Harmonic Reactive Power Compensation of the grid by UPQC by hybrid swarm intelligence with fuzzy logic

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Abstract- enhance the quality of power has becomes an effective area of research in power system and power electronics. The conditioners are required in the power systems due to high frequency switching and non-linear loads. Unified Power Quality Conditioner (UPQC) is an electronic device which solves the problem of voltage sag and total harmonics distortion problems. The conditioner is a combination of series active and shunt active power filters. The power quality is enhanced by integrating the power filters. The proposed work is done by using fuzzy logic with swarm intelligence approach and proposes a new UPQC system. This system reduces the sag and harmonic distortion. The PSO is used to optimize the reference signal which is generated by the fuzzy logic controller. The proposed experiment is done on the MATLAB/ Simulink environment. The results and output received on this is used for the analysis. The proposed fuzzy with PSO controller is better than the existing approaches in minimizing the sag and harmonic distortion. The whole process is enabling by using fuzzy membership functions

I. INTRODUCTION

Distributed Generation (DG) is predicted to play an important role in the electric power system in near future. It is widely accepted that photo voltaic generation is currently attracting attention to meet users' need in the distributed generation market. In order to investigate the ability of photo voltaic (PV) units in distribution systems, their efficient modelling is required. Distributed generation technology is a new, promising way of energy utilization. Where solar power is competitive to stand out from a variety of distributed power and become more developed relatively [1]. The control of grid-connected photovoltaic power generation system is a comprehensive process, which involves not only the technology about solar cell and grid-connected inverter, but also to the control and optimization problems of the system. In the end of the distribution network, the impact on power quality caused by the reactive load in the end of distribution network is more serious than which in centre grids. The fluctuations of reactive load will have a great impact on the supply voltage of power system, there by affecting other loads on this node [8]. The regulation of the PCC (Point of Common Coupling) voltage achieved by the PV system control scheme has a positive impact and important significance for the application of PV. The main circuit topology of three-phase active reactive power compensation device and three-phase grid-connected inverter is exactly the same. Thus, in support of a reasonable control strategy it can be integrated together with both function of grid connection and reactive power compensation control [4]. When it output from photovoltaic cells, the inverter transforms DC into AC current delivered to the power grid, while selectively supply a certain reactive current compensation. When the reactive load fluctuates, the reactive component of the output current can be adjusted to achieve reactive power compensation by the control of PV grid-connected inverter, thus reduce the reactive power provided by large power grids through the transmission line. By reducing the reactive power flow in the grid, it can reduce the energy loss in transmission lines and transformers caused by reactive power transmission. Since the voltage of grid-connected PV system mainly depends on the support of large power grid, when the reactive load fluctuates, a stable system voltage can be achieved by maintaining a constant reactive power output of large power grids [12] [24].

The solar based DG units plays an increasing role in power system of near future. The development of power electronics technology plays a key role in the integration of DG units which change the vertical power system to a horizontal one. DGs can be designed to provide ancillary services to the utility such as reactive power support, load balancing, voltage support, and harmonic mitigation.

Power quality is a very important issue in distribution system. Power quality is simply defined as a quality of electricity i.e. it is a concept that is use to describe the purity of the transferred energy. As per IEEE Std. 1100 Power quality is defined as concept of powering and grounding sensitive equipment in a manner that it is suitable for the satisfactory operation of that equipment. But, the power quality is disturbed or destroyed due to several problems occurring in the electrical network for e.g. voltage sag, Voltage swell, unbalance of voltage and current, harmonics produced in voltage and current flickers transient over voltage supply interruption etc. The allowable source voltage and load current distortion (THD) limit as per IEEE standards must be strictly maintained. Harmonic current components create several problems like:

- Increase in power system losses
- Overheating and insulation failures in rotating machinery
- Overheating and insulation failures of conductor, transformers, and cables
- Reactive power burden
- Low system efficiency
- Poor power factor
- System unbalances and causes excessive neutral currents
- Malfunctioning of the protective relays and untimely tripping.

