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Line Current Harmonic Reduction in AC-DC PWM Converter Using Genetic Algorithm

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Abstract — In this paper, AC/DC converters are widely used to get regulated power supply for battery charging and DC motor speed control. SCR converters are preferred in the field of High voltage DC energy transmission, superconductor magnetic energy storage, etc. However these converters have low power factor and also result in higher order harmonics. This paper proposes the application of Genetic algorithms (GAs) to find the switching angles for line current harmonic reduction in AC/DC type converter. Harmonic reduction is redrafted as an optimization problem and GA is applied.The harmonic elimination methods used in AC/DC converters are similar to those employed in PWM inverters or in AC choppers. The solution is obtained using genetic algorithm tool in MATLAB. The dual objectives of harmonic elimination and output voltage regulation are reframed as an optimization task and the switching instances are identified through the steps of GA.

Keywords **— Genetic Algorithm, Harmonic elimination.**

I. INTRODUCTION

AC/DC Converters are widely employed in many industrial applications such as battery charging, dc motor speed control. Triacs or thyristor pairs are usually employed as the power control elements of such controllers. The performance of conventional thyristor controlled AC power conditioning systems is adversely affected by the natural switching process of the thyristor devices. These converters have low power factor and also result in harmonic pollution of the mains. Several techniques were conceived to mitigate this problem and their approaches vary in complexity, application and utility. The first option is to use input LC passive filters. Other possibilities include the use of pulse width modulation (PWM) type converters or active filters. The advantage of PWM over other methods is that it does not require bulky and costly LC components. When PWM is employed, SCRs are not preferred as switching elements, since additional commutation circuits are required; instead power MOSFETs, power transistors and insulated gate bipolar transistors(IGBTs) are often used.

In phase controlled rectifier Line current harmonics and power factor have recently received increased scrutiny due to expanded rectifier usage in applications such as machine drives and uninterruptible power supplies. Line current harmonics reduce the rectifier power factor by increasing the RMS line current without delivering power and prevents full utilization of the available service. Line current harmonics cause over heating of power system components and trigger protective device unnecessarily. In addition, propagation of line current harmonics into the power system interferes with the operation of sensitive electronic equipment sharing the rectifier supply.

With PWM switching, the switching angles are evaluated for selective harmonic elimination using GA optimization technique. Conventional optimization techniques suffer from various drawbacks such as prolonged and tedious computational steps, convergence to local optima, etc. Further, the number of harmonics eliminated with this technique is linked to number of switching angles; thus the more number of harmonics to be eliminated, the larger the computational complexity and time.

The line current harmonics in AC/DC PWM converter can be reduced by finding the optimal switching angles using Genetic algorithm technique. A generalized method is developed with k number of pulses per half cycle for harmonic reduction together with output voltage regulation. This dual objective is achieved by defining a suitable fitness function, thereby reducing the computational burden significantly. The flexibility to modify this fitness function enables reduction of a specific order of harmonics.

II. PROPOSED SYSTEM

Fig 1 shows the block diagram of the proposed system. The block diagram consists of Power circuit, Microcontroller, Optocoupler isolation, Driver circuit.

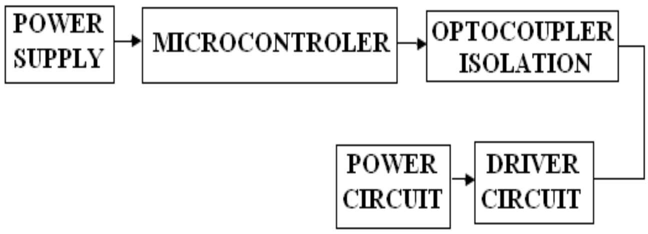

Fig 1 Block Diagram of the Proposed System

Optocoupler is used to provide electrical isolation between input and output. It consists of LED and phototransistor. Positive signal from control logic causes LED to emit light which is focused on the phototransistor.

This causes schmittrigger to change stage. The output of the schmittrigger is the optocoupler output. The driver circuit is used to drive the MOSFET. It gets pulses from driver to optocoupler and gives to the MOSFET. So, the isolation between gate and source can be obtained.

