European Association for the Development of Renewable Energies, Environment and Power Quality (EA4EPQ)

International Conference on Renewable Energies and Power Quality (ICREPQ'10)
Granada (Spain), 23rd to 25th March, 2010

Optimization of Single-phase PWM Rectifier Performance by Using the Genetic Algorithm

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Abstract. This paper is dealing with single phase PWM rectifier parameter optimization. A control loop has been designed to attain a suitable output DC voltage with minimum ripple, input current with minimum harmonic and maximum input power factor. In this paper these parameters have been optimized by using Genetic algorithm. To verify the effectiveness of proposed optimization, different simulations have been done. By using MATLAB simulink the simulation results prove that the proposed system working good.

Key words

Single phase PWM rectifier, Harmonic, Power Factor, Genetic Algorithm, MATLAB simulink

1. Introduction

Fixed DC voltage is one of the basic requirements of electronics' circuit in modern systems. Because of this, the conventional single-phase diode or thyristor rectifiers are used widely in many industrial applications where is required a high-power DC supply or an intermediate DC link of AC/AC converters. Generally, these type of AC/DC converters add a capacitor to the DC side for smoothing the DC bus voltage. The benefits of these circuits are low cost, simple structure, high safety and no need of control. The weakness of these circuits are low power factor, high harmonics in the input current, system size will increase and converters have a short lifetime in which this introduces several problems such as voltage distortion, heating of core of transformers, increased loss in distribution conductors and transformers, reduction of available power and lower rectifier efficiency due to large rms values of the input current, etc .

Decreasing the Total Harmonic Distortion (THD) of the input current, unity power factor and fixed DC output voltage with minimum ripple are the important parameters in single phase rectifier [1]-[7]. Hence, in these systems, rectifiers are considered as an important element. PWM rectifier is the most common rectifier in which capable to transfer power flow bi-directional. In order to make suitable output, different kinds of controls such as sin pulse width modulation (SPWM), Hysteresis and PWM have been used [1]-[7]. In these articles problems are that authors didn't consider all parameters together or considered but they didn't find best result in these articles. In this paper a method based on the GA is proposed in order to optimize output DC voltage ripple, THD of input current and unity power factor.[8]-[10]

2. Circuit Topology

In Fig.1 circuit of single phase PWM rectifier is shown in which i_S, V_S, L_S *and* R_L are input current, supply voltage, input inductor and load resistance, respectively. Assume that:

$$V_s(t)=\hat{V}_s \sin(\omega t) \tag{1}$$

$$i_s(t) = \hat{I}_s \sin(\omega t - \varphi) \tag{2}$$

Where $\hat{V}_s$ and $\hat{I}_s$ are peak values of supply voltage and current, respectively. Mathematic model can be written as below (3):

$$V_{ab} = V_s - L_s \frac{di_s}{dt} \tag{3}$$

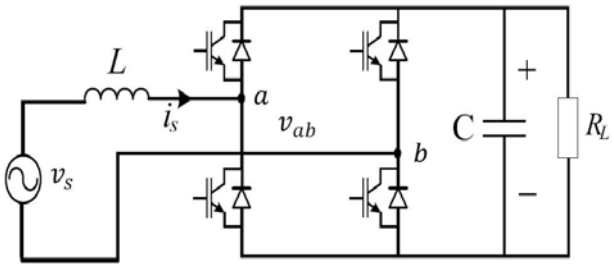

Fig. 1. Single-phase PWM rectifier circuit

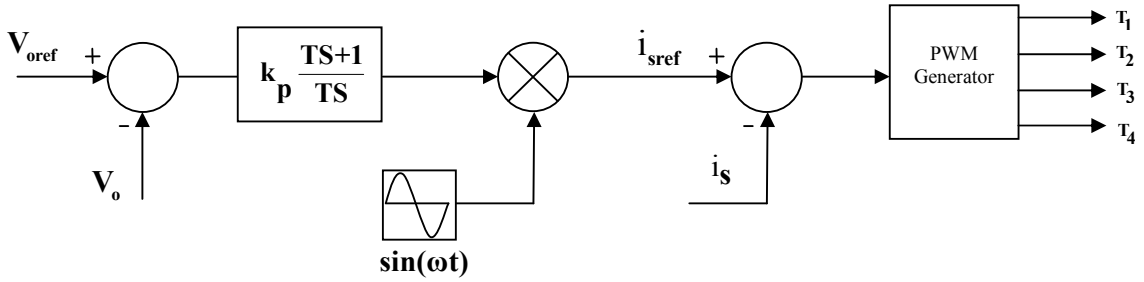

Fig. 2. Control scheme for PWM rectifier

V_{ab} is modulated voltage that by adjusting phase and amplitude of V_{ab} , i_s can be controlled.

