Reduction of Low Order Harmonic in Multilevel Inverter using Hybrid Algorithm

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Abstract— In this paper, a proposed hybrid algorithm (Genetic Algorithm and Particle Swarm Optimization) optimization technique is applied to 11-level multilevel inverter to determine optimum switching angles for reducing low order odd harmonics also minimize the total harmonics distortion (THD) while keeping up the required basic voltage and current. This hybrid algorithm optimization technique can be applied to 11-level multilevel inverter, and the optimum switching angles are calculated to eliminate 1st, 3rd, 5th, 7th, and 9th odd harmonics. The proposed hybrid algorithm optimization technique is implemented in Matlab/GUI Environment.

Keywords—*(Multilevel Inverter, Harmonic Elimination, Total Harmonic Distortion, Genetic Algorithm and Particle Swarm Optimization)*

I. Introduction

Electric power quality is a term which has discovered extending thought in charge or power designing in the present years. Notwithstanding the way that this subject has constantly been imperative to control engineers, it has expected impressive enthusiasm for the 1990's. Electric power quality means various things for other people's individuals [2]. To most electric power plans, the term implies a particular satisfactorily high audit of electric organization yet past that there is no far reaching assention. The live of vitality quality relies upon the needs of the equipment that is being given. What's great power quality for an electrical motor may not be good enough for a personal computer. Typically the administration quality implies keeping up a bended influx of transport voltages at evaluated voltage and recurrence [3]. The waveform of electrical power at age make is totally bended and free from any damage. A large number of the power transformation and utilization hardware are additionally intended to work under unadulterated sinusoidal voltage waveforms. In any case, there are numerous gadgets that contort the waveform. These bends may engender wherever all through the electrical framework. As of late, there has been associate degree dilated utilization of non-straight masses that has caused associate degree dilated a part of non-sinusoidal streams and voltages in electrical network [4]. Plan of vitality quality zones may be made by the wellspring of the issue, for instance, converters, attractive circuit non linearity, circular segment heater or by the wave state of the flag, for example, sounds, glimmer or by the recurrence range (radio recurrence obstruction) [5]. The wave wonders connected with management quality could be delineated into synchronous and non synchronous wonders. Synchronous wonders guide those in synchronizing with A.C wave at management repeat. The standard parts of electric power quality may be requested as:-

1. Fundamental concepts
2. Sources
3. Instrumentation
4. Modeling
5. Analysis
6. Effects

Figure 1.1 demonstrates a portion of the average voltage aggravations [18].

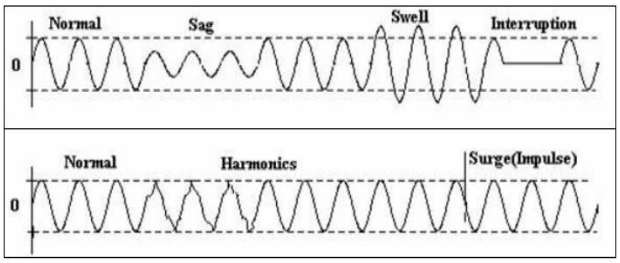

Fig.1.1. Average Voltage Representation [12].

Different Powers	Problems
Power Frequency Disturbance	• Low Frequency Phenomena • Produce Voltage Sag/Swell
Electro Magnetic Interferences	• High Frequency Phenomena • Interaction Between Electric and Magnetic Field
Power System Transient	• Fast, Short-Duration Event • Produce Distortion like Notch, Impulse
Power System Harmonics	• Low Frequency Phenomena • Produce Waveform Distortion
Electrostatic Discharge	• Current Flow with Different Potentials • Caused by Direct Current for Induced Electrostatic Field

Power Factor	• Low Power Factor Causes Equipment Damage

Table 1.1. Different Power Quality Problems [12].