The modern power distribution system is becoming highly vulnerable to the different power quality problems stated above [2], [3] The extensive use of nonlinear loads is further contributing to increased current and voltage harmonics issues. Furthermore, the penetration level of small/large-scale renewable energy systems based on, fuel cell, solar energy, wind energy etc. installations at distribution and transmission networks is increasing significantly. This integration of distributed generation in a power system is introducing new challenges to the electrical power industry to accommodate these systems [4]. For distribution system, UPQC is a most attractive solution for compensating power quality problems. Research is continued for use of UPQC to solve problems such as voltage sag, voltage swell, voltage, correction of power factor and unacceptable levels of harmonics in the current and voltage. The swells are more destructive in nature than sag, UPQC is being studied for mitigation of voltage sag and swell [5], [6]. For example, breakdown of components or equipment due to excessive over voltage during swell condition [7].

1.2 Grid Connected PV System

A. Elements Included in a System of Photovoltaic Conversion**:** The basic schematic diagram of a grid connected PV system with voltage source inverter is shown below.

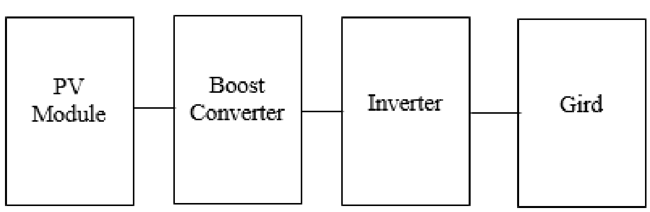


Figure 1Grid connected PV system block Diagram

The main elements that can be included in a system of photovoltaic conversion are Photovoltaic modules, converters, utility grid, loads DC and AC, and Inverters [2] [3].It is an arrangement used in PV standby power supply units, it's called grid connected system without a battery backup. Although systems with battery backup confront the issue of reliability of the grid supply but it is more complicated and more expensive. PV module: The solar panel is the power source of all photovoltaic installation [19]. It is the result of a set of photovoltaic cells in series and parallel. PV cell directly converters the solar irradiance into electricity in the form of dc when sunlight interacts with semiconductor materials in the PV cells. Figure 1.2 shows the equivalent circuit of a PV, from which non-linear I-V characteristic can be deduced. Hence, the cells are connected in series and in parallel combinations in order to form an array with desired voltage and power levels, solar cells are combined to form 'modules' to obtain the voltage and current (and therefore power) desired.

II. RELATED WORK

Ali Reaz Reisi, et.al [1] firstly discussed the overview of grid-associated photovoltaic systems (PVs). Secondly, the experts analyzed a more deep detailed look over grid-connected PVs via the technology of active filter. This part explained the modelling of shunt active filter and photovoltaic panel. In other part, the analysts enroll distinct MPPT (maximum power point tracking) methods and also enroll various method for designing DC link in terms of a common bus of photovoltaic system and shunt active filter. In the final part, Simulink/ MATLAB simulations verified the performance of the model proposed.

Beena V, et.al [2] presented a methodology in which the process of enhancing the quality of power was ensured including control of power for grid collective inverter. The work dealt with analyzing and modeling of a grid-associated inverter (transformer less) with reactive and active power control by the control of the phase angle-based inverter output and the amplitude in connection to the voltage of the grid. In conjunction to voltage and current control, the control of power quality was made to curtail the THD i.e. total harmonics distortion. The grid interactive inverter simulation was carried out in the environment of MATLAB/SIMULINK.

Daxa Rathva, et.al [3] presented the concept of compensating the reactive power for grid solar-based PV system. In this type of modeling STATCOM, inverter control, and the controlling strategy using the concept of dq0 transformation of 3-Φ PWM inverter was employed in grid associated PV generation and the PWM inverter control system was used to control the reactive and the active power. In the strategy of inverter control the experts have used various techniques such as PWM, dq0 transformation, and PLL techniques. Using the concept of STATCOM one can eliminate harmonics and compensate reactive power.

Mehrdad Tarafdar Hagh, et.al [4] investigated a grid-connected PV system with injection of active power, compensation of reactive power and the capability of eliminating harmonic current. The electrical equivalent model was presented in the analysis of literature used for implementing the photovoltaic system. In case of non-linear loads, the methods of low frequency-based SRF (synchronous reference frame) were not capable of eliminating the second and third order harmonics that appears in the current of the grid. This study involves a SRF approach based on mathematical analysis in order to compensate the reactive power of the system and to eliminate the harmonic current of non-linearized load with injection of active power. The results based on simulation were presented to verify the feasibility of the system and it also verified the suggested control method.

