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Avoid Over Voltages and Unbalance Voltage Sags in Grid Connected PV Plants Using Fuzzy Based Individual Phase Current Control

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ABSTRACT

Free present control of each period of a three-phase voltage-source inverter under unbalanced voltage sags is proposed to viably meet grid code prerequisites for framework associated photovoltaic power plants (GCPPPs). Under current grid codes, GCPPPs should booster network voltages by infusing reactive current during voltage lists. Such infusion must not permit the network voltages of the non-defective phases to surpass 110% of their nominal esteem. Be that as it may, grid over-voltages can happen in the non-defective phases, particularly if the currents infused into the grid by the GCPPP are adjusted. In light of another necessity of the European Network of Transmission Framework Operators distributed in 2012, a transmission framework administrator is permitted to present a prerequisite for uneven current infusion. In this letter, this grid code is tended to by controlling individual phases and infusing unbalanced currents into the grid during voltage droops.

Keywords : GCPPP, Fuzzy Based Individual Phase Current Control, PV Plants, Transmission Framework Administrators, FSPLL

I. INTRODUCTION

The control of grid associated voltage-source inverters (VSIs) under uneven voltage droops has been broadly tended to in the specialized writing. Some examination has focused on dynamic power control methodologies and two techniques have been exhibited to give the present references to the VSIs [1], [2]. As on account of synchronous generators in traditional power plants, VSIs ought to stay associated during voltage lists and bolster the grid voltages with the infusion of receptive current [3], [4]. This is important to ride-through a fault. The infusion of adjusted receptive current to help unbalanced voltage hangs may prompt over-voltages in the non-flawed stages [5]. To keep this, new framework codes (GCs) require the infusion of unequal receptive currentduringuneven voltage lists, and for this reason diverse control strategies have been proposed. In [6] and [7], an adaptable voltage bolster technique was presented in light of the sort and seriousness of the voltage droops. For this reason, the measure of responsive power infused by means of positive-and negative-successions is controlled with a disconnected control parameter. A broadened speculation of past investigations was completed in [8], whereby the responsive power reference and the control parameter were refreshed with a specific end goal to reestablish the dropped voltage amplitudes. Another examination in [9] proposed a strategy to set the positive-and negative-succession receptive power references in view of a proportionate impedance grid model to keep away from over-and under-voltages in the stages. In that paper, the new current references were refreshed in light of the past responsive power references. A decoupled twofold synchronous reference outline current controller was presented in [10], with the capacity of controlling the dynamic and receptive intensity of the positive-and negative-sequences freely. Be that as it may, the present references were controlled disconnected. With respect to singular control of current and voltages of the three stages, the new necessity of the European Network of Transmission System Operators infers that transmission framework administrators (TSOs) are permitted to present a prerequisite for unequal current infusion [11]. Hardly any papers have considered or announced this idea to date. Some exploration was accounted for in [12] to help the stages with lopsided responsive power. In any case, the technique utilized as a part of that paper was not all inclusive for a wide range of voltage lists [13].

The target of this letter is to propose a control strategy in view of individual control of the stage current under unbalanced voltage lists. The measure of receptive current in each stage is resolved in view of the measure of voltage drop in that stage, which infers no responsive current infusion for the non-broken stages. Execution of this technique requires information of the framework voltage edge of each stage. For this reason the stage bolted circle (PLL) proposed in [14] is utilized. Additionally, the framework current, including both dynamic and receptive ebbs and flows, are constrained with a specific end goal to shield the GCPPP from air conditioning over-ebbs and flows, tending to the fault ride-through (FRT) necessity. Since the framework current are characterized freely for each stage, two techniques are proposed to keep the controllers from endeavoring to infuse a zero sequence into the grid. In this investigation, the proposed control procedure was tried tentatively of every a downsized GCPPP associated with a low voltage (LV) programmable air conditioning power supply. The rest of this letter is sorted out as takes after: Section II acquaints the synchronization technique utilized with extricate the

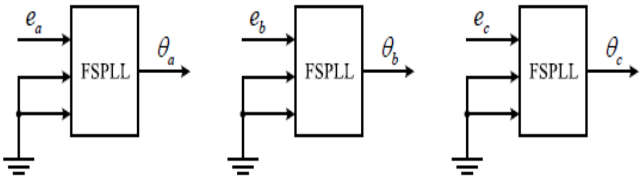

Fig. 1. Individual phase angle extraction based on the FSPLL.

