ABSTRACT

Harmonics are destructive phenomenon in power systems. These harmonic currents cause extra losses in the loads which in turn require derating of the load. The effect is especially severe for lower order voltage harmonics at the terminals of rotating machines. The electrical machines are mainly affected by lower order harmonics, whereas capacitor banks are affected by higher order harmonics. These harmonics lead to large energy loss either in transmission systems or in distribution systems. Different harmonics resonate with network components, like capacitors and transmission lines, which enlarge the harmonic energies and increase their impacts. Many scholars endeavoured to make a study on these negative impacts generated by harmonics and developed many strategies to handle power system harmonic problems. These strategies operate as either active modes or passive modes. As a kind of active mitigation strategy, possessing the features of flexibility and efficiency, pulse width modulation controlled power electronic devices have obtained more and more recognition.

Selective harmonic elimination pulse width modulation technique is one of the special kinds of optimal pulse width modulation techniques. It generates high quality output waveform through elimination of specific lower order harmonics. The inverter switching angles are determined by solving a set of non-linear equations. The main challenge associated with such techniques is to obtain the analytical solutions of non-linear transcendental
equations that contain trigonometric terms which naturally exhibit multiple solutions. These transcendental equations are derived from the signal frequency domain analysis and have disadvantages in excessive harmonics distribution in the output spectrum. They are also heavily ill-conditioned when the number of eliminated harmonics becomes large. The major problem of the traditional method is the determination of initial values for calculating switching angles, which greatly affects the convergence of these equations. In solving a set of non-linear equations numerically, the primary concern is the convergence of the method used. Unlike solving a single non-linear equation, where there are many methods of obtaining prior information on the location of the root, the convergence itself is a serious problem in solving a set of equations. Meanwhile, the root search with traditional algorithm depends on the iteration initial values and can only be used in off-line situations because of the low calculation speed.

To overcome the disadvantages of the original selective harmonic elimination pulse width modulation technique, several optimal harmonic elimination techniques are presented in this thesis. Optimal pulse width modulation is a method that theoretically offers the highest quality of the output waveform. By optimizing the switching angles distribution, the harmonic content can be flexibly redistributed and high quality output waveforms are obtained.

To avoid these problems and difficulties, the other options are the non-traditional methods. Non-traditional methods do not affect the initial feasible solution, when the non-linear transcendental equations are solved.
Genetic algorithm is a kind of artificial intelligence approach, and it has its origin from optimizing problems. It has entirely different operation mechanisms when compared with numerical methods based on mathematical differential operation. Genetic algorithm is used to solve the non-linear transcendental equations because it has the ability of parallel searching of the solution space, rather than the point by point searching in a small region. In this thesis, genetic algorithm is used to find the N switching angles to eliminate the N-1 non-triplen harmonic contents up to 13th in voltage source inverter. The optimization technique assisted with a genetic algorithm is applied to reduce the computational burden associated with the non-linear transcendental equations of the selective harmonic elimination pulse width modulation method that has been applied to the voltage source inverter.

Evolutionary programming is one of the probabilistic search technique used to determine the most optimal switching pattern to eliminate the harmonics content in the voltage source inverter. Evolutionary programming is another non-traditional method to solve these non-linear equations with N switching angles to eliminate N-1 non-triplen harmonics in the voltage source inverter. Using evolutionary programming approach, additionally 17th and 19th harmonics are eliminated along with the N-1 non-triplen harmonics. This method does not use the dual transformer to eliminate 5th and 7th harmonics in the voltage source inverter.

The variable neighbourhood search is a heuristic method and it is applied to solve the non-linear transcendental equations along with genetic algorithm. Genetic algorithm does not need initial information like the
guessed initial switching angles required for variable neighbourhood search. It is applied to solve selective harmonic elimination pulse width modulation problem efficiently, and it is more suitable when compared to the traditional numerical algorithm, due to its ability to search and find the optimal value in the global space. A combination of genetic algorithm and variable neighbourhood search has been found very suitable for selective harmonic elimination techniques. Genetic algorithm is used to find the best feasible solution for non-linear transcendental equation for selective harmonic elimination pulse width modulation problem. This solution obtained using genetic algorithm is used as the initial feasible solution for variable neighbourhood search. The basic idea is to determine the N switching angle to eliminate N-1 harmonic contents in the voltage source inverter. This hybrid technique also eliminates the additional harmonics 17th and 19th from the output voltage waveform of voltage source inverter.

Tabu search is a high level local search method to solve complex non-linear transcendental equations. Applied to optimization problems, the tabu search algorithm starts at some initial solution and then moves to a neighbourhood solutions. A neighbourhood solution is generated by a set of admissible moves. At each iteration, in this method, the current solution moves to the best solution in the neighbourhood solution. The genetic algorithm is used to supply the initial values of switching angles because of its ability to handle huge amount of data and avoid local optimal points. A combination of genetic algorithm and tabu search are used to solve the non-linear transcendental equation of selective harmonic elimination problems.
This hybrid method provides the solution which is far better than other non-traditional methods.

The genetic algorithm and tabu search method is used to find $N$ switching angles to eliminate the $N-1$ non-triplen harmonics in the voltage source inverter. But the efficiency of this method eliminates the additional lower order harmonics other than $N-1$ harmonic order. By using this hybrid method, load voltage and current harmonics up to $25^{th}$ are eliminated in the voltage source inverter. The usage of twelve pulse rectifier circuits and the dual transformer equipments can be avoided, which leads to extra cost and increase in the size of the equipment. The additional non-triplen harmonics are eliminated using this approach. The non-linear transcendental equations are solved using MATALB 7.0 and the solution obtained using the hybrid optimization technique is simulated using PSIM software. The prototype lower power experimental setup is made to test the simulated results. The obtained results using the simulation software are compared and validated with the experimental results.