Abdalla Y.Mohammed, et.al [5] presented the mechanism of interfacing of 3-Φ grid associated PV system. Here, a boost DC-DC converter with MPPT i.e. maximum power point tracking was used for extraction of maximum power gained from the sun and further transfers it to the grid system. Comprehensive implementation and simulation 3-Φ grid associated inverter was presented for validation of the controller proposed for the grid associated PV system.

Kola Yekant, et.al [6] presented a proposed controller that help in utilizing the references of power showing some of the compelling advancements in theoretical part along with a simple controlling topology. DC-DC convertor was meant for connecting the PV module to the Shunt Active Filter DC side. The converter-based switch was mainly controlled by P&O (Perturb & Observe) and MPPT (Maximum Power Point Tracking) algorithms and it helps in eliminating the limitations in traditional system of PV. An MATLAB Simulink based on emulation was shown for validating the benefit of the system proposed.

[7] Sreedevi, J., Ashwin, N., & Raju, M. N. (2016, December). A study on grid connected PV system. In 2016 National Power Systems Conference (NPSC) (pp. 1-6). IEEE.

J Sreedevi, et.al [7] studied various effects grid associated PV system through the process of system simulation in a software, namely, RSCSD software in practical real time basis on the methodology of RTDS (Real Time Digital Simulator). The load-based power factor variation, PV penetration variation, harmonics introduction into the system using PV inverter and the effect of anti-islanding PV system was studied. Finally, grid associated PV system Performance Ratio was evaluated to find the grid connectivity and reliability of PV system.

Ali Rahnamaei, et.al [8] proposed a grid connected PV (Photovoltaic System) that functions as an APF (Active Power Filter) with MPPT (Maximum Power Point Tracking). The filter-based reference current was derived with the help of Fourier Transform. In inverter switches, by considering a reduction of 33%, there was reduction in cost of the grid-connected PV. Using such an approach, it was possible to compensate for the local loads based harmonic and reactive components; moreover this process help in injecting active power (generated) into grid at MPPT of of PV cells. During daytime, the system proposed mainly injects the active power to grid and simultaneously compensates for load-based reactive power. In case if there is no sunlight, the inverter of the system performs compensation for local loads only.

Mihai Ciobotaru, et.al [9] introduced a technique of active damping for grid-associated converter system with the help of LCL filter. The adaptive form of Notch filter (NF) considered was mainly implemented in a Canonical Form and it presented accurate discrete-time characterization with advanced technique of matched zeroes and poles. However, it also investigated the NF allowing tuning based on real-time of its bandwidth and resonance frequency that might be important on critical basis in case of LCL filter-based resonance frequency varying due to achievable changes in line inductance or non-linear inductors usage engaging magnetic materials, where the concept of inductance was a function of the current that was applied.

Bhavesh M. Jesadia, et.al [10] presented a grid associated photovoltaic system with the concept of using MPPT (Maximum Power Point Tracking). VSI (Voltage Source Inverter) has been related between the ac grid and PV system based dc output. The applied control strategy was based on the p-q theory i.e. instantaneous theory of reactive power. During day time, the system sends active power to the grid and simultaneously compensates the load-based reactive power and it also compensates the harmonics. In case of no sunlight, the system available only compensates for harmonics and load-based reactive power. The p-q theory controlling method applicability has been tested over the system test using MATLAB/Simulink simulation.

Li Fusheng, et.al [11] introduced the microgrid structure, integration, composition, control modes, and operation along with microgrid classification using demand function, AC/DC type, and capacity of the system.

Samir Kouro, et.al [12] presented a survey of existing PV based energy conversion system that addressed the configuration system of distinct PV power plants, and the topologies of PV converter have found real world applications for grid-associated systems. Additionally, the technology of PV converter was discussed underlining the possible benefits as compared to the already existing technology. Among all the topologies of the converter, it was found that the most significant appearance has been revealed by the converters of multilevel type, mainly the H-bridge and T-type for high applications of power and also for residential type of applications in the low-voltage range and kilowatt.

Renukadevi V, et.al [13] represented a strategy based on synchronous reference frame and a grid associated PVG i.e. photovoltaic generation system that sends active power to grid, absorbing the reactive power and compensating harmonics generated by the local loads. The models of converter controller were put into action using MATLAB/SIMULINK. Implemented PV model performance was studied related to isolated load. The strategy of synchronous reference frame was used for generating current reference for the process of compensation and traditional PI controllers were used for controlling purpose. The approach helps in utilizing co-ordinate transformations for separation of the harmonic and reactive content present in load current.

