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Power QualityImprovement using GI based Fuzzy Controller for SingleStage Grid Interfaced-Solar Energy Conversion System

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Abstract- Increased generation and grid interfacing of the renewable energy sources has impacted power quality concerns in the network. The abnormalities during grid interfacing has leads to maloperation of energy conversion devices which in turn leading to failure of other electrical equipment.This paper presents control methodology using fuzzy logic controller to improve the power quality for single stage grid interfaced solar energy conversion.To get the maximum power from solar photo voltaicMPPTtechnique is used. The proposed method is to increase the power quality by using fuzzy logic controller. This control technique can give the accurate results, reduction of total harmonic distortion in Grid side, fast response, unity power factor operation and smoothvoltage and currentwaveforms. This project is simulated on MATLAB simulink and the results are obtained. The THD analysis for the grid parameters are performed which evaluates the effectiveness of the control mechanism which results inimprovement of power quality and the system stability.

I. INTRODUCTION

Excess usage of non-renewable energy resources has made a drastic impact on environment. Degradation of fossil fuels is a serious issue and increased carbon footprints in environment has raised the discussion on health factor. To overcome the former difficulties transition to renewable energy(RE) sources is the only answer that can be found. RE sources such as solar, wind, tidal energy and geo thermal energy etc. provides clean energy which are environment friendly. Hence to increase the power generation through renewables many countries globally had adopted incentives and subsidies for installment of the RE sources [1]. These also come under distributed generation (DG) where the RE sources are installed near to the load like householdsetc. meeting the demand. This simplifies the network as there is no need of extra transmission system and it is less prone to large scale failures of the whole system increasing the reliability and resiliency of the whole system.

Solar photo voltaic (PV) systems has found many advantages like lossless energy conversion and high-power extraction capabilities[2]. moreover, it gained much importance for grid interfaced system. various techniques have been introduced for effective implementation as in [3-5]. Maximum power point tracking (MPPT) is used to obtain peak generation from the PV arrays under various environmental conditions. MPPT algorithms use different methods like perturb and Observe (P & O), Fuzzy logic analysis, ArtificialNeuralnetworks (ANN) and Increment conductance etc. for analysis of comparative performance, convergence rate and cost applications [4-5]. However, the operation of unbalanced and nonlinear loads has risen the power quality issues of the grid. They draw harmonics into the distribution network leading to mal operation of power conversion devices [6].

Many researchers in the literature has drawn attention to mitigate the issues raised in the Grid interfaced systems and to improve the power quality[7-11]. Authors in [9] used second order generalized integrator (SOGI) which has poor harmonics eliminating capability that lowers the system performance. synchronous reference frame

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(SRF) algorithm is designed in [11] used complex computations due to high transformations and low dynamic response rate due to low pass filters. The Lyapunov algorithm given by the authors in [10] has increase in sampling time due to its complexity and computational burden raising the algorithm operation period. Improved generalized integrator fulfils multiple objectives like frequency tracking, eliminating DC offset and higher order harmonics are given by the authors in [12-14]. However, the control algorithm for the improved GI uses proportional integrator (PI) control for the single stage solar energy conversion system (SECS). the mitigation of the harmonics from the study shows optimal response, but the distortion in currentsdue to harmonics can be still reduced for increasing the reliability of the system.

This paper improvises thecontrol methodology of [15] by proposing fuzzy logic controllerfor powerquality improvement by reducing Total Harmonic distortion levels at grid side currents for the grid interfaced SECS system.

II. SCHEMATIC DIAGRAM AND CONFIGURATION

The single stage grid interface solar energy conversion system schematic operational diagram for power quality improvement is as shown in Fig.1. it consists of three phase grid, Solar PV array with DC link capacitor, Voltage source converter (VSC), ripple filter for reducing the harmonics and diode bridge rectifier as non-linear load. The design can be found for the grid tied SECS from the literature [15]. For capturing the high-power generation of solar PV array, the perturb and observe MPPT algorithm is used under different atmospheric levels.

The PV array is interfaced to grid at the Point of common coupling (PCC) through VSC, interfacing inductors to smoothen the current and frequency parameters under the prescribed limit of < 5%. A fuzzy logic control methodology is defined at the controller side, based on which the VSC obtain the firing pulses to minimize the THD of the injecting power into the grid.

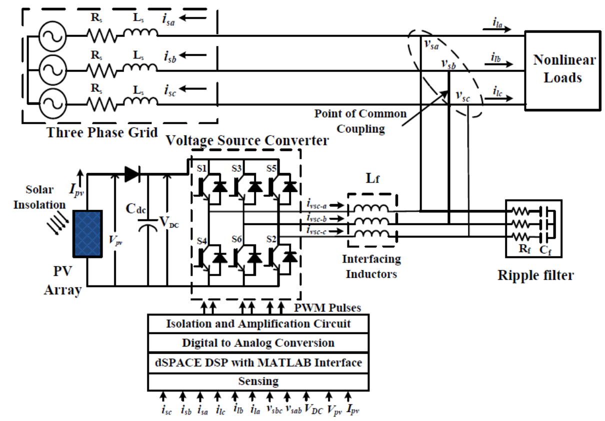

Fig.1. Schematic diagram of single stage grid solar energy conversion system.

