Power System Stability Enhancement Of Single Phase Pwm Rectifier Using Genetic Algorithm

Arkaja Agrawal[1], Manoj Kumar Nigam[2]

Power Electronics, Department of Electronics Engineering
Raipur Institute Of Technology
Raipur

Abstract

This paper present an efficient Genetic Algorithm based solution for Harmonic elimination in single phase PWM rectifier. A control loop has been designed to attain a suitable DC voltage with minimum ripple, input current with minimum harmonic and maximum input power factor. Theoretical studies have been carried out to show the effectiveness and robustness of the proposed method for elimination of harmonics. Theoretical results are validated through simulation using MATLAB software package.

Keyword: Single phase PWM rectifier, Harmonics, Power Factor, Genetic Algorithm (GA), MATLAB

"1 . Introduction"

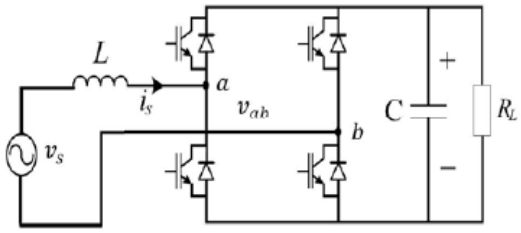
Diode rectifiers are widely used in industrial fields and consumer products thanks to its advantages of low cost, simple structure, robustness and absence of control. However, this type of converters may results in only unidirectional power flow, low input power factor, high level of harmonic input currents, malfunction of sensitive electronic equipment, increased losses and also contributing to inefficient use of electric energy. To maintain supply

quality at acceptable levels, various standards and guidelines specify limits of current harmonic content for certain types of applications. Recently, many promising power factor correction techniques have been proposed for rectifiers.

Apart from application of active and passive filters, the best solution is in using pulse width modulated (PWM) rectifiers. Research interest in three-phase PWM rectifiers has grown rapidly over the last few years due to some of their important advantages, such as power regeneration capabilities, control of dc-bus voltage over a wide range, and low harmonic distortion of input currents. Since the converter has abilities to control the input current in sinusoidal waveforms, unity power factor operation can be easily performed by regulating the currents in phase with the power-source voltages. Various control techniques have been proposed in recent works on this type of PWM rectifier [1-2]. It is well known that in order to obtain better ac supply power quality and high performance of these converters, it is preferable to directly control the magnitude and phase angle of three phase supply currents. So direct current control is probably the simplest technique used to forcing the supply current to follow the reference current. There are mainly six kinds of direct current control algorithm : hysteresis current control, predictive current control, current tracking control, sliding mode control, state feedback control and space vector control. Closed-loop PI controller based on the current tracking control strategy is a most widely used current tracking control strategy. But this control algorithm is difficult to realize parameters tuning of the controller and its ac current is easy to have the distortion [3-6]. 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

"2.Circuit Topology"

In Fig.1 circuit of single phase PWM rectifier is shown in which is ,Vs , Ls and RL are input current, supply voltage, input inductor and load resistance, respectively.
Assume that:



"Figure 1. Single-phase PWM Rectifier Circuit"