Panduri Renukeshwar, et.al [14] presented a grid (multi-functional) interactive PV system using the concept of fuzzy logic on the basis of MPPT. The proposed controller of MPPT was able to check and track the accurate form of MPP under rapidly changing and uniformly varying insolation and it provides fast process of convergence in terms of a variable step size in case of duty ratio when it was applied genetically with the help of algorithm. The fuzzy controller proposed maintains the voltage-based dc link within a specified limit for injection of power into grid system. Injection of active power during the interval of daytime, the PV-based inverter also help in compensating the reactive power and harmonics during the day as well as the night time. The current i.e. drawn from grid system was of sinusoidal form and the harmonic distortion in total was below the specified limit in IEEE-519 standard.

M.T.L.Gayatri, et.al [15] presented a review of distinct methods of compensating the reactive power in microgrid on the basis of control algorithms, devices, and methods. Several techniques were proposed for traditional grids and these techniques/approaches were adopted for compensation of reactive power in micro grid structures, progressively improved devices and methods were suggested and applied further. Among these devices, the growth in FACTS i.e. Flexible AC Transmission Systems was possibly meant for providing the compensation of reactive power in micro grids on dynamic basis. Finally, this paper represents various applications and techniques of FACTS devices for compensation of reactive power in microgrids.

Proposed Framework

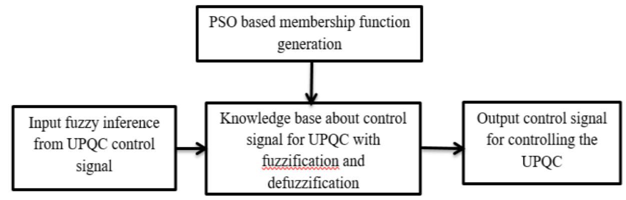


Figure 4.1: Flow Chart for the proposed Methodology

4.2 Methodology

Particle swarm optimization (PSO) algorithm is essentially a system based on agents which simulate the natural behavior of ants, including mechanisms of cooperation and adaptation. It is designed to reproduce the ability of Particle to determine the shortest paths to food. Real ants can indirectly communicate by pheromone information without using visual cues and are capable of finding the shortest path between food sources and their nests. The particle find local and global optimize rules on the trail while walking, and the other ants follow the (i) each path followed by an ant is associated with a candidate solution for a given problem. (ii) When a particle follows a path, the amount of local deposited on that path is proportional to the quality of the corresponding candidate solution for the target problem. (iii) When a particle has to choose between two or more paths, the path(s) with a larger amount of particle have a greater probability of being chosen by the optimization. This algorithm is most simple and involves only a few steps for finding challenging solutions even in complex domain. PSO is used to find the fuzzy membership functions for the control of UPQC.

4.2 Algorithm Used

In this section the algorithms are explained in detail. In the proposed work we use fuzzy logic with PSO, ACO and only fuzzy logic. The below given section contains Fuzzy logic, Particle swarm optimization and Ant colony optimization. The PSO and ACO algorithms are bio-inspired algorithm and solve the meta-heuristic problems. These algorithms work effectively when they hybrid with fuzzy rules and gives better outcomes.

4.2.1 Fuzzy Logic

The word fuzzy represents the thing which is not clear. In the daily life we encounter some situation in which we can’t determine the true or false state but the fuzzy logic provides a way and a flexible reasoning. The computer system depends on the binary approach in which 0 represents the false and 1 represents the true but in the fuzzy logic there is also a logic for partially and partially false condition.

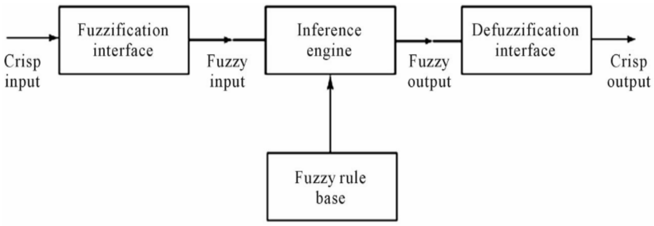


Figure 4.2: Fuzzy Logic Architecture

Fuzzification: This system converts the crisp input into fuzzy sets and then this input is send to inference engine.