III. PROPOSED METHOD

A. Fuzzy logic controllers:

In incremental conductance methods one of popular method is a fuzzy logic controller [16]. it can operate knowledge based on fuzzy rules. In the fuzzy logic controller,it performs three main process fuzzification, rule base/knowledge base and defuzzification as shown in Fig.2. Inputs are errors and change in errors to the FLC. The inputs are processed using some linguistic variables which are defined in the membership functions representing the dynamic system.

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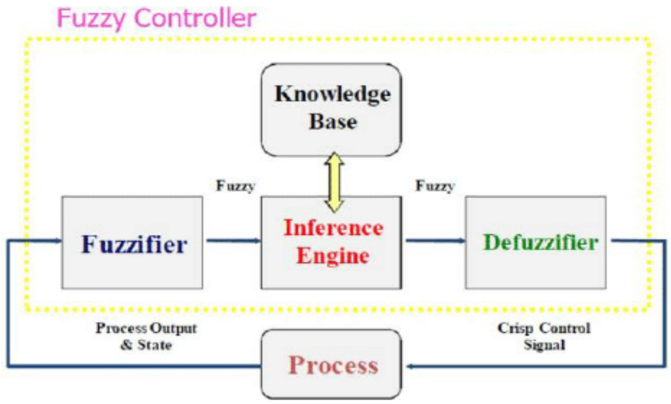

Fig.2. functional diagram of Fuzzy logic controller

The process of fuzzification or Fuzzifier includes the conversion of the input variables to the fuzzy variables (linguistic variables) for information processing the inputs may be numericals, words or some crisp sets. These inputs upon conversion assigned with membership functions(MFs). Some of MFs like triangular,trapezoidal,sigmoidal, bell MFs are used by fuzzifier. Moreover,some hybrid MFs are also used in fuzzification.

Inference system consists of knowledge base or rule base and an inference engine which performs reasoning mechanism. Rule base consists of If-Then rules like a human thought paradigm. If part is antecedent and then part is called consequence. These are converted into linguistic variables after fuzzification for the execution of rules. The database stores all the membership functions used by the rules. Finally reasoning mechanism performs thought process like human brain according to the situation in codes of software.

Defuzzifier is completely opposite to the fuzzifier .it will change the fuzzy values that are processed by inference engine into the crisp sets. Mamdani model is preferred in the control process as it follows the Compositional Rule of Inference strictly in its fuzzy reasoning mechanism.[17]

The process of defuzzification was defined in followingstrategies.

- Center of sums (COS)
- Centroid of area(COA)/ center of Gravity (COG)
- Bisector of area(BOA)
- Weighted area method
- Maxima methods.

Center of sums method (COS):

It is one of the commonly used methods where overlapped area considered twice. The equation represented by COS method is (1).

(1)

Where N- number of fuzzy variables
n- number of fuzzy sets
- membership function for kth fuzzy set

Centroid of area method (COA) :

In this method the total membership area is represented small sub area. The corresponding MF area and the center of gravity or centroid of each sub-area is determined followed with summation of all these sub-areas is taken to find the defuzzified value. The equation is represented as in (2)

(2)

Where are the output membership functions

Bisector of area method(BOA):

This method calculates the position/area under the curve where the area data on both sides are equal. The BOA generates the action where the area is partitioned in two parts equally.equation satisfied by the BOA is (3)

(3)

Where
α is the minimum values
β is the maximum values

Mean of maximum: it can reach the z value to the maximum. the equation can be as (4) follows

(4)

The following graph in fig.3 showsthe ranges of the z values for various strategies