$$V_{ab} = V_s - L_s \frac{di_s}{dt} \quad (3)$$

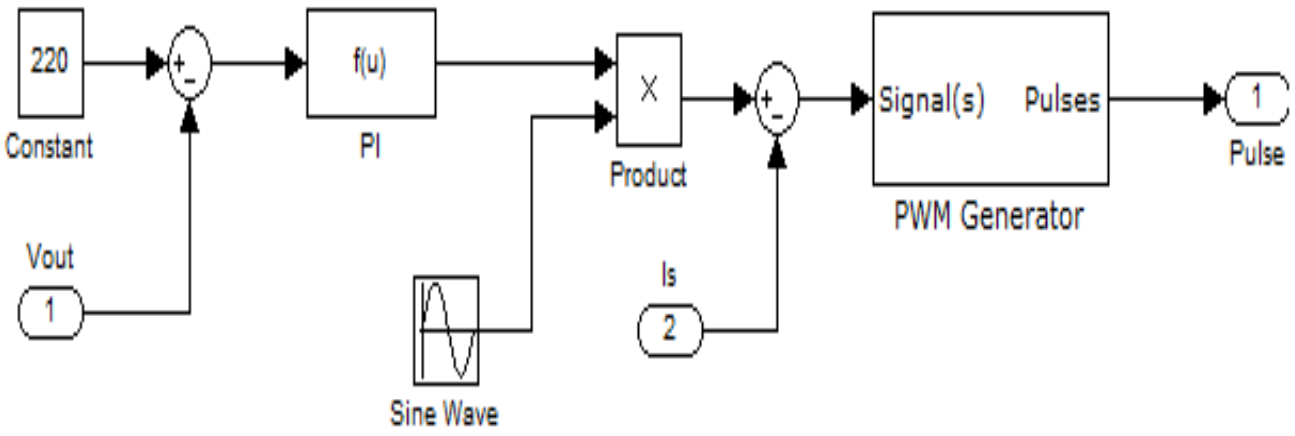
Mathematic model can be written as above

Where *Vs* and *Is* are peak values of supply voltage and current, respectively.

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

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

Vab is modulated voltage that by adjusting phase and amplitude of *Vab*, I_s can be controlled. In this control system output measured voltage is compared with output voltage V_{out} 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 the is_{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[5-10]. Switching frequency (*fs*) is other parameters that have effect on generate the fires by PWM generator and was determined in PWM generator's box



"Figure 2. Proposed Block Diagram"

"3.Genetic Algorithm"

A genetic algorithm is a problem solving method that uses genetics as its model of problem solving. It's a search technique to find approximate solutions to optimization and search problems. GA handles a population of possible solutions. Each solution is represented through a chromosome, which is just an abstract representation. Coding all the possible solutions into a chromosome is the first part,

but certainly not the most straightforward one of a Genetic Algorithm. A set of reproduction operators has to be determined, too. Reproduction operators are applied directly on the chromosomes, and are used to perform mutations and recombination over solutions of the problem. Appropriate representation and reproduction operators are really something determinant, as the behavior of the GA is extremely dependents on it. Frequently, it can be extremely difficult to find a representation, which respects the structure of the search space and reproduction operators, which are coherent and relevant according to the properties of the problems. Selection is supposed to be able to compare each individual in the population. Selection is done by using a fitness function. Each chromosome has an associated value corresponding to the fitness of the solution it represents. The fitness should correspond to an evaluation of how good the candidate solution is. The optimal solution is the one, which maximizes the fitness function. Genetic Algorithms deal with the problems that maximize the fitness function. But, if the problem consists in minimizing a cost function, the adaptation is quite easy. Either the cost function can be transformed into a fitness function, for example by inverting it; or the selection can be adapted in such way that they consider individuals with low evaluation functions as better. Once the reproduction and the fitness function have been properly defined, a Genetic Algorithm is evolved according to the same basic structure. It starts by generating an initial population of chromosomes. This first population must offer a wide diversity of genetic materials. [11-13]The gene pool should be as large as possible so that any solution of the search space can be engendered. Generally, the initial population is generated randomly. Then, the genetic algorithm loops over an iteration process to make the population evolve. Each iteration consists of the following steps:

"3.1Selection"

The first step consists in selecting individuals for reproduction. This selection is done randomly with a probability depending on the relative fitness of the individuals so that best ones are often chosen for reproduction than poor ones.

"3.2Reproduction"

In the second step, offspring are bred by the selected individuals. For generating new chromosomes, the algorithm can use both recombination and mutation.

"3.3Evaluation"

Then the fitness of the new chromosomes is evaluated.

"3.4Replacement"

During the last step, individuals from the old population are killed and replaced by the new ones.The algorithms stopped when the population converges toward the optimal solution.