II. Literature Review

Harmonic decrease is a standout amongst the most difficult issues identified with multilevel inverters. As per various methodologies on finish harmonics of a fell construction supply electrical converter. Here the fundamental idea is to dispose of particular harmonic with a legitimate decision of switch angles. During this paper proposed hybrid algorithm rule improvement procedure is use to accomplish applicable switch angle for decrease the all harmonic and finish of a particular lower compose harmonics with real portions at the pined for regards. This paper displays an outline of different topologies for Selective harmonics elimination of multilevel inverts have been proposed over the year. One important application of multilevel converters is focused on medium and high-power conversion [1] [2]. Now days, there exist three commercial topologies of multilevel voltage-source inverters: neutral point clamped (NPC), cascaded H-bridge (CHB), and flying capacitors (FCs) [3] [4]. Among these inverter topologies, cascaded multilevel inverter reaches the higher output voltage and power levels and the higher reliability due to its modular topology. Battery and renewable energy like fuel cell; solar cell etc also can be used as DC unequal voltage sources [5]. To eliminate harmonics, improve performance and output quality, several methods are suggested. Those are [6], sinusoidal pulse width modulation [7], selective harmonic elimination PWM [8], space-vector modulation [9] [10], and optimal minimization of Total Harmonic Distortion. It is possible to eliminate selective harmonics and minimization of total harmonics distortion by solving the non linear equation of multilevel inverter. Several iterative numerical techniques have been suggested like Newton-Raphson method, Bisection method, Polynomial theory, Resultant theory, Particle swarm optimization etc are implemented to solving the non linear equations [11]. The Newton–Raphson (N–R) method is commonly used to solve the non linear SHE equation [12]. The disadvantage of this method is, it depends on that initial guess and divergence problems are likely to occur for large numbers of inverter levels. In this paper Selective Harmonics Elimination technique is used to eliminate the lower order harmonics like fifth, seventh, eleventh, thirteenth etc. and minimize the THD, while maintaining the required fundamental voltage. The transcendental non-linear equations are solved using Genetic Algorithm and Particle Swarm Optimization [13]. The calculated switching angles are used to trigger switching devices of eleventh level cascaded multilevel inverter which is modeled in MATLAB and harmonic analysis is carried out. Segment II exhibits a theoretical diagram of set up and case setup. One amount of a multilevel inverter is talked concerning Section III. SHE-PWM is mentioned in Section IV. Proposed hybrid calculation (GA and PSO) is analyzed in Section V. Simulated results are introduced in Section VI. In conclusion, discourses and finishing up comments are introduced in Section VII.

III. Cascaded Multilevel Inverter

The idea of electrical converters has been presented since 1975. The term multilevel began with the three-level gadget [4]. Multilevel or structure inverters are actuation certain the profound world and additionally business within the current decade for high-voltage and medium-voltage vitality management. It combines a sought after voltage from a many levels of dc voltages as inputs. By taking sufficient number of dc sources, a nearly sinusoidal voltage waveform can be synthesized [4].A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources [5]. Structure inverters have changed into a productive and right down to earth announces expanding the facility and diminishing the hints of AC waveforms. Stood out from the standard two-level voltage supply electrical converter, the stepwise yield voltage are those the genuine favorable position of multilevel inverter.

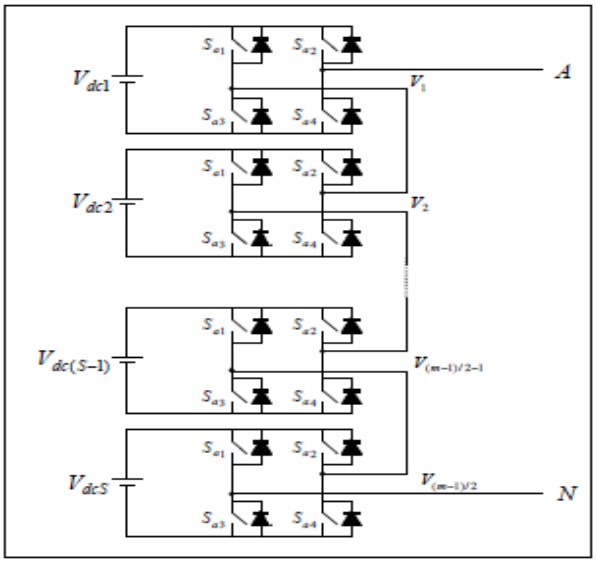

Fig.1.2. Cascaded Multilevel Inverter [6].