Stage points of the grid voltages exclusively. Age of the present references is portrayed in Section III, whereby a two-arrange current limiter and two techniques for disposing of the zero-succession from the present references are proposed. The gridcurrent are managed utilizing corresponding resounding (PR) controllers exhibited in Section IV. Exploratory outcomes from a downsized research facility model with the proposed control strategy are introduced in Section V. At long last, Section VI outlines the fundamental finishes of this letter.

II. METHODS AND MATERIAL

2. SINGLE-PHASE PLL PHASE EXTRACTION FOR THREE-PHASE SYSTEMS

As the point of the proposed technique is to control the stage current freely, it is important to extricate the stage edge of every one of the grid voltages. In this manner, the recurrence versatile PLL is executed in view of the examination in [14]. This PLL depends on the sifted sequence PLL (FSPLL) presented in [15]. The primary phase of the FSPLL isolates the positive grouping of the network voltages from the negative succession and a few sounds by methods for an offbeat d-q change and moving normal channels (MAFs). The FSPLL incorporates a standard synchronous reference outline PLL (SRF-PLL) to get the edge of the extricated positive se-quence. In [14], three FSPLLs were utilized to distinguish the edges of the three-stage framework i.e. a, b, and c, for stage a, b, and c, separately, as appeared in Fig. 1.

A solitary stage voltage is acquainted with each FSPLL, while alternate sources of info are set to zero as takes after: ea0 = (ea; 0; 0), eb0 = (eb; 0; 0) and ec0 = (ec; 0; 0), in which ea, eb and ec are the network voltages.

3. GENERATION OF PHASE CURRENT REFERENCES

In this area, the strategy for acquiring the present references to encourage the present control circles is displayed. The plentifulness of the dynamic current (iA) is characterized to manage the dc-connect voltage, while the individual responsive current amplitudes(iR x) are found from the hang control, characterize as:

$$\hat{i}_{R-x} = droop\,|de_x|\,\hat{I}_n, \quad \text{with } x \in \{a,b,c\}$$
$$\text{for } \frac{|de_x|}{E_{n-ph}} \geq 10\% \quad \& \quad droop \geq 2, \qquad (1)$$

where jdexj is the measure of stage voltage drop from its nominal rms esteem (En▯ph), ^In is the abundancy of the nominal stage current of the inverter, and hang is a steady esteem in view of the German GCs [4]. An esteem _ 2 for hang infers that, for voltage bolster, the infusion of receptive current at the LV side of the transformer must be no less than 2% of the nominal current per every percent of the voltage drop [4]. The dclink voltage circle is controlled by a relative essential (PI) controller furnished with a hostile to windup innovation that makes a difference.

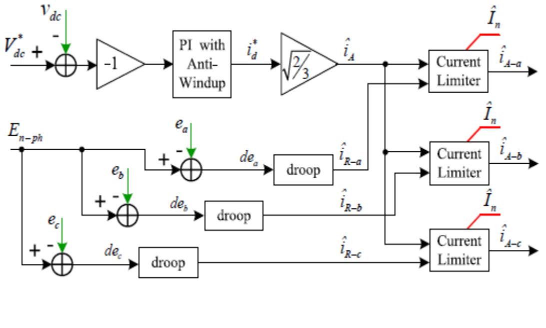

Fig. 2. Control diagram for obtaining the active and reactive current references.

Accomplish the pre-fault qualities rapidly after fault evacuation. This can be found in the control chart of Fig. 2. In this figure, vdc is the dc-interface voltage, V _ dc is its reference esteem, and i_ d is the dynamic current reference in the dq-reference outline.

A. Constraining the Phase Currents

Under a voltage list condition, the controller expands the dynamic current to keep up the power infused into the framework. In the meantime, receptive current should be infused into the defective stages to help the grid voltages. Therefore, the amplitude stage current may increment over the maximumacceptable qualities, which would in the end trigger the overcurrent assurance. To evade this circumstance, need is given to the receptive current infusion to help the framework voltages. Along these lines, the amplitudes of the dynamic current are constrained in light of the receptive current required for each stage (Fig. 2). The need under a voltage list is to help the grid voltages with the infusion of responsive current. Be that as it may, the current of each stage can't go past the most extreme satisfactory valuedefined for the inverter. In this way, on account of overcurrent in one stage, the dynamic current of that stage ought to be restricted. The present limiter in Fig. 2 is characterized as takes after:

$$\hat{i}_{A-x} = \begin{cases} \hat{i}_A, & \text{if } \sqrt{\hat{i}^2_{R-x} + \hat{i}^2_A} \leq \hat{I}_n \text{ and} \\ \sqrt{\hat{I}^2_n - \hat{i}^2_{R-x}} & \text{if } \sqrt{\hat{i}^2_{R-x} + \hat{i}^2_A} > \hat{I}_n, \end{cases} \qquad (2)$$

where x remains for stages a, b, and c. The real current reference for each stage is gotten by duplicating the amplitudes of the dynamic and responsive current by the cosine and sine, separately, of the stage edge got from the PLLs [14]. The last current reference for each stage is accomplished by including the dynamic and responsive current segments. Fig. 3 outlines the method for acquiring the present reference i_a for stage a. The present references for alternate stages are gotten utilizing a similar technique.

B. Zero-Sequence Elimination from the Current References

Since the current of the three stages are directed freely, the amplitude of the three ebbs and flows may not be zero. This would mean dissemination of a zero-succession current segment through the ground. This can't occur if the ground circuit

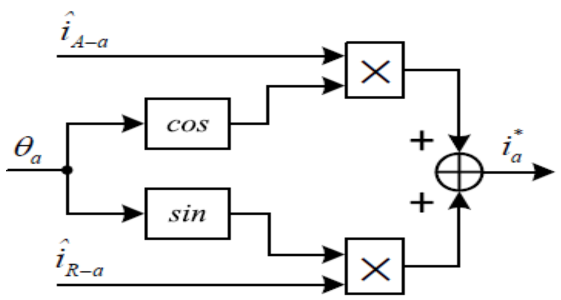

Fig. 3. Current reference generation for phase a.

is open. Besides, if the ground circuit offers a low impedance, dissemination of this current may not be a coveted circumstance. Along these lines, this zero-sequence ought to be expelled from the present references. This can be accomplished by applying the Clarke change (abc=__) to the present references. For this situation, the third part in the Clarke change, i.e. the orzerosequence segment, is neglected. Therefore, the present vector will lie in the __ plane, matching with its projection prior to the zero-succession was expelled. Thusly, the __ parts of the reference current will be saved. An identical method for expelling the zero-grouping is changing the present references of each stage by subtracting 33% of the normal current part from every one of them, as takes after

$$i_a^{*'} = i_a^* - k_a i_0 \tag{3}$$

$$i_b^{*'} = i_b^* - k_b i_0 \tag{4}$$

$$i_c^{*'} = i_c^* - k_c i_0 \tag{5}$$

where:

$$i_0 = i_a^* + i_b^* + i_c^* \quad \text{and} \tag{6}$$

$$k_a = k_b = k_c = 1/3. \tag{7}$$

Duringadjusted activity, the regular part i0 will be zero or low. Be that as it may, duringlopsided voltage lists, the basic part may have a noteworthy esteem. Thusly, subsequent to applying (3)– (7), the new references i_0 a , i_0 b , and i_0 c may vary concerning the first qualities.

Along these lines, the receptive parts of the non-broken stages may build, causing a voltage transcend the cutoff points. An elective answer for maintain a strategic distance from this issue is clarified beneath. The proposed sequence depends on changing the present references relying upon the initiation of the responsive current infusion for each stage, keeping the reference(s) of thephase(s) with no receptive current infusion unaltered. For instance, if stage an is non-defective under a lopsided voltage hang, ka will be set to zero and the zero-sequence is dispensed with by changing the present references of alternate stages, i.e. kb + kc = 1. In this letter, the zero-sequence disposal is separated similarly between the broken stages, i.e. kb = kc = 1=2.

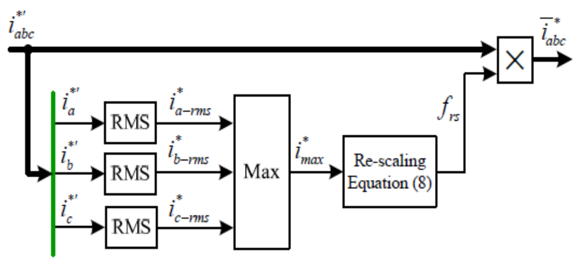

Fig. 4. Control diagram for re-scaling the current reference to avoid over currents