In short, the basic four steps used in simple Genetic Algorithm to solve a problem are:

The representation of the problem

1 The fitness calculation

2 Various variables and parameters involved in controlling the algorithm

3 The representation of result and the way of terminating the algorithm

"4.Proposed Method"

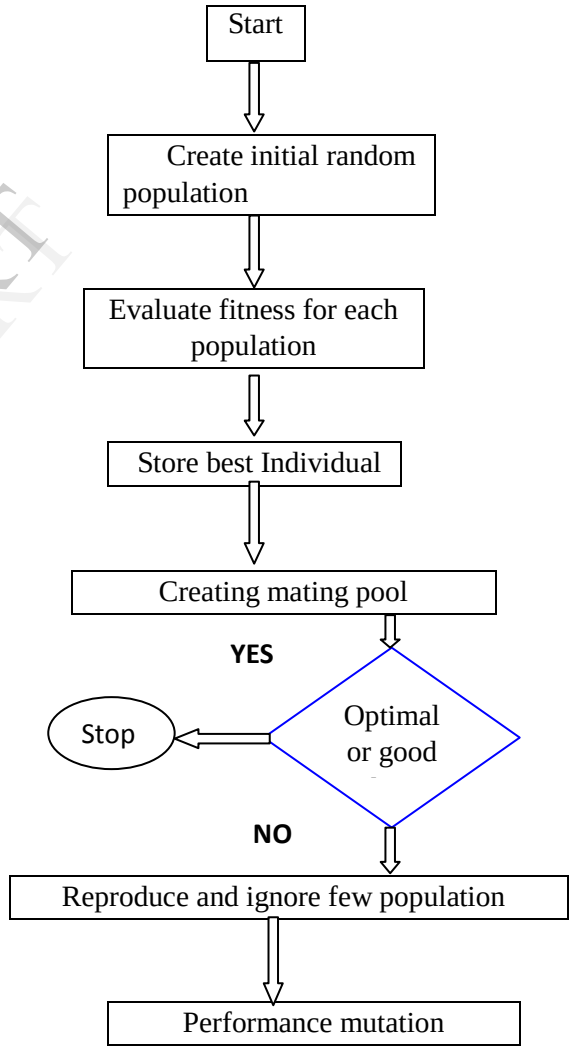
One of the optimization methods which can be used to obtain the best results of the system is the Genetic Algorithm. In this article, four factors including ripple of the output voltage, harmonic of the input current, settling time and power factor are considered to be optimized by using the Genetic algorithm. [10-12] For gaining the best results for the considered parameters above, four parameters including the switching frequency (*fs*) , *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. The input voltage of rectifieris 220 V, 50 Hz and the load parameters are L=10mH and R=200Ω.

" 5.Simulation Result "

Dedicated software is developed in MATLAB [10] for the application of GAs for voltage harmonic elimination in the PWM single phase inverter. The parameters of GAs, such as crossover and mutation probability, population size and the number of generations, are usually selected as common values given in literature, or by means of a trial and error process to achieve the best solution set.

"Table1. Applicability Range for Four Variable Parameters"