Inference Engine: It is used for matching degree for the crisp input and then rule according to input field.

Defuzzification: It changes the fuzzy set from the inference engine into the crisp value for output.

4.2.2 Particle Swarm Optimization

PSO remains for particle swarm optimization. PSO is a stochastic optimization calculation which depends on the conduct of flying creatures. It works like the hereditary calculation. In PSO is instated with a gathering of irregular particles. In each cycle, every particle is refreshed by the two "best" qualities. The principal best arrangement demonstrates the wellness of the particles and this called as pbest. The second best esteem is followed by the enhancer is the best esteem. This esteem is called as worldwide best (gbest).When a particle removes a portion of the populace as its topological neighbors; the best esteem is a nearby best and is called lbest.

Algorithm PSO

Step1: In PSO model for each particle i in S do
Step2: for each dimension d in D do
Step3: //initialize each particle's position and velocity
Step4: $x_{i,d} = \boldsymbol{Rnd}(\boldsymbol{x_{max}}, \boldsymbol{x}_{\min})$
Step5: $\boldsymbol{v_{i,d}} = \boldsymbol{Rnd}(-\boldsymbol{v_{max}}/3, \boldsymbol{v_{max}}/3)$
Step6: end for
Step7: //initialize particle's best position and velocity

$$\boldsymbol{v_i}(k+1) = \boldsymbol{v_i}(k) + \boldsymbol{\gamma 1_i}(\boldsymbol{p_i} - \boldsymbol{x_i}(k)) + \boldsymbol{\gamma_{2i}}(G - \boldsymbol{x_i}(k))$$

New velocity

$$\boldsymbol{x_i}(k+1) = \boldsymbol{x_i}(k) + \boldsymbol{v_i}(k+1)$$

Where
i- index of particle
k- index of discrete time
v_i – i^{th} particle velocity
x_i –i^{th} particle position
p_i- best position found by i^{th} particle(personal best)
G- best position found by the swarm (global best, best of personal bests)
$G_{(1,2)i}$- random number over the interval[0,1]applied to the i^{th} particle
Step8: $\boldsymbol{pb_i} = \boldsymbol{x_i}$
Step9: // update global best position
Step10: if $\boldsymbol{f}(\boldsymbol{pb_i}) < \boldsymbol{f}(\boldsymbol{gb})$
Step11: $\boldsymbol{gb} = \boldsymbol{pb_i}$
Step12: end if
Step13: end for

IV. RESULT ANALYSIS

RESULTS

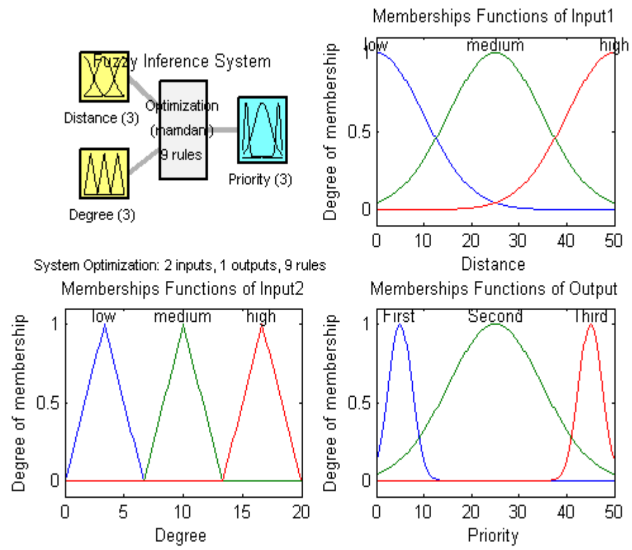


Figure 5.1 Fuzzy Inference System outputs

In figure 5.1 the input of the fuzzy inference system is presented by using graphical method. The membership function of input 2 and output of this input is presented in this figure. The blue line represents the low degree of membership, green represented medium degree and red represents the high degree of the membership function.