In order to control output DC voltage, input current and power factor, the conventional control loop is used, which is shown in Fig. 2. In this control system output measured voltage is compared with $V_{o\,ref}$ that will be choose arbitrary and its output is multiplied by PI controller. The obtained result will be multiplied by sinusoidal wave. Previous operation result shows $i_{s\,ref}$ which will be compared with i_s . The current controller, which can be hysteresis controller or linear controller pulse PWM modulator, must respond fast enough to achieve sinusoidal current. BY using PWM generator the output of this comparison is applied to PWM generator as an input and in order to fire the switches. Switching frequency (f_s) is another parameters that has effect on generate the fires by PWM generator and was determined in PWM generator's box. Next section is the review about Genetic algorithm.

3. Genetic Algorithm

Optimization is the process of trying to find the best solution to a problem that may have many possible solutions. Most problems involve many variables that interact based on given formulas and constraints.

Genetic algorithm (GA) is a global search technique, modeled after the process of natural selection, which can be used to find near optimal solutions to highly non-linear optimization problems; it was first introduced by J. H., Holland [4]. Unlike conventional

search technique, GA starts with initial set of random solutions called population (P). Population is a group of solution's simulation. Each element of population is chromosome. Each chromosome represents a solution of the problem. A character in a GA chromosome is called a gene. Each gene encodes the value of a special component [i.e. k_p , T, Capacitor (C) and (f_s)].

At each step, the algorithm uses the individuals in the current generation to create the next population. To create the new population, the algorithm scores each member of the current population by computing its fitness value based on a given fitness function and scales the raw fitness scores to convert them into a more usable range of values and then selects members, called parents, based on their fitness. Some of the individuals in the current population that have lower fitness are chosen as elite.

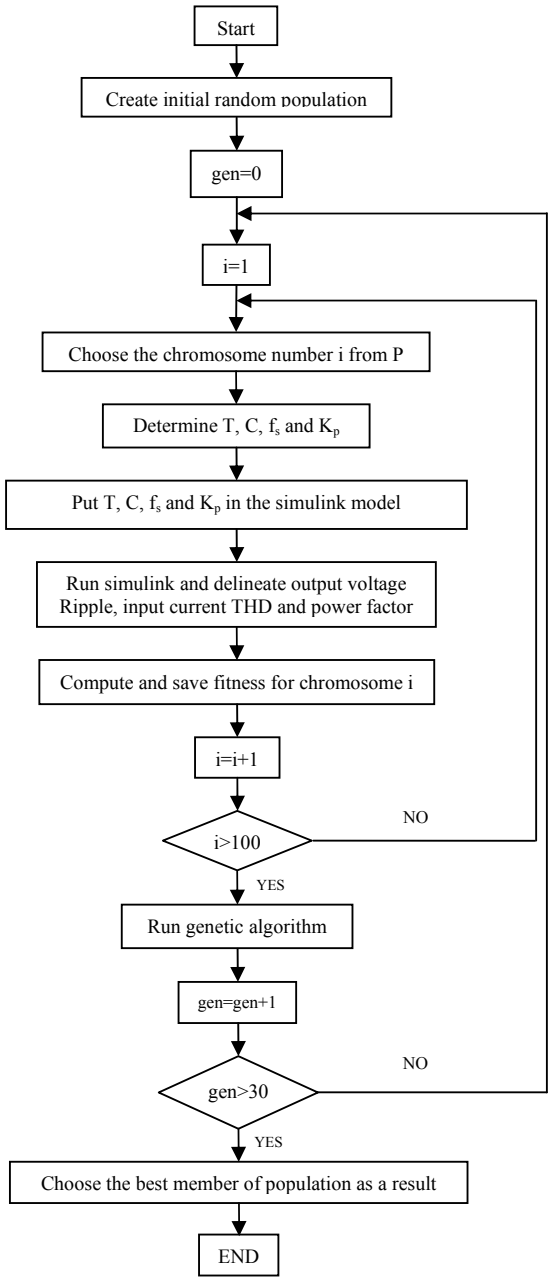

Fig. 3. GA flowchart to optimize a PWM Rectifier

These elite individuals are passed to the next population. Children are then produced from the parents. Children are produced either by making random changes to a single parent—mutation or by combining the vector entries of a pair of parents—crossover. The value of crossover and mutation generally ranges between 0.7 to 0.9 and 0.01 to 0.03, respectively.
In Fig. 3 GA optimization flowchart has been showed. In this figure population size is 100.and 30 new generations was created.
In the next section the results of conventional control have been illustrate.