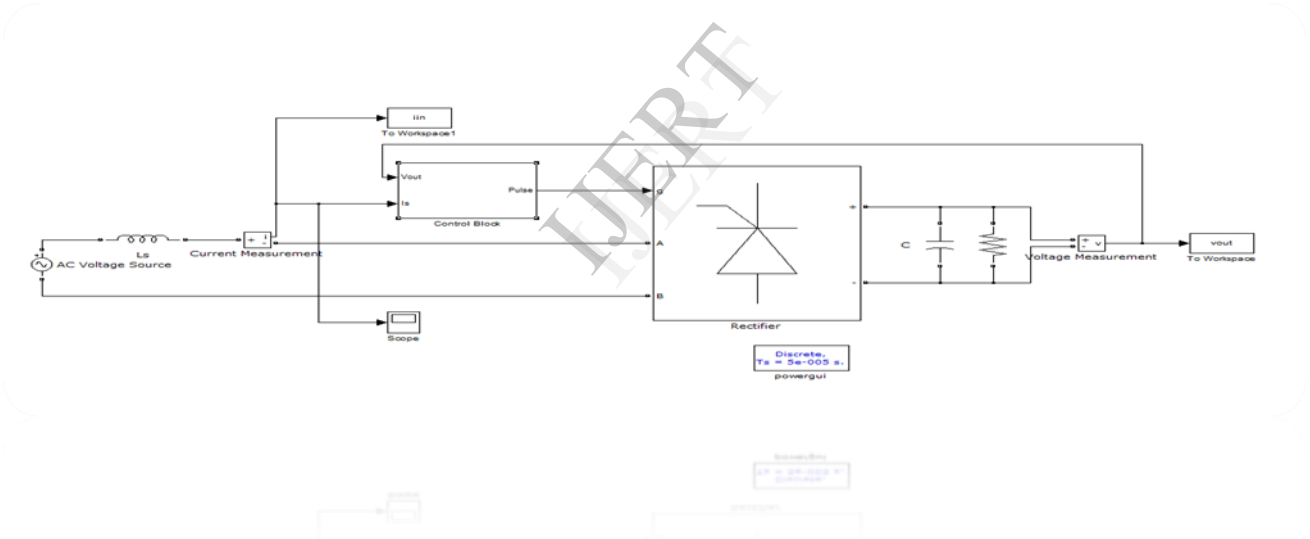
Variable	Applicable range	
fs (Hz)	35000	70000
C(μF)	390	1200
Kp	2	5.1
T	0.01	0.08



"Figure 3.Block Diagram of Genetic Algorithm"

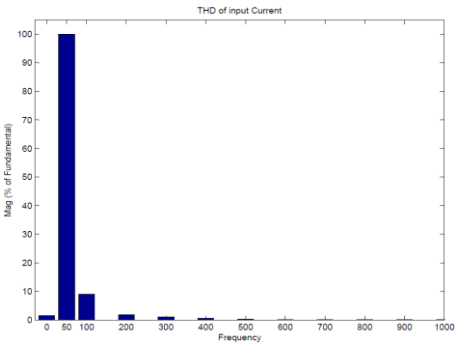
"Table 2. The Best Result from the Genetic Algorithm"

Variable	The best result
Fs	68500.8432 HZ
k p	2.8557
T	0.028026
C	0.028026



Although these parameters influence the dynamics and quality of convergence of the GAs, the proper determination of these parameters for a particular problem is still an open question. A higher population might increase the rate of convergence but also increase the execution time. The selection of an optimum sized population requires some experience in GAs. In the present work, the authors vary the parameters and study the impact.

"Figure 4. Simulink Model of Proposed Work"



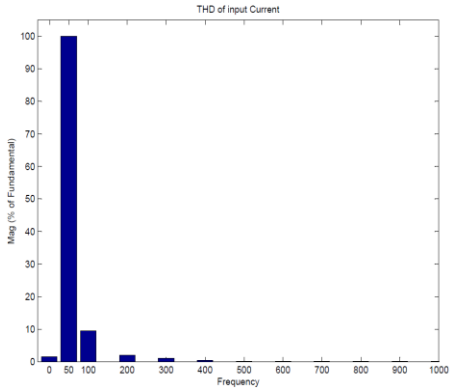
"Figure 5.TDH of Input Current Without GA"

Variable	Result
F_s	60000
C	0.00039
K_p	2
T	0.035

Calculated THD = 7.2076 %

"Table4. Simulation Results for Optimized Value by Genetic Algorithm"

Variable	Result
F_s	68500.8432
C	0.00041578
K_p	2.8557



"Figure 6.TDH of Input Current With GA"Table3.Simulation Results for Arbitrary Values"

figure is 3.5 %. Thus the GA is reducing THD almost to half as in un-optimized parameters.