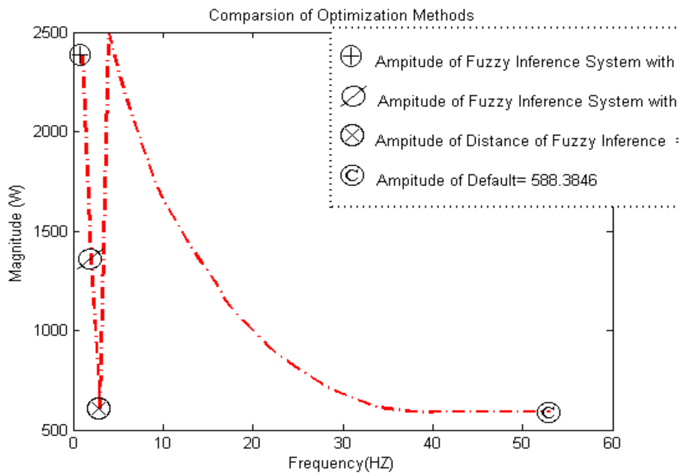


Figure 5.3 Comparison of Optimization models

The figure 5.3 presented the comparison between the amplitude of Fuzzy inference system with PSO, Fuzzy inference system with ACO and only fuzzy system. The graph is drawn between frequency and magnitude of the different algorithms. The graphical representation shows the effective results of the Fuzzy inference system with PSO among three algorithms.

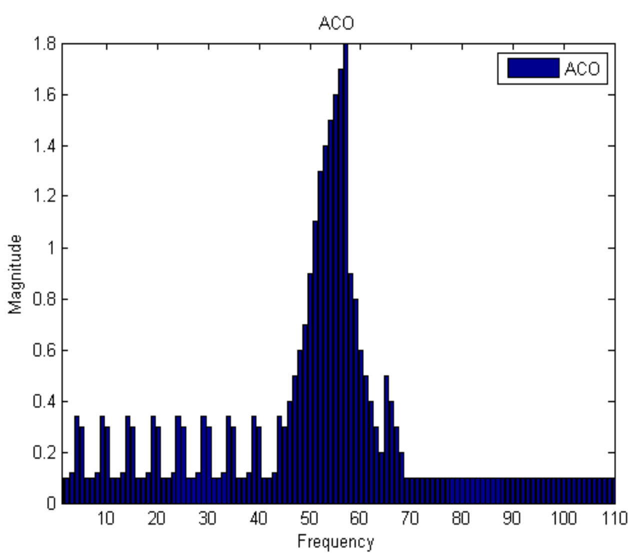


Figure 5.5 Output of the ACO with Fuzzy algorithm

The figure 5.5 presents the output of the fuzzy algorithm. The X-axis of the graph show frequency and Y-axis show magnitude values. The Fuzzy value on the frequency 45-70 is higher and the value is stable from 70-110 frequency.

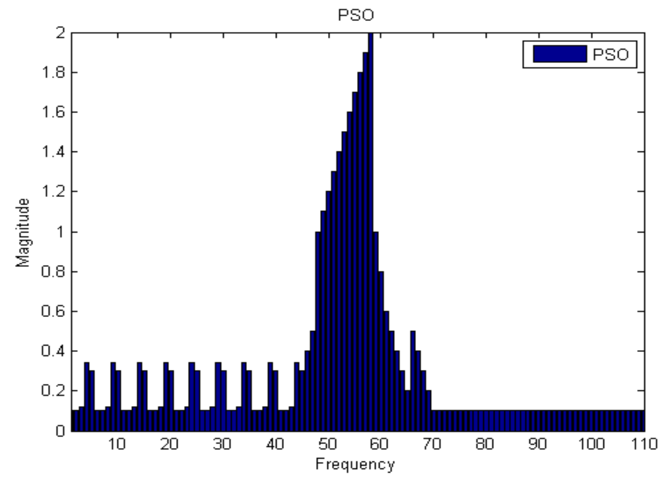


Figure 5.6 Output of the PSO with Fuzzy algorithm

The figure 5.6 presents the output of the fuzzy algorithm. The X-axis of the graph show frequency and Y-axis show magnitude values. The Fuzzy value on the frequency 45-70 is higher and the value is stable from 70-110 frequency.