4. Proposed Method

One of the optimization methods which can be used to obtain the best results of the system is the Genetic Algorithm. In this article, four factors including ripple of the output voltage, harmonic of the input current, settling time and power factor are considered to be optimized by using the Genetic algorithm. For gaining the best results for the considered parameters above, four parameters including the switching frequency (f_s), k_p, T and the value of the capacitor (C) have been varied in the simulink and the simulations have been done 50 times by using the Genetic algorithm. Applicability rang for four variable parameters have been shown in Table I.

Table I: Applicability rang for four variable parameters

variable	Applicable rang	
f_s (Hz)	35000	70000
C(μF)	390	1200
K_p	2	5.1
T	0.01	0.08

The input voltage of rectifier is 220 V, 50 Hz and the load parameters are L=10mH and R=200Ω.

By using this Algorithm the best result is showed in Table II:

Table II. The Best Result From The GENETIC ALGORITHM

Variable	The best result
f_s	55000 HZ
k_p	4
T	0.045 *S*
C	$1200\times10^{-6}F$

5. Simulation Results

In this section from applicable rang of parameters 10 random states have been chosen and their effect on objectives' values were illustrate in table III. And oalso in end row of this table optimized parameters by using GA and its objective value has been shown.

Table III: effectiveness of variables on Objectives' values

Variables				Objectives' values			
f(Hz)	C(μF)	K_p	T	Settling time	Ripple	THD	Power Factor
60000	390	2	0.035	0.1667	11.12	5.83	0.9997
50000	700	2.5	0.018	0.1669	6.1054	4.52	1
70000	1000	3.6	0.032	0.217	4.2631	6.01	0.9999
45000	1100	4.1	0.023	0.1639	3.9399	6.03	1
35000	470	2.3	0.04	0.1777	9.08	6.47	0.9997
40000	680	3	0.012	0.2582	6.3701	5.36	1
65000	1000	3.4	0.025	0.1738	4.2722	5.92	1
55000	900	3.7	0.019	0.23	4.8018	6.19	1
50000	800	2.7	0.036	0.2032	5.3542	4.75	0.9999
50000	1200	2.5	0.018	0.38	3.35	4.29	1
55000	1200	4	0.045	0.1828	3.3	3.26	0.9998

Table III shows Objectives' values depend on whole variables parameters and optimized parameters couldn't achieve without use the optimization method.
One of the 10 states with $f_l=50Hz$, $f_S=60000Hz$, $k_p=2$, $T=0.035$ and $C=390\mu F$, have been shown in following figures.

