have been developed. The experimental results of the above converter under supply disturbances and load disturbances are presented and analyzed.

Keywords:PI controller, DC-DC converter, Luo converter and Genetic algorithm and optimization techniques.

I. Introduction

Many industrial applications require power from variable DC voltage sources. However, DC-DC converters are required for the conversion of fixed DC input voltage to a variable DC output voltage for use in such applications. In fact, these converters can also be used for interfacing between DC systems of various voltages levels. To the family of said converters, NOELC is a new entry. For positive supply voltage, NOELC has the capacity to provide negative load voltage.To beat the effects of the parasitic elements that bound the voltage conversion ratio, we could use Luo converters. Strictly speaking, these converters usually have difficult non-linear modes with restricted variation tech. Proper response cannot be expected from PI technique controllers because they are truly time varying systems. Thus, it is evident that, for regulating the NOEL converters, optimization techniques are to be employed. In this work, Genetic algorithm (GA) technique based PI controller is hardware implementation using TMS320C5420 DSP for the above Luo converter.

II. ANALYSIS OF NEGATIVE OUTPUT ELEMENTARY LUO CONVERTER

Usually, a negative output elementary Luo converter (Fig.1) performs step-up/step-down conversions from positive input DC voltage to negative output DC voltage and, the voltage transfer ratio of such a converter is (k/(1-k)) where k is the duty ratio. State-space approaches used for the circuits (Fig.2 and Fig.3) of the switch-on and switch-off modes of the chosen converter. In the state-space averaging technique, the two models are averaged over a single switching period T. The state variables are: X1 = IL, X2 = Vc, X3 = ILo, X4 = Vco, U = Vi, Y =Vo.The system matrices A1, A2 input matrices B1, B2 and output matrices C1, C2are obtained using the above state variables.

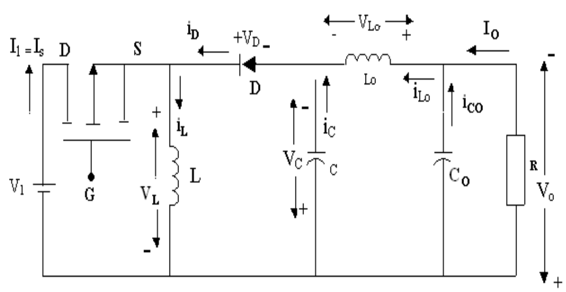

Fig.1 Negative Output Elementary LUO Converter

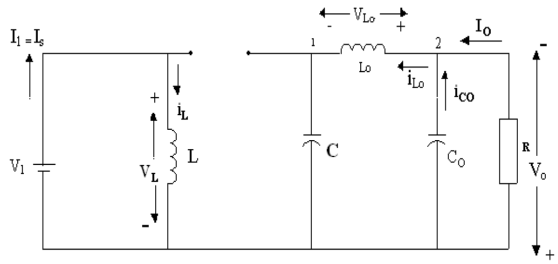

Fig.2 Negative Output Elementary LUO Converter (On Mode)

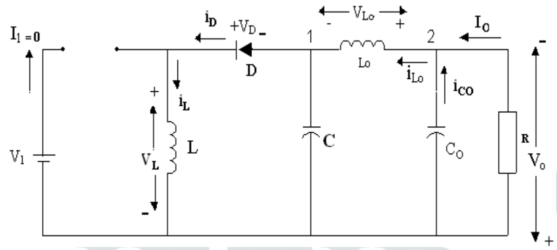

Fig.3 Negative Output Elementary Luo converter (Off Mode)

Table .1 parameters of NOELC

Parameters	Symbol	Value
Input Voltage	V_{in}	10 V
Output Voltage	V_o	40V
Inductor	L	100µH
Capacitor	C	5µF
Load resistor	R	10Ω
Switching frequency	fs	50KHZ
Duty ratio	D	0.1-0.9

III. DESIGN OF ZN-PI CONTROLLER

Converter modeling can be done using the state-space approach modeling. Here, the state matrices are constructed using state-space model approach both in the on-mode and off-mode. Averaging the circuit parameters of the above converter and the matrices, the transfer function model is obtained using MATLAB software. Using Ziegler-Nichols (ZN) tuning method based on the converter open loop step response, the corresponding conventional PI controller setting K_p and K_i are designed. After evaluation of the minimum values of rising time, settling time and peak overshoot, the optimal controller settings are found. The circuit parameters of the chosen positive output Luo converters are listed in Table 1. PI control is developed using the control system toolbox. Error in the output Voltage and the duty cycle of the MOSFETs are respectively the input and output of the PI controller.

IV. DESIGN OF GA- PI CONTROLLER

It is well known that, Genetic Algorithms (GAs) are a stochastic global search method that imitates the PI controllers, it is one of the methods used widely. Improvements in computational systems make GA useful for optimization. Generally, the genetic algorithms start with no knowledge of the correct solution. To reach at the best solution, genetic algorithms depend entirely on responses from surroundings and evolution operators such as reproduction, crossover and mutation to arrive at the best solution.