" 6.Conclusion "

T	0.028026

Calculated THD = 3.7458 %

Simulation results have been shown in figure above. Figure 4 showing the THD of input current with arbitrary parameters of simulation, the THD value obtained of figure is 7.2 %.The genetic algorithm toolbox is used for optimization of parameters. Figure 5 is showing the THD of input current with optimized parameters of simulation, the THD value obtained of

An efficient technique of calculating switching angles through the Genetic Algorithm method is illustrated. An optimized PWM-SHE switching method is proposed for Single-phase Rectifier circuit. In this paper, a single phase pulse width modulated rectifier is presented and first simulated with arbitrary parameters. Then to obtain DC voltage with minimum harmonic of input current, genetic algorithm is used to optimize the operational parameter. Result of simulation shows the impact of optimized parameter over the total harmonic distortion of input current. Particle swarm optimization

technique has shown the improvement in results then genetic algorithm in many electronic domain problems, thus our work can be proposed to replace GA and improve THD of input current.

“ 7.References "

[1] M. P. Kazmierkowski, R. Krishnan, F. Blaabjerg “Control in Power Electronics” Academic Press 2002.

[2] M.Malinowski “Sensor-less Control Strategies for PWM Rectifiers”, PhD Thesis, Warsaw University of Technology, 2000.

[3] J.R. Espinoza, G.Joos, M. Perez, T.L.A. Moran “Stability issues in three-phase PWM current/voltage source rectifiers in the regeneration mode”, Industrial Electronics, 2000. ISIE 2000. Proceedings of the 2000 IEEE International Symposium on, Volume: 2, 4-8 Dec. 2000.

[4]V. Blasko, V. Kaura “A new mathematical model and control of a three-phase AC-DC voltage source converter”, IEEE Transactions on Power Electronics, Volume: 12 No. 1, Jan. 1997.

[5] D. Zhou, D. Rouaud, “Regulation and design issues of a PWM three-phase rectifier”, in proc. IEEE-IECONConf., pp. 485-489, 1999.

[6] M. Malinowski, “Adaptive modulator for three-phase PWM rectifier/inverter”, in proc. EPE-PEMC Conf., Kosice, pp. 1.35-1.41, 2000.

[7] V. Blasko, “Analysis of a hybrid PWM based on modified space-vector and triangle-comparisonmethods”, IEEE Trans. Ind. Application., vol.33, no.3. PP.756-764, 1997.

[8] J.Holtz. “Pulse-width Modulation for Electronic Power Conversion”, Proceedings of the IEEE, Volume:82, Issue: 8, pp. 1194 – 1214, Aug. 1994.

[9] F.Z. Peng,“Harmonic sources and filtering approaches”, Industry Applications Magazine, IEEE,volume: 7 Issue: 4, July-Aug. 2001.

[10] F. Jafari, A. Dastfan, “Optimization of Single-phase PWM Rectifier Performance by Using the GeneticAlgorithm”, ICREPQ, 2010.

[11] Yasuyuki Nishida, Osamu Miyashita, ToshimasaHaneyoshi, Hideo Tomita and Akeshi Maeda, “A Predictive Instantaneous-Current PWM Controlled Rectifier with AC-side Harmonic Current Reduction”, IEEE Transactions on industrialelectronics, vol. 2, pp. 1204-1209, November 1993.

[12] S. Somkun, P. Sehakul, V. Chunkag, “Novel Control Technique of Single-phase PWM Rectifier by Compensating Output Ripple Voltage”, IEEE, International Conference on Industrial Technology(ICIT), pp. 969-974, Dec. 2005.

[13] Mehjabeen A. Khan, Akeed A. Pavel, M. Rezwan Khan and M. A. Choudhury, “Design of a single phase rectifier with switching on AC side for high power factor and low total harmonic distortion”, IEEE Region 5 TechnicalConference, pp. 289-292, April 2007.