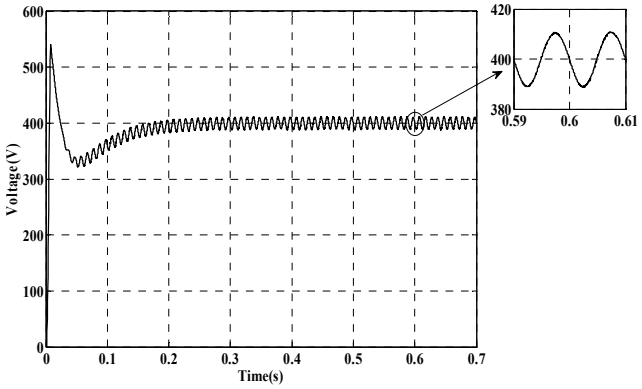

Fig. 4. Output voltage with f=50HZ

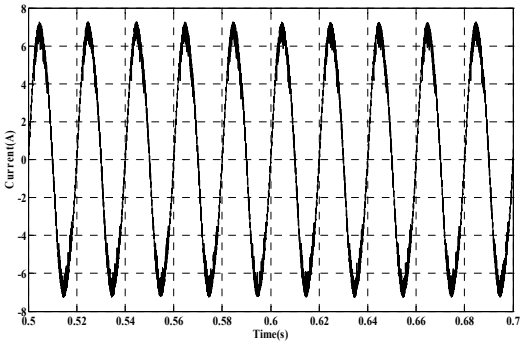

Fig. 5: Input current with f=50HZ

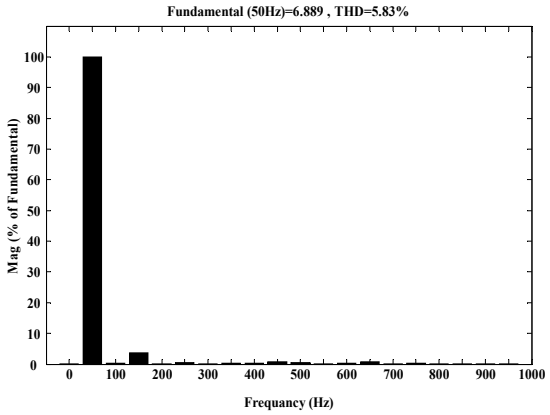

Fig. 6. input current THD

Fig. 4 shows the output voltage that it is fixed in desire voltage with 11.12V ripple which is around 3%. Another result, Fig. 4 shows that it takes around 0.31s so that the rectifier arrives to the steady state and t_S=0.31s .

In comparison fig 5 and fig 8 we can see that the input currents are near to sinusoidal form and also fig 8 has lower THD whish is illustrate in fig 6.

In some systems the time that voltage arrives to the desire mount is so important so that we need to lose it. Fig. 6 shows THD of input current is 5.83% which its amount is acceptable and satisfactory but by using special way choose the best input parameters until get the optimum output and save energy and safe vehicle that one way is the Genetic Algorithm. The Genetic Algorithm will provide the best parameters for attaining optimal outputs. By using the parameters that obtain from the genetic Algorithm voltage ripple to 3.3V was decreased which is around 1% and settling time will increase to 0.1828s that it was shows in Fig. 7. For this result input current, input current THD was illustrated in below:

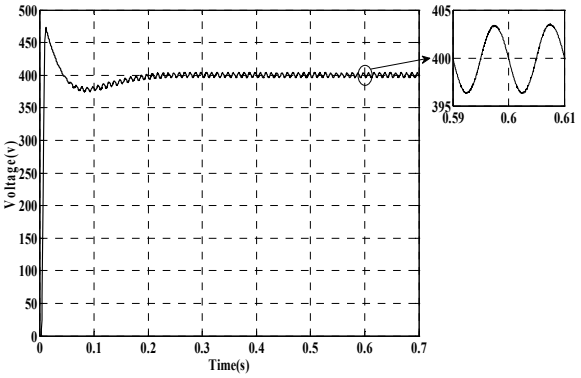

Fig. 7. Output voltage

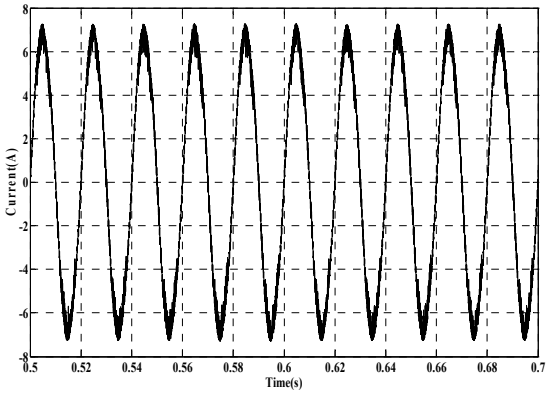

Fig. 8: Input current with f=50HZ

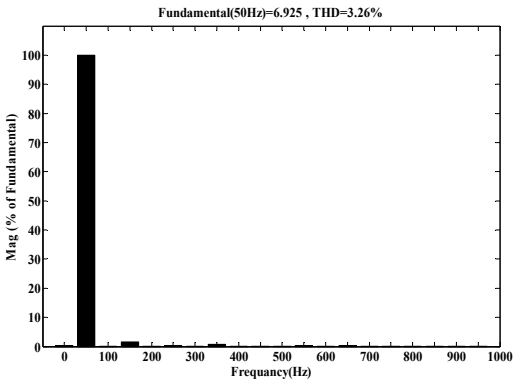

Fig. 9. input current THD

Fig. 9 shows that by using these parameters THD has been decreased.

6. Conclusion

In this paper, for obtaining DC voltage with minimum ripple, minimum harmonic of input current and maximum power factor a conventional scheme was proposed which is used MATLAB simulink and for optimizing desired outputs, the Genetic Algorithm was used. By using this intelligent algorithm those parameters were optimized in which the simulation results indicate obtained results by the Genetic Algorithm are so suitable.

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