Genetic algorithms start at several independent points. It searches in parallel, and avoids local minima but, converges to sub optimal solutions. Starting with an initial chromosome, the genetic algorithms check for the fitness values. From the chromosomes, the fittest ones are taken as parents. Then, they are spawned, crossed over & mutated. The offspring is checked for the value of the fitness. Depending on this fitness value, it is either taken or neglected from the population.

Given a clearly defined problem to be solved and a simple GA works as follows:

1. A randomly generated population of chromosomes is initially used for starting the algorithm. That is, they are considered as candidate solutions to the given problem. After every iteration, candidate solution is considered as the solution (values of K_p and K_i).
2.The population size is selected. Then, the limits of the roots (i.e. Kp and Ki) or the bounds are specified.
3. The selected root values viz. K_p and K_i are the initial values of the roots required.
4. Normalized Geometric Selection method is applied so that, any random value can be selected. Selection is based on the fitness value of the root.
5. Now the reproduction of the selected roots (i.e. K_p and K_i) are required so as to get an optimized solution.
6. To alter the roots to get an optimized root (i.e. K_p and K_i), crossover called arithmetic crossover &uniform mutation are performed.
7. For each root (i.e. K_p and K_i) in the population, calculate the fitness $f(x)$ (using fitness function/ performance index).
8. The following steps are to be repeated until 'n' offspring have been created.
9. The fitness function (performance index MSE) is used to find the value of the error in the generation (iteration).
10. Roots having the highest fitness values are chosen.
11. Chosen roots are the final values of K_p and K_i.
12. If the obtained value are not according to the required ones (fitness value is not up to themark) then go to step 2. Each iteration of this process is called a generation.

The algorithm is usually iterated from 0 to 500 or more generations. An entire set of generations is called a run. There are often one or more highly fit chromosomes in the population, at the end of a run. Generally, two runs with different random-number seeds produce different detailed behaviors because,randomness plays a vital role in each run.

V. IMPLEMENTATION OF ZN-PI AND GA-PI CONTROLLER

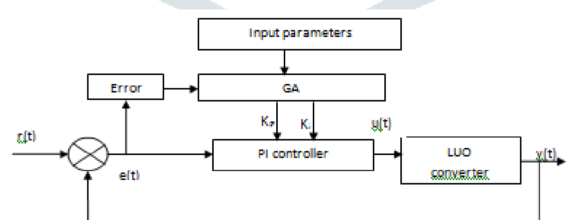

Fig. 4 Block diagram of Implementation of ZN-PI and GA-PI Controller

In this proposed work,a program which is coded in matlab calls the Luo converter model for a fitness function i,e cost function. This is in order to use GA to tune the PI controller for Luo converter. A matlab m-file is developed based on genetic algorithm with the specifications given in Table 2. Optimum values of controller-tuning parameters of NOELC with respect to time are estimated by executing the matlab file. The whole process is coded in matlab and after running the program, we get the optimized values of K_p and K_i as in Table2.

Table.2 Parameters value of GA-PI

parameters	Values
Population size	50
Variable bounds [K_p and K_i]	[0 100; 0 100]
Maximum Number of generations	100
Crossover probability	>0.8
Mutation probability	<0.05

VI. HARDWARE IMPLEMENTATION

The proposed PI and GA-PI controllers for the NOELC are implemented using TMS320C5420 DSP. This is a 16-bit fixed point DSP that combines the flexibility of a high-speed controller. It has the statistical capability of an array processor that is considered an inexpensive alternative to multichip bit-slice processors. It is estimated that, this highly paralleled architecture gives a speed of 40 MIPS, which makes it flexible too. The high processing speed of 40 MIPS is an advantage in that it permits the user to compute the parameters in real time. It also avoids the usage of look-up tables that have to be resident in the memory. The converter output voltage is initially scaled down suitably by a resistance divider network in the signal conditioning circuit. The output voltage of the divider circuit is fed to the on-chip ADC of DSP through the high impedance differential amplifier to compute the digital equivalent of output voltage.

This is compared with reference voltage to compute the error which are processed by the DSP based PI control and GA-PI control technique so suitably adjust the duty cycle of PWM signal. This PWM pulse of DSP is applied to the MOSFT through optocoupler and MOSFET driver. Optocoupler HCPL3180 provides isolation between DSP and gate of MOSFET. In order to strengthen the pulse, IRF540 driver is used. The switching device is N- channel MOSFET IRF250N. Peak overshoot and settling time are very much reduced in the GA-PI controller as compared to the PI controller, it is observed. The hardware kit for above converter is shown in figure 5. Table 3 shows the performance analysis of NOELC with PI and GA-PI controllers.