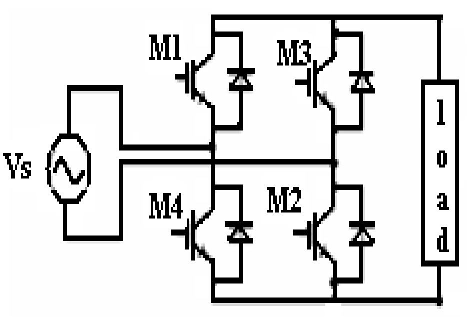

Fig 2 Circuit diagram of AC\DC converter

The power circuit of a MOSFET – based PWM AC/DC converter is shown in Fig 2. The structure of AC/DC converter consists of a single bridge module with AC input. The bridge module consists of four Metal Oxide Semiconductor Field Effect Transistors (MOSFETs). With appropriate switching algorithm, the PWM results in an input current waveform which is almost sinusoidal.

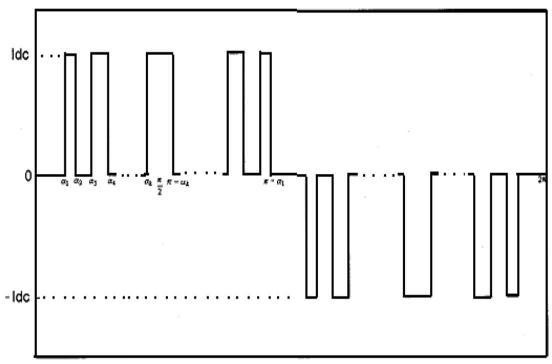

Fig 3 Line Current of AC/DC converter

Fig 3 shows the line Current of AC/DC converter. AC Supply is given as input to the AC/DC converter. Basically there are two modes of operation. In mode 1, that is in positive half cycle, MOSFET switches M1 and M2 are in conduction and in mode 2 that is in negative half cycle, MOSFET switches M3 and M4 are in conduction. The DC output voltage is measured across the load.

III. Harmonic Reduction

A harmonic is a sinusoidal component of a periodic wave of quality having a frequency that is an integral multiple of the fundamental frequency. Harmonics have been around for a long time and will continue to do so. Electrical generators try to produce electric power where the voltage waveform has only one frequency associated with it, the fundamental frequency. In North America, this frequency is 60Hz. In European countries and other parts of the world, the frequency is usually 50Hz. There are in between frequencies which are also called inter harmonics. There is also a special category of inter harmonics which have frequency values less than the fundamental frequency value called sub harmonics.

A. Need for Harmonic Reduction

- Excessive neutral current resulting in over heated neutrals
- Incorrect readings
- Reduced true power factor
- Over heated transformer
- Mis-operation or failure of electronic equipments
- Nuisance operation of protective devices So the harmonics generated is reduced by using the Genetic Algorithm technique.

IV. Genetic Algorithm

GA are optimization methods, which operate on a population of points, designated as individuals. Each individual of the population represents a possible solution of the optimization problem. Individuals are evaluated depending upon their fitness. The fitness indicates how well an individual of the population solves the optimization problem.

GA begins with random initialization of the population. The transition of a population to the next takes place via the application of the genetic operators: *Selection*, *crossover*, and *mutation*. Through the selection process, the fitter individuals will be chosen to go to the next population. Crossover exchanges the genetic material of two individuals creating two new individuals. Mutation arbitrarily changes the genetic material of an individual. The application of the genetic operators upon the individuals of the population continues until a sufficiently good solution of the optimization problem is found. The solution is usually achieved when a pre-defined stop condition, i.e., a certain number of generations is reached.

GA has the following general features:

GA operates with a population of possible solutions (individuals) instead of a single individual. Thus the search is carried out in a parallel form.

GA is able to find optimal or sub-optimal solutions in complex and large search spaces. Moreover, GA is applicable to nonlinear optimization problems with constraints that can be defined in discrete or continuous search spaces.

GA examines many possible solutions at the same time. So there is a higher probability that the search converges to an optimal solution.

V. Genetic Operators

Through the application of the genetic operator's *selection*, *crossover*, and *mutation*, GAs generates a new population from an existing population. In the following section, these three operators are described.