This advantage results in higher power quality, better electromagnetic compatibility, lower switching losses, higher voltage capability, and needlessness of a transformer at distribution voltage level, thereby reducing the costs. Plentiful multilevel converter topologies have been proposed during the last two decades. Multilevel inverters are generally divided into three configurations: diode-clamped, flying capacitor, and cascaded H-bridge multilevel inverters [6]. Among these electrical converter topologies, electrical converter accomplishes the upper yield voltage and power levels and furthermore the higher enduring quality in view of its

measured structure. Electrical inverters depend on an arrangement association of a few single stage full scaffold inverters. This structure is supplied for achieving medium yield voltage levels utilizing simply normal low voltage segments [6]. A structure electrical converter, an influence electronic convenience, is equipped for giving wanted substituting voltage level at the yield utilizing various lower level DC voltages as data. Electrical converter appeared in Figure 1.2 has been decided for the execution of firefly control by virtue of its deliberate quality, effortlessness of administration, require less assortment of components, general less weight and cost once appeared differently in relation to exchange styles of electrical converter [8]. To allow a curved yield, a couple of H-bridge structure converter is associated in arrangement. Every cell contains one H-expansion and yield voltage made by electrical converter is absolutely the entire of the respectable variety of voltages created by each cell i.e. on the off likelihood that there are k cells in electrical converter then the amounts of yield voltage levels would be 2k+1 [9]. 11-level electrical converter is decided for execution of firefly run the show.

IV. Selective Harmonic Elimination

In case of SHE, selected lower order harmonics are eliminated while remaining harmonic components are reduced to minimize THD [12]. In this paper bring down request sounds i.e. i.e. fifth, seventh, eleventh, thirteenth are wiped out. The articulation wants key voltage in below specify equation. Additionally, the connection between the essential and also the greatest approachable voltages is given by modulation index (m11) is portrayed on the grounds that the extent of the focal yield voltage to the foremost extreme potential major voltage [16]. The greatest essential voltage is no inheritable once when the entire switch angles are zero i.e.

$$V_{1max} = \frac{4V_{dc}}{\pi} \qquad (1)$$

In this manner the articulation for m_{11}

$$m_{11} = \frac{\pi V_1}{4V_{dc}} (0 \le m_{11} \le 1) \qquad (2)$$

Numerical harmonic eliminated issue can be defined as

$$\begin{aligned} cos(\theta_1) + cos(\theta_2) + \cdots + cos(\theta_m) &= m_{11}M \\ cos(5\theta_1) + cos(5\theta_2) + \cdots + cos(5\theta_m) &= 0 \\ cos(7\theta_1) + cos(7\theta_2) + \cdots + cos(7\theta_m) &= 0 \\ cos(11\theta_1) + cos(11\theta_2) + \cdots + cos(11\theta_m) &= 0 \\ cos(13\theta_1) + cos(13\theta_2) + \cdots + cos(13\theta_m) &= 0 \\ \cdots \\ \cdots \\ cos(n\theta_1) + cos(n\theta_2) + \cdots + cos(n\theta_m) &= 0 \qquad (3) \end{aligned}$$

The condition (3) will be an arrangement of supernatural condition, known as SHE condition. From the condition obscure exchanging point or switching angle square measure designed with the assistance of the given estimation of n (from zero to one) for trigger semiconductor switches [17]. Harmonic distortion is caused by nonlinear devices in the power system. A nonlinear device is one in which the current is not proportional to the applied voltage. While the applied voltage is perfectly sinusoidal, the resulting current is distorted. Increasing the voltage by a few percent may cause the current to double and take on a different wave shape. This is the source of most harmonic distortion in a power system.