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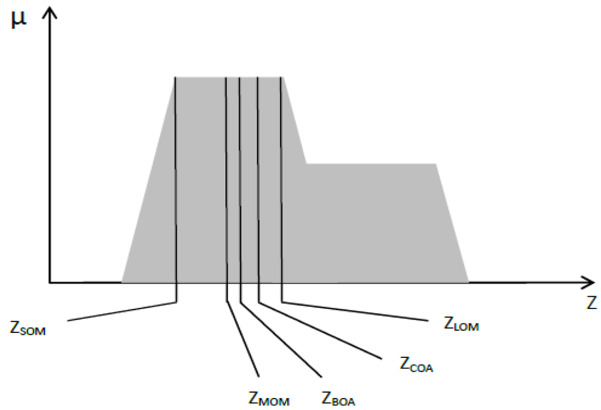
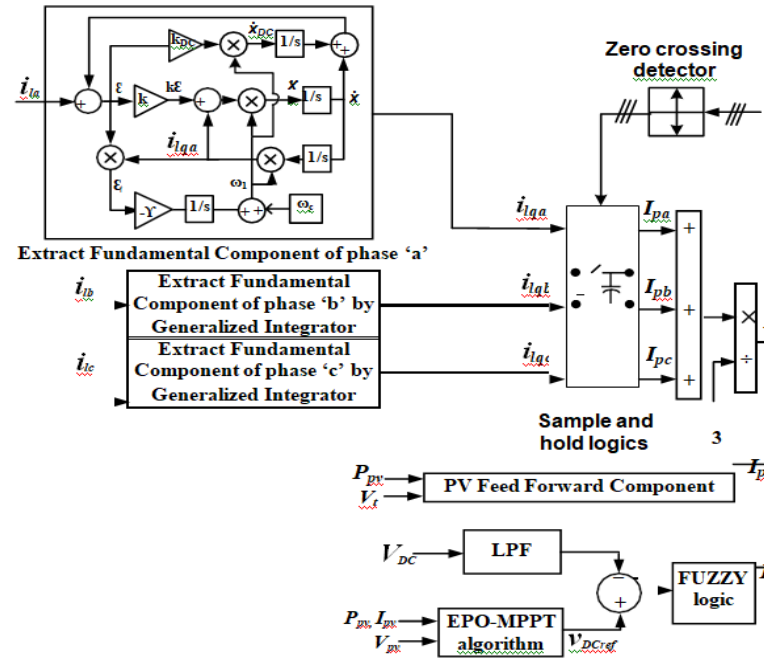


Fig.3. various strategies obtaining crisp values of z



B. Control Strategy:

Fig. 4 shows the control scheme block diagram for the improved grid induced solar energy conversion system using fuzzy logic controller for power quality improvement. Control scheme methodology includes MPPT algorithm for high PV capture and switching pulses generation for VSC. To overcome the oscillation in grid currents due to intermittent atmospheric situations a PV feed- forward term is added in the control flow algorithm.

The PV feed- forward term is calculated from PV power and terminal voltage amplitude as in (6)

(3)

In MPPT algorithm Vpv is estimated from fixed amount of insolated data of PV array, next perturb is obtained from change of Ppv power. Effective operation of P & O technique is done by ensuring change in MPPT should be less than inverse of settling time. The current and voltage of pv are sensed at higher frequencies before Vpvupdation. The mathematical model P & O technique is as shown below

Based on the the positive and negative perturbations decided based on the condition stated above.

The terminal voltage is evaluated by estimating the phase units processed from band pass filters. The phase units(are calculated from division of phase voltages () and terminal voltage Vt. As in [20].

The control scheme uses fuzzy logic controller to minimize the effect of harmonics in the network. The inputs to the FLC are given from the low pass filter and the MPPT output.

The fundamental component of the load currents are extracted as shown in structural block diagram, nominal frequency is ω_0. for non linear load currents the fundamental component is obtained using Sample and hold circuit (S & H) and zero crossing detector as shown in fig.4. the ZCD generates the pulses on corresponding zero

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crossings and fed to S&H logic. This captures the input pulse when triggered.

IV. SIMULATION RESULTS

To evaluate the performance of the system using FLC the system is designed in MATLAB/Simulink platform and simulated under different scenarios. The three-phase single stage grid interfaced solar PV generation system performance is based on the control of improved generalized integrator with FLC controller. The corresponding signals such as grid currents, voltages are analyzed.
The currents at the VSC and the real and reactive powers are recorded to identify the performance. Totalharmonic distortion in the currents are verified using FFT tool in the MATLAB. The waveforms of Vdc, Ipv, Vpv, Ppv and Qpv are shown in fig.5. under unbalanced load conditions, the waveforms obtained at VSC is given in fig.7. upon sudden change in load at the frequency change can be seen in the waveform showing in fig.8. with the spike. On the control mechanism using FLC the currents and voltage waveforms of source currents are shown in Fig. 9&10.