A. Selection

The *selection* process chooses the fittest individuals from a population to continue into the next generation. GAs use Darwin's principle of natural selection, "survival of the fittest" to select individuals. *Selection* compares the fitness of one individual in relation to other individuals and decides which individual goes on to the next population. Through selection, "good individuals" are favored to advance with high probability, while "bad individuals" advance with low probability to the next generation.

Here another important term, *the selection pressure*, is introduced. The selection pressure is the degree to which the better (fitter) individuals are favored: The higher the selection pressure, the better individuals are more favored (Miller and Goldberg, 1995). A too high selection pressure in the GA might cause premature convergence to a local optimum. Conversely a too low selection pressure can lead to a slow convergence. The convergence rate of GA is determined to a wide extent by the selection pressure. GA is able to find optimal or sub-optimal solutions under different selection pressures (Goldberg et al, 1995).

Theoretical investigations and comparisons of the efficiency of different selection methods can be found in (Blickle, 1997). In the following section, two of these are described: The *proportionate selection*, which is used with the classical GA, and the *tournament selection*, which is being used in this work.

B. Proportionate Selection

In the proportionate selection, the probability of selection, i.e. the probability that an individual c_i advances to the next generation, is proportionate to its relative fitness p_i. The expected number of offspring's ξ, of an individual c_i, is obtained by the product of the relative fitness p_i times the number of individuals of the population μ, i.e., $\xi = p_i \cdot \mu$. The number of fields of the roulette wheel corresponds to the population size. Each individual is assigned exactly one field on the roulette wheel. The size of the field is proportional to the fitness of the individual belonging to the field. The probability that the marker stops on a certain field is equal to the relative fitness of that individual. The roulette is spun μ times, which corresponds to the number of generations.

Proportionate selection, developed originally by Holland for classical GA, is only applicable to non-negative fitness. For negative fitness, it is necessary to use a *fitness scaling* method (Goldberg, 1989). Studies indicate that the tournament selection method presents better performance (Blickle, 1997).

C. Tournament Selection

Here, the fittest individual chosen from a group of z individuals of the population advances to the next population. This process is repeated μ times. The size of the group of *z* individuals is called *tournament size*. The selection pressure can be easily increased, by increasing the tournament size. On average, the winner of a larger tournament has a greater fitness than the winner of a smaller tournament. In many applications of this selection method, the tournament is carried out only between two individuals, i.e., a binary tournament. An important characteristic of this selection method is that there is no requirement for fitness scaling, thus negative fitness is also allowed.

D. Crossover

In the selection process only copies of individuals are inserted into the new population. *Crossover*, on the contrary, generates new genetic material by exchanging genetic material between individuals of a population, thus creating new individuals. Two individuals are chosen and crossed. The resulting offspring's replace the parents in the new population. Crossover manipulation can lead to the loss of "good" genetic material. Therefore, the crossover of two individuals is carried out with a probability p_c, the *crossover probability*, which is fixed before the optimization process. Successively $\mu \cdot p_c/2$ pairs of individuals are chosen to crossover.

The crossover operation takes place as follows: A random number between zero and one is generated. If this number is smaller than the *crossover probability*, then two individuals are randomly chosen, their chromosome pairs are split at a crossover point. The crossover point determines how the genetic material of the new individuals will be composed of. For each pair of individuals, the crossover point is randomly determined again. The representation determines how the crossover operator is applied to the individuals. In the following sections, the crossover operator is described for the binary and real representation.

E. Mutation

The mutation process effects a random variation upon the gene of an individual. A mutation is executed with the probability p_m, the *mutation probability*, which is fixed before the optimization. For each individual, a random number between 0 and 1 is selected which is compared with the mutation probability. If the random number is smaller than the probability of mutation, a gene is mutated.

VI. Simulation Results

Fig 4 shows the simulated circuit diagram of AC/DC PWM converter for practical implementation purpose. In this circuit, voltage and current waveforms are measured with voltage and current measurement block. The output of the pulse generator is given to the MOSFETS M1, M2 and the output of the same pulse generator with 180 degree phase shift is given to the MOSFETS M3, M4. Fig 5 shows the subsystem model which is used to generate the gating pulses for the MOSFETs. Fig 6 shows the waveform of Input voltage and Output voltage and the Fig 7 shows the waveform of Input current and Output current. Fig 8 shows the Fitness value vs. generation graph obtained from GA. It shows the variation of fitness function with respect to generation. From the graph it is evident that with increase in the number of generations, the best fitness value obtained decreases.