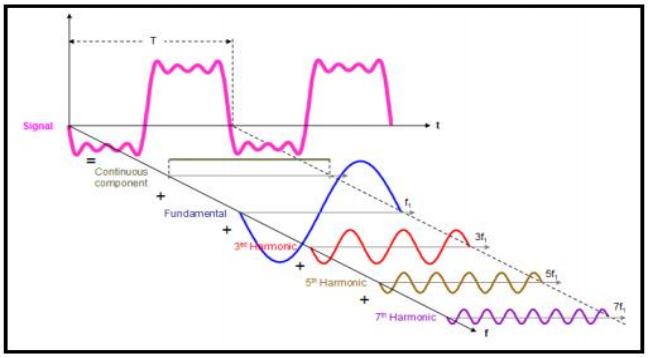

Fig.1.3. Harmonics.

V. Proposed Approach

During this paper proposed hybrid algorithm (GA and PSO) optimization technique can be applied to 11-level multilevel inverter, and the optimum switching angles are calculated to eliminate 1st, 3rd, 5th, 7th, and 9th odd harmonics.

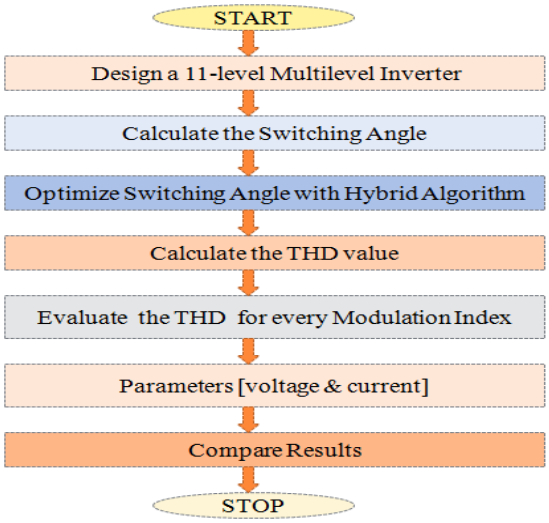

Fig.1.4. Flow Diagram of Hybrid Algorithm.

A. Genetic Algorithm

GA operates with a collection of chromosomes, called a population. The population is normally randomly initialized.

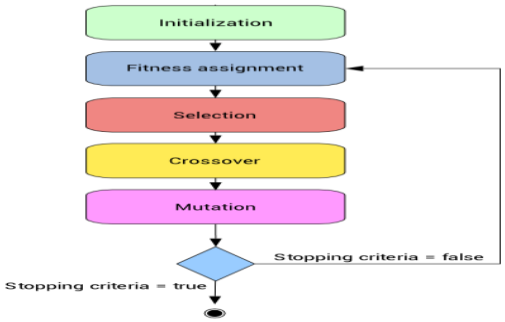

Fig.1.5. Flow Diagram of Genetic Algorithm.

As the search evolves, the population includes fitter and fitter solutions, and eventually it converges, meaning that it is dominated by a single solution. Holland also presented a proof of convergence (the schema theorem) to the global optimum where chromosomes are binary vectors.GA use two operators to generate new solutions from existing ones: crossover and mutation [15].

B. Particle Swarm Optimization

PSO algorithm is an adaptive algorithm based on a social-psychological metaphor; a population of individuals (referred to as particles) adapts by returning stochastically toward previously successful regions. Particle Swarm has two primary operators: Velocity update and Position update. During each generation, each particle is accelerated toward the particles previous best position and the global best position [18].

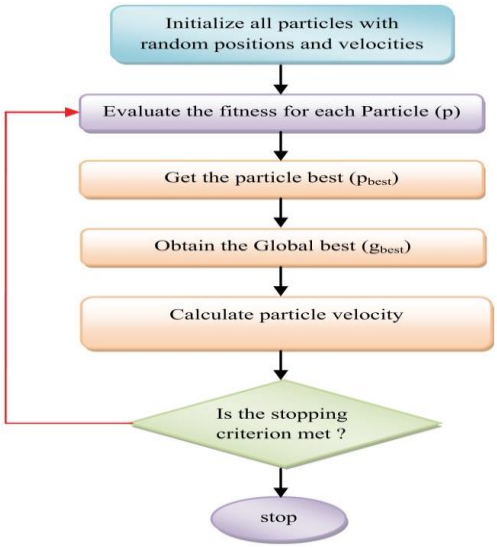

Fig.1.6. Flow Diagram of Particle Swarm Optimization.