C. Second Current Limiter

Once the zero-succession segment is expelled from the present references, the amplitudes of the current change, which may create overcurrents. To confine the stage current at or underneath the greatest esteem (In), a strategy to gauge the rms estimation of the ebbs and flows ought to be actualized. The accompanying condition can be utilized for this:

$$i^*_{x-rms} = \sqrt{\frac{1}{T_w}\int_{t-T_w}^{t} (i_x^{*\prime})^2 \, dt}, \qquad (8)$$

In which i_ x□rms is the rms estimation of the stage current x, where x speaks to the three stages (x 2 fa; b; cg), and Tw is the window-width utilized for the rms figuring, regularly T=2 or T, T being the framework voltage period (T = 1=freq). The greatest current of the three stages (i_ max) is contrasted and the nominal incentive In. On the off chance that it surpasses In, every one of the current are re-scaled by a factor frs characterized as:

$$f_{rs} = \begin{cases} \frac{I_n}{i^*_{max}} & \text{if } i^*_{max} > I_n \\ 1 & \text{if } i^*_{max} \leq I_n. \end{cases} \qquad (9)$$

The final current references are set as:

$$\vec{i}^*_{abc} = f_{rs}\vec{i}^{*\prime}_{abc}. \qquad (10)$$

The proposed technique for re-scaling the current is shown in Fig. 4. The extents demonstrated with the subscript "abc" speak to the three stage sizes of the framework, e.g., iabc remains for ia, ib, and ic. The way toward creating the stage current references incorporates two limiters. The first, appeared in Fig. 2, is to constrain the dynamic current to give enough space to the required receptive current infusion. The second one depends on re-scaling all the present references after the zero-sequence disposal. This procedure is proposed here out of the blue and has never been tended to in some other examination.

4. CURRENT CONTROL LOOP

The present control is made out of two parallel circles that manage the current in a stationary edge. Since the control factors are sinusoidal, PR controllers were picked, as customary relative indispensable (PI) controllers neglect to expel enduring state mistakes while controlling sinusoidal waveforms. The control outline of the current is appeared in Fig. 5. The contributions to this control outline are the present references got from (10).

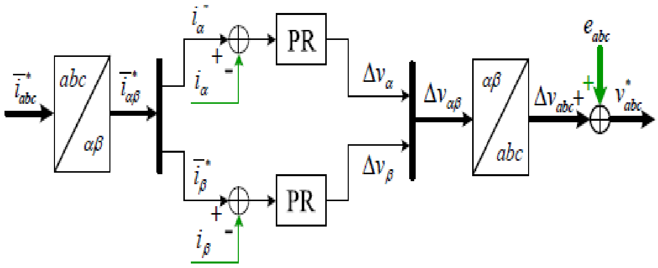

Fig. 5. Current control loop with PR controllers.

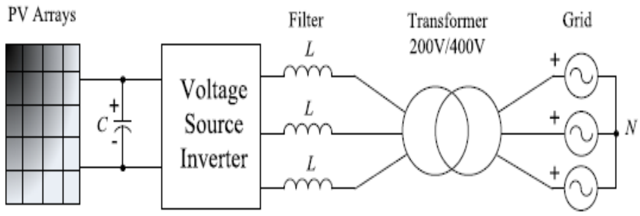

Fig. 6. Diagram of a GCPPP

CONTROLLER USING FUZZY LOGIC:

Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1. By contrast, in Boolean logic, the truth values of variables may only be 0 or 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions.

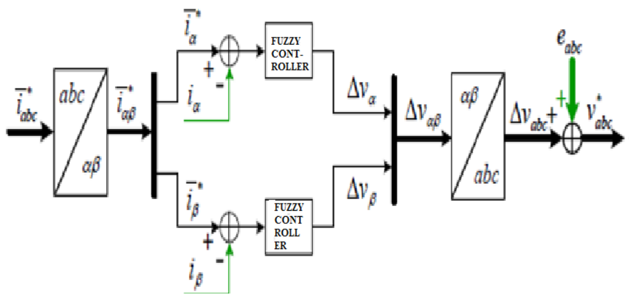

Fig. 7. Current control loop with Fuzzy controllers.