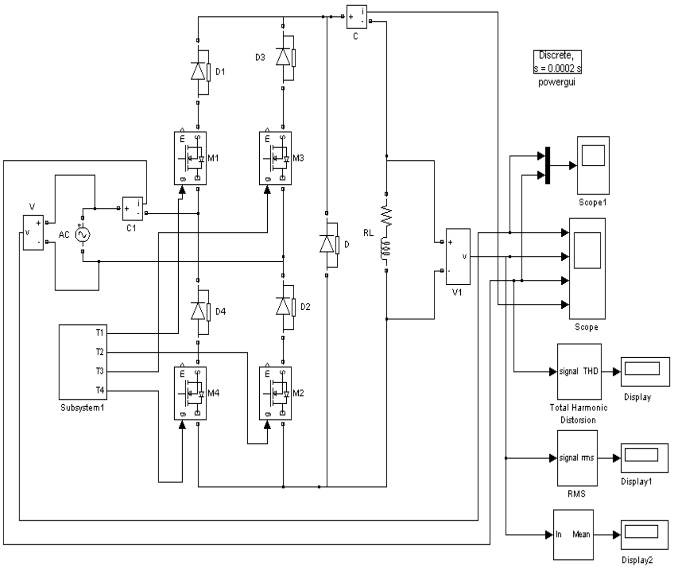

Fig 4 Simulated circuit diagram

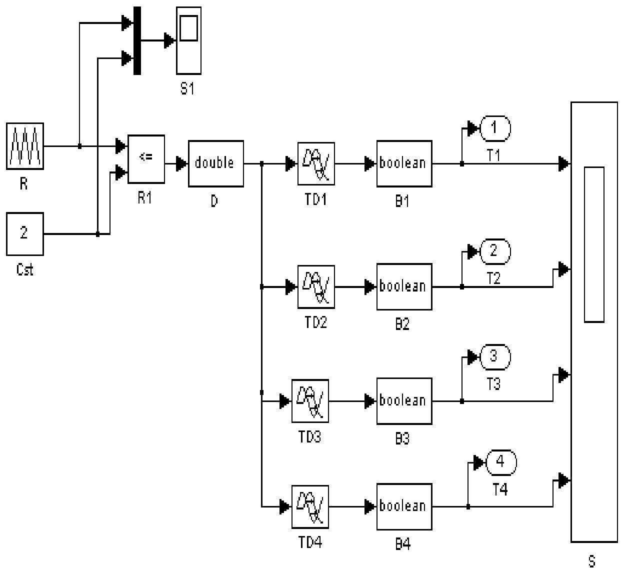

Fig 5 Subsystem

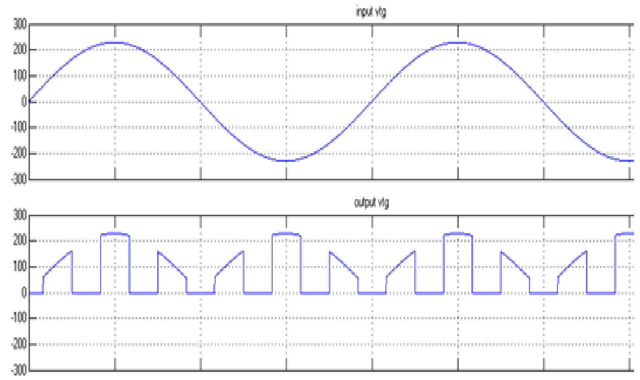

Fig 6 Input voltage and Output voltage waveform

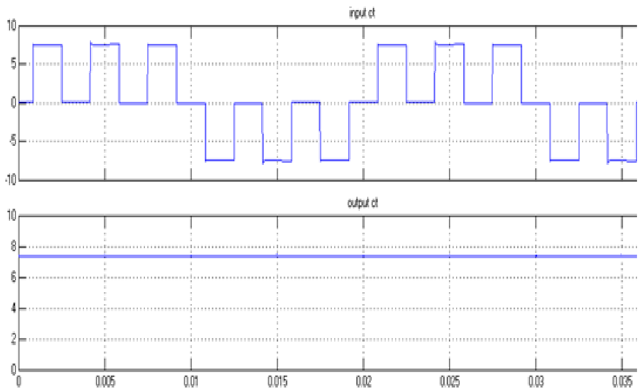

Fig. 7 Input current and Output current waveform

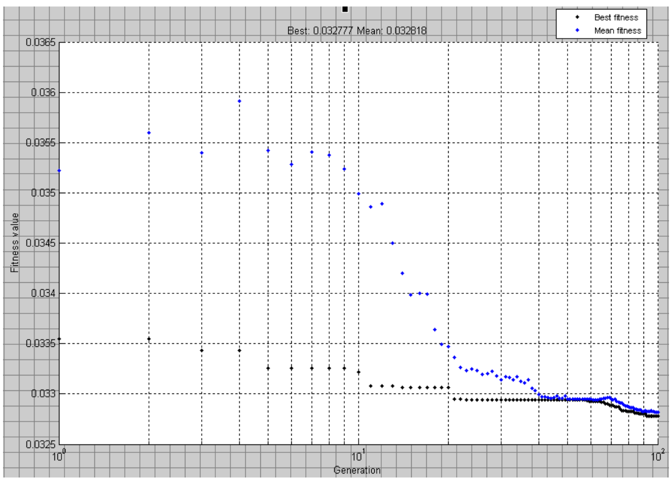

Fig 8 Fitness value vs. generation

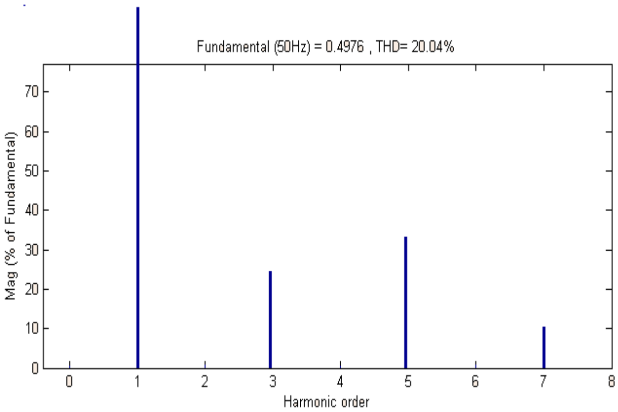

Fig 9 Total harmonic distortion resulted from GA

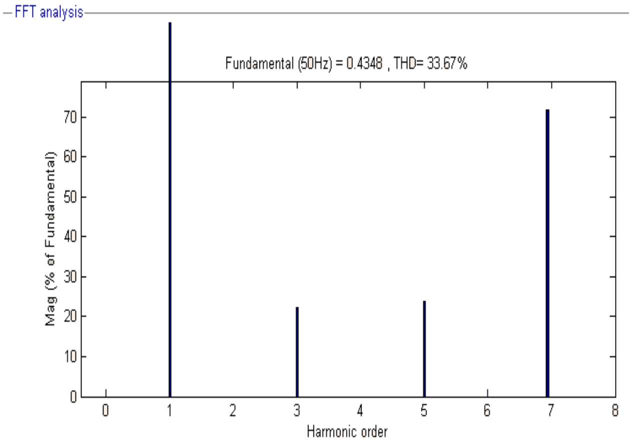

Fig 10 Total harmonic distortion resulted from Newton Raphson method

Fig 9 and Fig 10 shows the Total harmonic distortion resulted from GA and Newton Raphson method respectively. Results obtained from GA are compared with that from Newton Raphson method. Newton Raphson method is a conventional and an iterative optimization technique. In this technique, the solution mainly depends on the initial guessing. In GA the Total Harmonic Distortion is 20.04% whereas in Newton Raphson method the Distortion is 33.67%. It shows that GA is an efficient method compared to the conventional technique.

VII. Conclusion

In this work, GA is used as an optimization tool in minimizing the line current harmonics in a PWM type AC/DC converter. GA technique is used to find the switching angles of the converter for the reduction of harmonics. It is observed that the GA works efficiently for line current harmonic reduction compared to Newton Raphson technique. The proposed approach is general in nature and can be easily extended for harmonic elimination in other power electronic converters. In this work, 3 pulses per half cycle were considered. This work can be extended further for any number of pulses per half cycle.

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