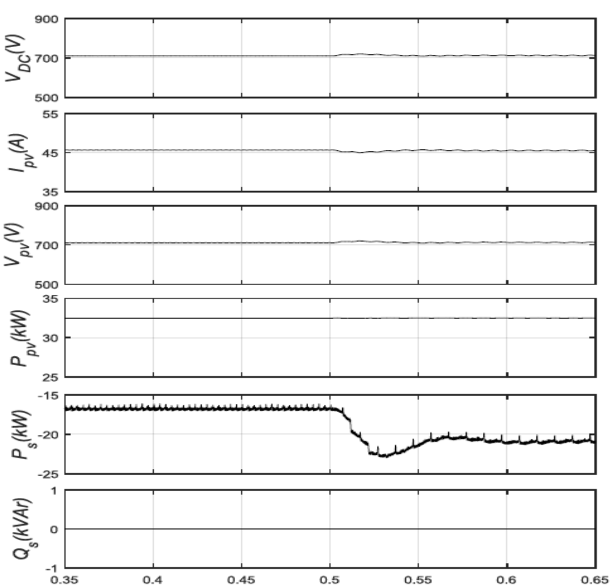

Fig.5. simulation results of system under load unbalancing

In load unbalancing time there is no change in solar power generation and reactive power in grid is zero. In this time UPF operation is possible in grid. when the fault occurs Thesource power is reduced on the distribution side as shown in the reference waveform in fig.11. By using this technique, we can analyze the supply current, voltage, VSC and frequency waveforms as shown in figures.

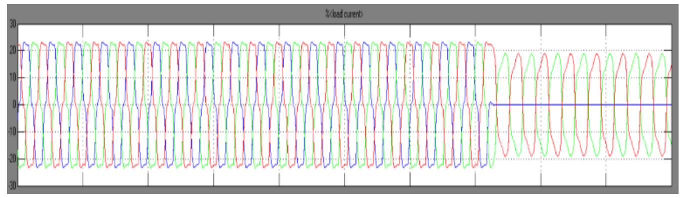

Fig.6. load current waveform

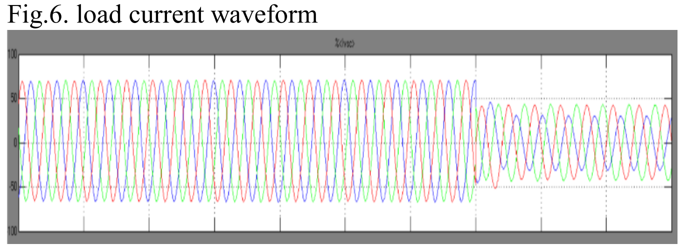

Fig.7. voltage source converter currents waveform

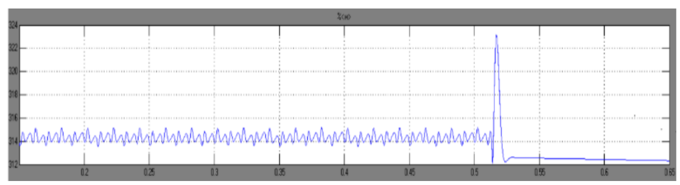

Fig.8. frequency waveform

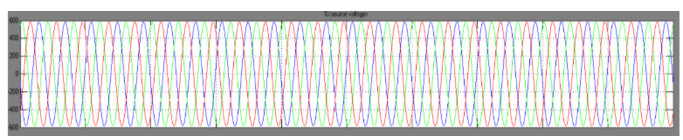

Fig.9. source voltage waveform

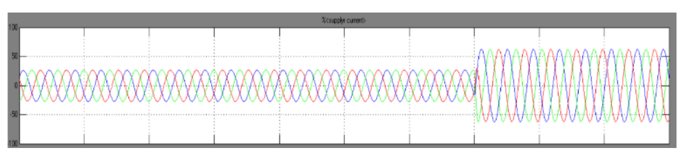

Fig.10.supply current waveform

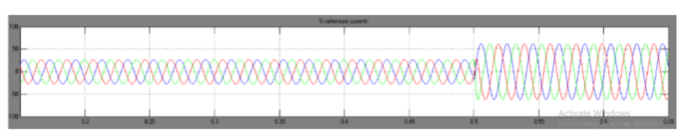

Fig.11. Reference current

THD analysis is analyzed for the corresponding grid current and voltage waveforms which gives the effectiveness of the proposed control mechanism.

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With the proportional integrator control methodology, the THD level of the grid parameters at the PCC is 6.07,3.48,5.58 for each phase of grid voltage which means the distortion is nearly 6% before VSC switching which has reduced to 2.27,1.81, 2.79 of voltages, 3.44,3.12,2.50 for the currents. On use of FLC the THD levels for grid are 1.74,1.82,1.63 which is lower than the previos methodology i.e. PI controller. Hence the distortion can be lowered by using the approach of fuzzy logic and improve the power quality and system stability.

V.CONCLUSION

The methodology proposed improves the power quality by using fuzzy logic controller. This FLC control technique gives the accurate and better results than the existing PI control method. By using this fuzzy controller, the results shown that the total harmonic distortion is reduced. So that we can improve the power quality and can maintain the system stable under fault or abnormal conditions. Compared to existing method voltage and current waveforms are smoother. Grid voltages and currents distortion levelsare maintained within the permissible limits. Which increases the system reliability in unbalanced, nonlinear load operation, switching conditions.

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