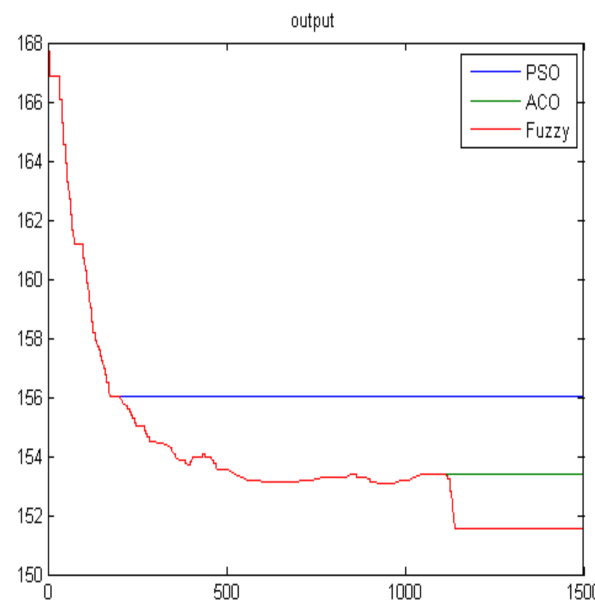
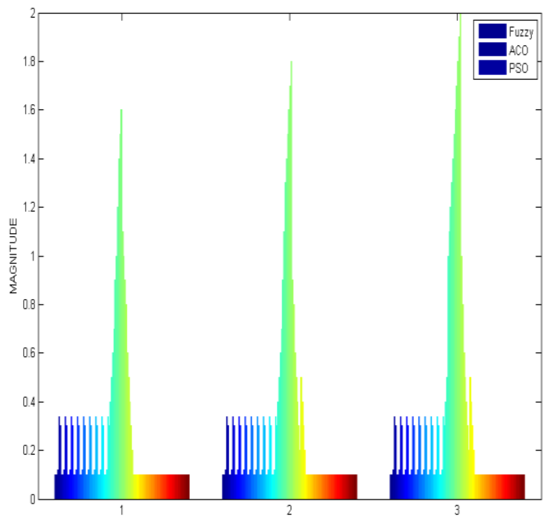


Figure 5.7 Output of the three algorithms

The aforementioned figure 5.7 represents the output of the fuzzy algorithm, ACO with fuzzy algorithm and PSO fuzzy algorithm. The X-axis of the graph show iteration and Y-axis show quality values. The Red curve represents the Fuzzy, Green represents the ACO and Blue curve represents the PSO. The stability in the output of PSO shows the effectiveness of outcomes in this figure.

Figure 5.8 Comparison of results of different algorithms.



In figure 5.8 it depicts the outcomes of the three algorithms fuzzy algorithm, ACO with fuzzy algorithm and PSO fuzzy algorithm. The magnitude of the PSO with fuzzy is effective among all and gives best outputs.

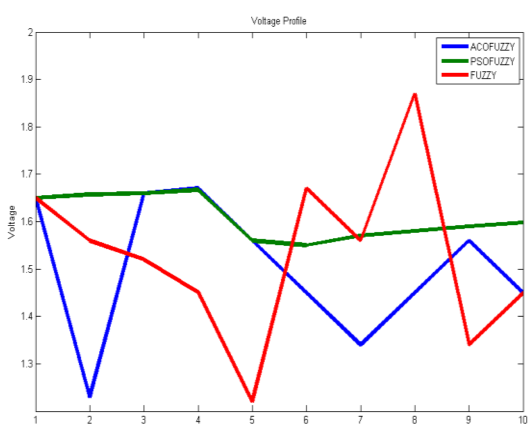


Figure 5.9 Voltage profile comparison of different Algorithms.

In figure 5.9 Comparison of the Fuzzy, PSO Fuzzy and ACO Fuzzy is presented. This comparison shows the voltage profile of the different algorithms which is based on the bus number and voltage. The voltage stability in the PSO Fuzzy is more than other two algorithms because in fuzzy and ACO Fuzzy is more fluctuating.

IV CONCLUSION

The power quality is enhanced by integrating the power filters. The proposed work is done by using fuzzy logic with swarm intelligence approach and proposes a new UPQC system. This system reduces the sag and harmonic distortion. The PSO is used to optimize the reference signal which is generated by the fuzzy logic controller. The proposed experiment is done on the MATLAB/ Simulink environment. The results and output received on this is used for the analysis. The proposed fuzzy with PSO controller is better than the existing approaches in minimizing the sag and harmonic distortion. The whole process is enabling by using fuzzy membership functions and optimize by swarm optimization algorithm. The main aim of using the swarm algorithm is to minimize the voltage imbalance and harmonic distortion. The reactive power and negative-sequence current parameters will be considered in the near future.

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