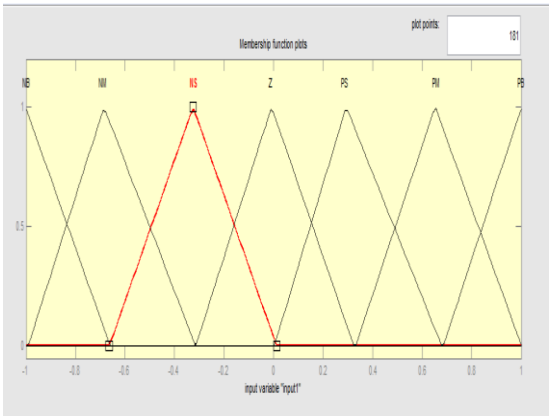

Fig. 8. Membership functions of current error

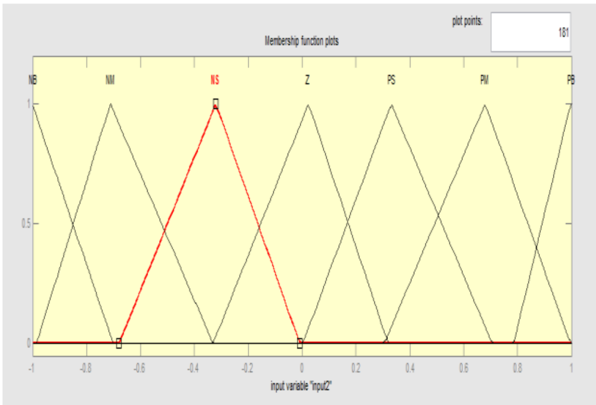

Fig. 9. Membership functions of changing current error

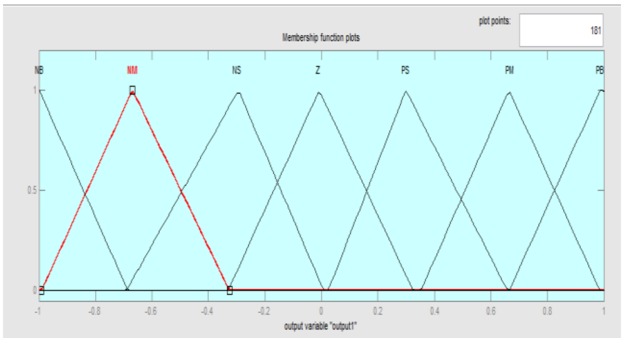

Fig.10. Membership functions of voltage error

e/Δe	NB	NM	NS	Z	PS	PM	PB
NB	**NB**	**NB**	**NB**	**NB**	**NM**	**NS**	**Z**
NM	**NB**	**NB**	**NB**	**NM**	**NS**	**Z**	**PS**
NS	**NB**	**NB**	**NM**	**NS**	**Z**	**PS**	**PM**
Z	**NB**	**NM**	**NS**	**Z**	**PS**	**PM**	**PB**
PS	**NM**	**NS**	**Z**	**PS**	**PM**	**PB**	**PB**
PM	**NS**	**Z**	**PS**	**PM**	**PB**	**PB**	**PB**
PB	**Z**	**PS**	**PM**	**PB**	**PB**	**PB**	**PB**

Table.1. RULE BASE OF FLC

SIUMULATION RESULTS USING COVENTIONAL METHOD:

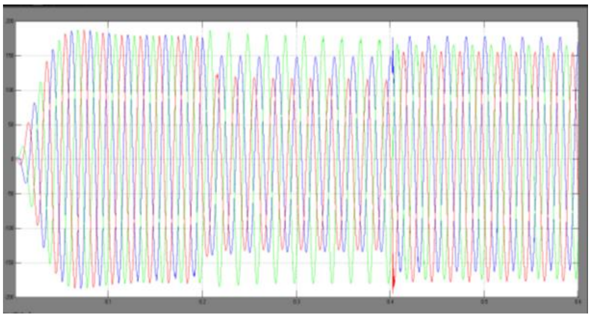

Fig.11.grid voltages at the LV side of the transformer

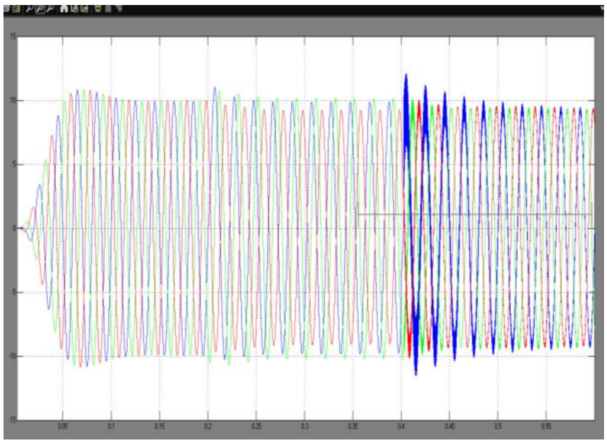

Fig.12.output currents at the LV side

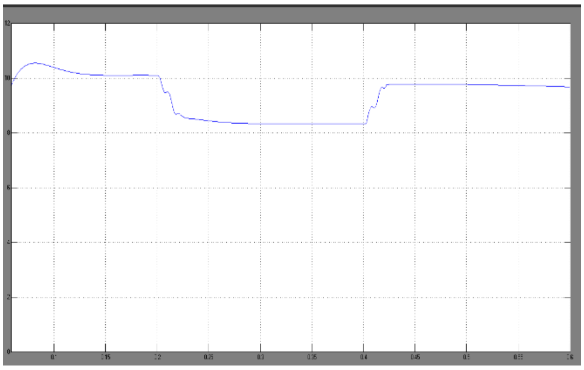

Fig.13.reactive current reference

SIUMULATION RESULTS USING PRCONTROLLER

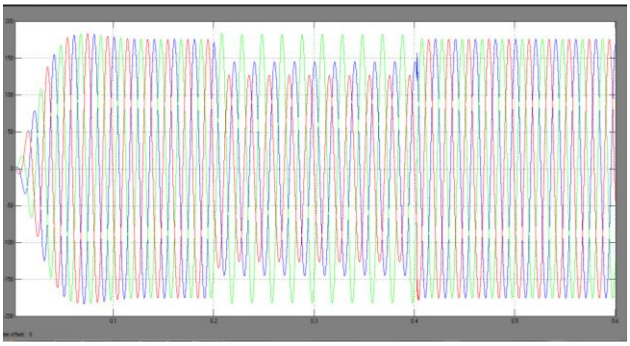

Fig.14. Grid voltages LV side of the transformer

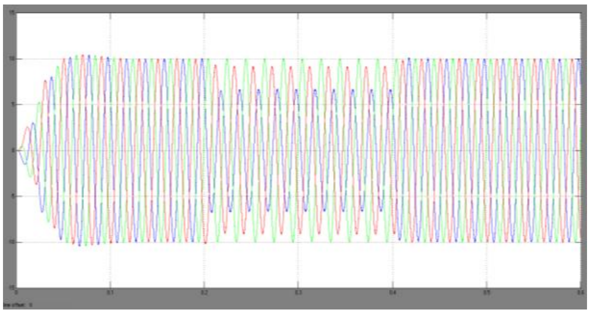