VI. Simulated Results

As indicated by proposed approach actualize the genetic calculation on an eleventh level and ideal switching angle are resolved to wipe out low request harmonics and to limit THD in MATLAB. The outcomes for ideal switching angles shown in Figures 1.7 demonstrates the best switch angle once this strategy is connected to an 11-level electrical converter to limit the harmonic distortion.

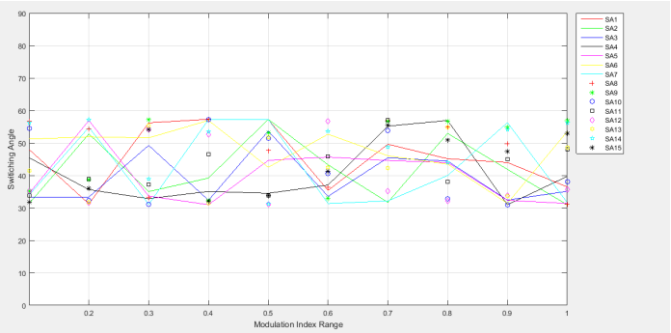

Fig.1.7. Switching Angle w.r.t Modulation Index.

Figures 1.8 demonstrates the optimizing switching angles in 11-level multilevel inverter by using graphical optimization algorithm.

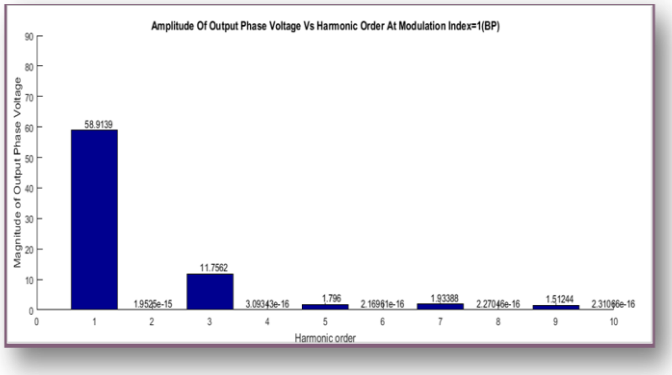

Fig.1.8. Harmonic Orders w.r.t Previous Algorithm.

Figures 1.9 demonstrates the optimizing switching angles in 11-level multilevel inverter by using hybrid algorithm optimization technique.

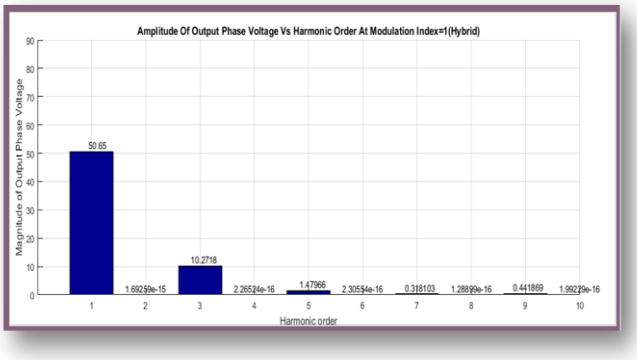

Fig.1.9. Harmonic Orders w.r.t Proposed Algorithm.

Table 1 demonstrates the different values of Low order Harmonics using previous (graphical optimization algorithm)

and proposed hybrid algorithm (GA and PSO) optimization technique.

Harmonic Order	Previous Rule	Proposed Rule
1st Order	58.9139	50.6500
3rd Order	11.7562	10.2718
5th Order	01.7960	01.4797
7th Order	01.9339	00.3181
9th Order	01.5124	00.4419

Table 1.2. Harmonic Order w.r.t Previous and Proposed Algorithm

VII. Summary/Conclusion

During this paper proposed hybrid algorithm (Genetic Algorithm and Particle Swarm Optimization) optimization technique is proposed to minimize the selective odd harmonics (1st, 3rd, 5th, 7th, and 9th) as well as overall total harmonics distortion of the output voltage of 11-level multilevel inverter. For further extent of the work, new Artificial Intelligence (AI) technique can also be used for harmonics reduction in the n-level multilevel inverter.

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