Figure.5 Hardware kit for NOELC

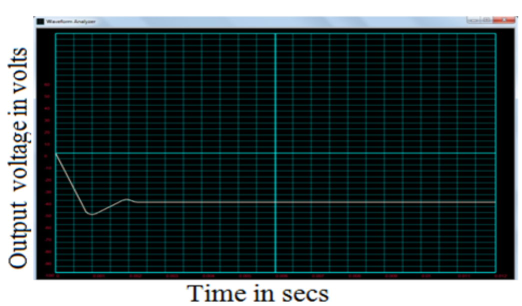

Fig. 6 Closed loop response of NOELC with ZN-PI controller

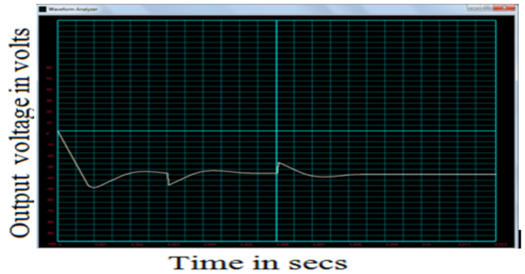

Fig 7 Closed loop response of NOELC with ZN-PI controller under sudden line disturbance from 10V - 12 V (20%) at 0.003 sec and10V - 8V(20%) at 0.006 sec.

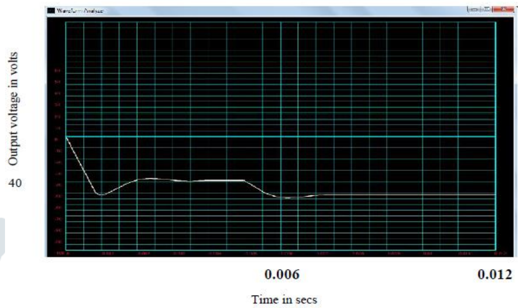

Fig 8 Servo response of NOELC with ZN-PI controller under sudden increase in reference voltage from 40V – 50V at 0.005 sec

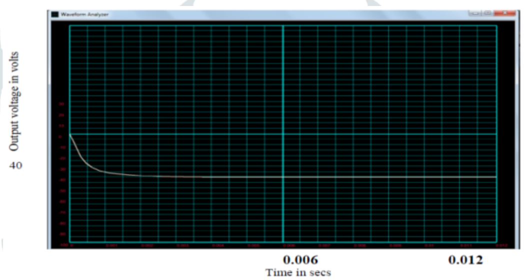

Fig. 9 Closed loop response of NOELC with GA-PI controller

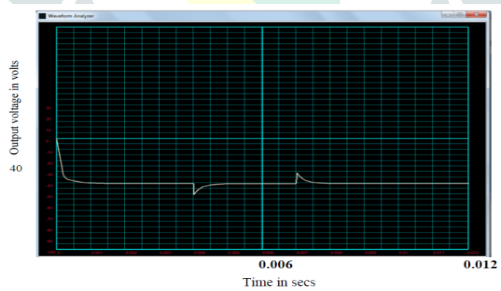

Fig 10 Closed loop response of NOELC with GA-PI controller under sudden line disturbance from 10V - 12 V (20%) at 0.003 sec and10V - 8V(20%) at 0.006 sec

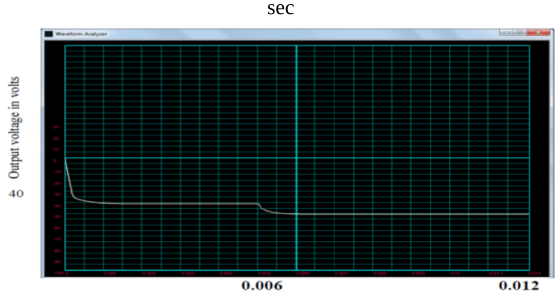

Fig. 11 Servo response of NOELC with GA-PI controller under sudden increase in reference voltage from 40V – 50V at 0.005 sec.

Table 3 performance comparison of ZN-PI and GA-PI controller for NOELC

		Tuning parameters	ZN-PI controller	GA-PI controller
Start-up Transient		Rising time (m sec)	0.65	1
		Settling time (m sec)	3.5	3
		Peak Overshoot %	30	0
Line Disturbance	Supply increase 20%	Settling time (m sec)	2.7	1.5
		Peak Overshoot %	28.75	28
	Supply decrease 20%	Settling Time (m sec)	2.4	1.4
		Peak Overshoot %	26	26
Servo Response	20% set point	Settling Time (m sec)	5	3
		Peak Overshoot %	35	0

VII. CONCLUSION

This paper presented the hardware implementation of PI and GA-PI for NOELC. DSP based PI and GA-PI for above converter have been implemented. The experimental results (Table 3) show that the performances of the PI controllers are found to be better than PI control based on the performance indices such as overshoot, rise time and settling time.

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