Fig.15. Output currents at LV side

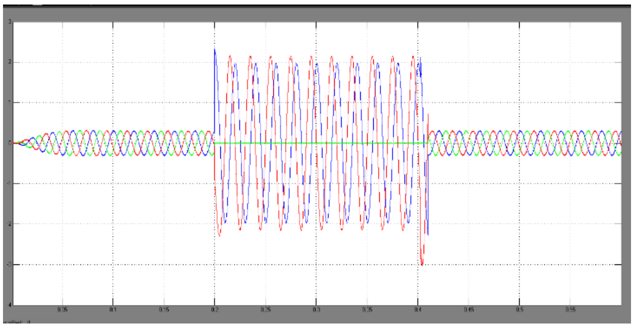

Fig.16. Generated reactive current references

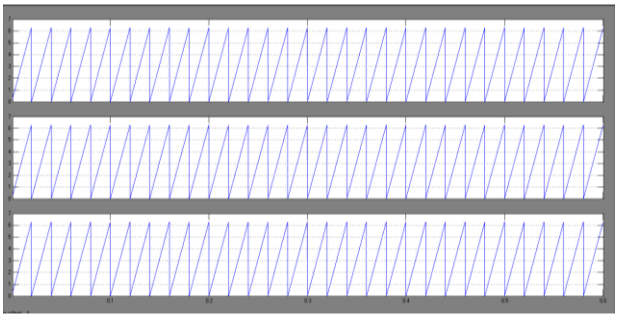

Fig.17. Detected angles of phases a, b andc,

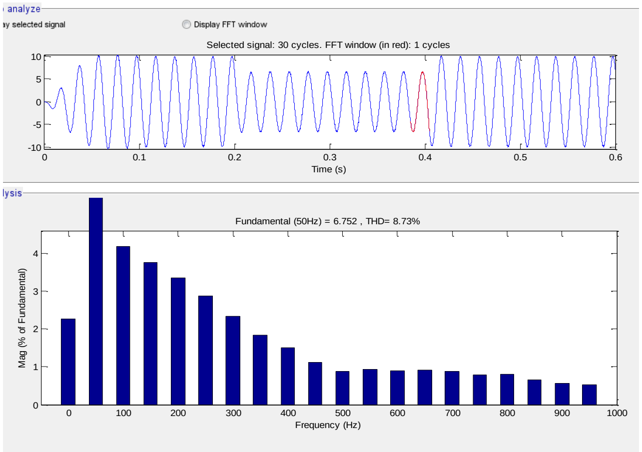

Fig18. Current thd

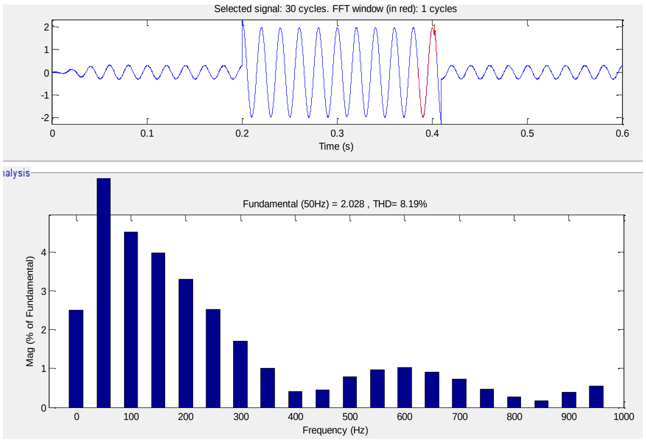

Fig.19. Reference current thd

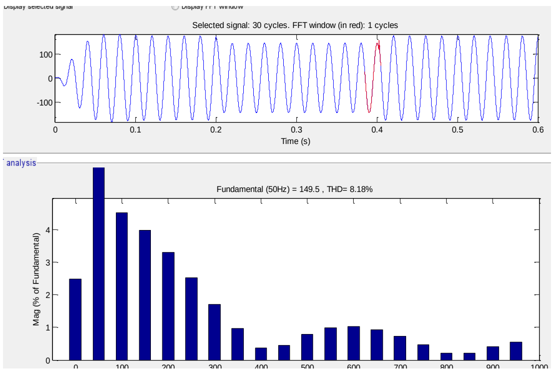

Fig.20. Grid voltage thd

SIMULATION RESULTS USING FUZZY CONTROLLER:

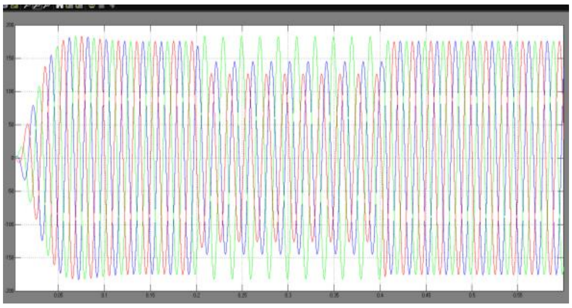

Fig.21.Grid voltages at the LV side of the transformer

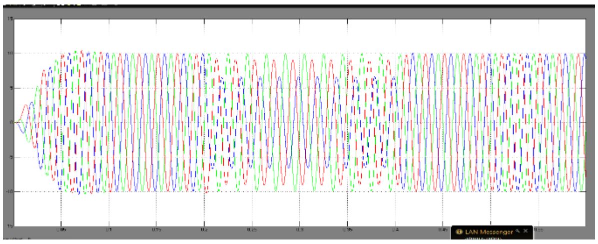

Fig.22.generated reactive current references,

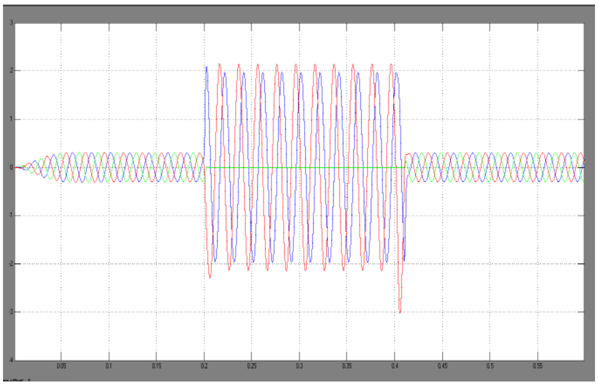

Fig.23.output currents at the LV side

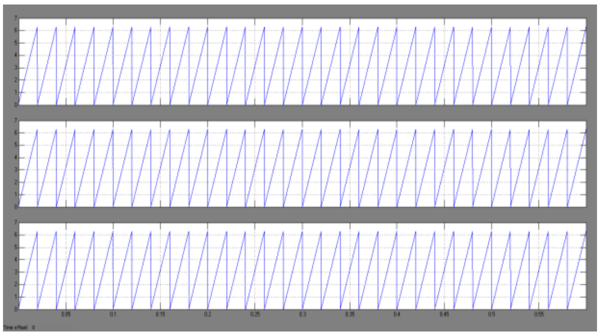

Fig.24.detected angles of phases a, b and c,

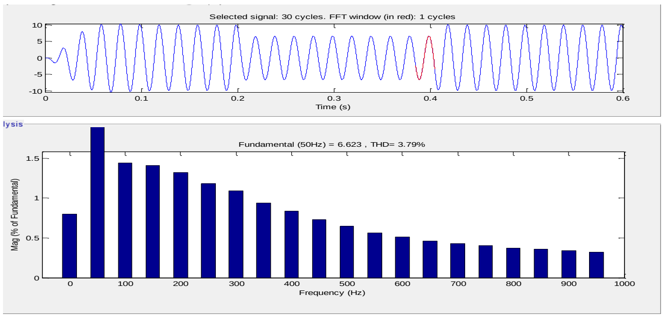

Fig.25.Current thd

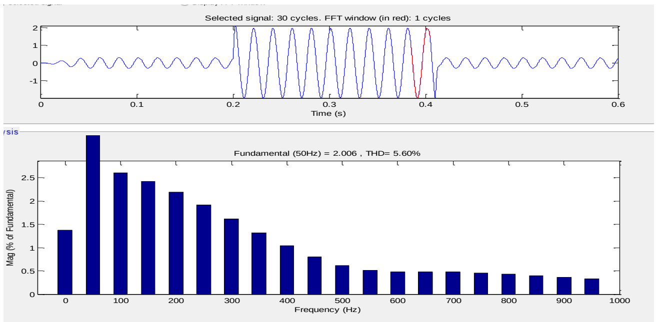

Fig.26.Reference current thd

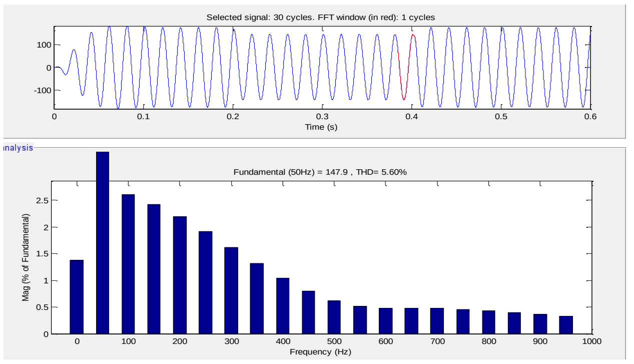

Fig.27.Grid voltage thd

III. Conclusion

In this letter, a new control method based on individual control of the three phases of a CPPP has been proposed. The independent control of the reactive currents injected into the grid protects the non-faulty phases from over-voltage. The reactive currents are determined separately based on the amount of voltage drop in each phase. The active current references of each phase need to be limited based on the required amount of reactive currents. Furthermore, in a three-phase system, it is necessary to eliminate the zero-sequence from the current references generated. In this letter two solutions for removing the zero-sequence component have been proposed. Finally, a method for re-scaling the instantaneous current references to avoid producing overvoltages in the non-faulty phases, while preventing the GCPPP from over-currents has also been proposed. This proposed control method has been tested experimentally on a scaled-down laboratory prototype operating with a “weak” grid.

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Penamalli Abhisheik received B. Tech Degree in Electrical and Electronics Engineering from NBKR Institute of Science and Technology, Vidyanagar Nellore in 2014. Presently pursuing M. Tech degree specialization in power Electronics in Visvodaya Engineering College. His research interests include several areas of power electronics and drive maintenance studies and energy saving projects.