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Control of Grid Connected PV System under Unbalanced Voltage Sag and Eliminate Over Voltages Conditions Using Fuzzy Based Individual Phase Current Control

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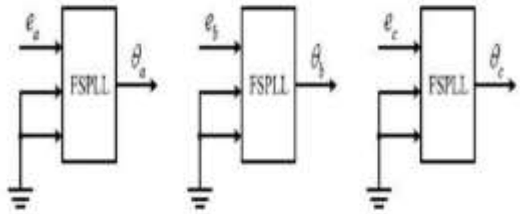
Abstract:

It is suggested to fulfil grid code requirements for framework connected solar power plants by allowing free present management of each inverter period under unbalanced voltage sag conditions. GCPPPs are required to enhance network voltages by injecting reactive current during voltage lists, according to existing grid standards. Non-defective phase network voltages shall not exceed 110 percent of their nominal esteem in the event of such an infusion. However, grid over-voltages may occur even during the non-defective periods if the GCPPP's injected currents are altered. Uneven current injection is authorised by the European Network of Transmission Framework Operators (ENTFO) published in 2012 because of another need. During voltage droops, unbalanced currents are injected into the grid in order to maintain this grid code.

INTRODUCTION

V-Source Inverter (VSI) regulation in the context of unequal voltage droop has been widely discussed by specialists. Two strategies for dynamic power regulation have been shown to provide the current references for VSIs [1], [2]. It is essential that VSIs remain connected to the grid during voltage lists so that they may provide responsive current, which will help to maintain grid voltages. [3] To get around a problem, you'll need to know this. In the absence of flaws, injecting a responsive current adjustment to aid imbalanced voltage hanging may lead to over-voltages [5]. Uneven voltage lists need the use of different control techniques to maintain this, hence new framework codes (GC) demand the use of unequal receptive current during uneven voltage lists. The severity and kind of voltage droops were taken into consideration while developing an adaptive voltage bolster approach in [6] and [7]. Therefore, a disconnected control parameter is employed to regulate the amount of responsive power injected through positive and negative successions. This. Refreshed responsive power reference and control parameter were used in [8] in an expanded interpretation of previous studies to restore voltage amplitudes that had been dropped. Using a proportional impedance grid model, [9] advocated setting the positive-and-negative-successive receptive power references to avoid over-and under-voltages in the stages. As a result, the new current references were re-evaluated in light of the previous responsive power references. According to [10], a decoupled twofold synchronous reference outline current dynamic and receptive intensity of the positive and negative sequences may be arbitrarily controlled by the controller. Regardless, the current references were managed independently. The European Transmission Network is now necessary because of the increasing need for single-stage management of current and voltages in the three stages. According to System Operators, transmission framework administrators (TSOs) might submit a need for uneven current infusion [11]. It hasn't even been mentioned in any academic articles to this far. [12] provided for some exploration in order to aid stages with uneven response power. That paper's methodology was not comprehensive enough to cover a broad variety of voltage lists [13].



Under imbalanced voltage lists, this letter proposes a mechanism for individual control of the stage current. Each stage's receptive current is calculated based on its voltage drop, which implies that no responsive current is infused into the stages that aren't damaged. This method's execution requires knowledge of each stage's framework voltage edge. As a result, the suggested stage bolted circle (PLL) in [14] is implemented. Fault ride-through (FRT) must be taken care of, so the framework current, which includes both dynamic and receptive current ebbs and flows, is limited to protect the GCPPP from air conditioning overflows. Two methods have been presented to prevent controllers from trying to infuse a zero sequence into the grid since the framework current is described arbitrarily at each stage. Every GCPPP coupled with a low voltage (LV) programmable air conditioning power source was tested using the suggested control technique. The remainder of this message is organised as follows: Section II explains the synchronisation method used to free the trapped object.

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

1. stages of the voltages on the grid Section III depicts the current references' age, where a two-arrange current limiter and two methods for removing the zero-succession from the current references are presented. Resounding (PR) controllers shown in Section IV are used to regulate the grid current. Section V presents preliminary findings from an experiment using a smaller research facility and the aforementioned control technique. Section VI, the last section, summarises the letter's main conclusions.
2. **SINGLE-PHASE PLL PHASE EXTRACTION FOR THREE-PHASESYSTEMS**

The stage current can only be controlled freely if the grid voltages can be extricated from the stage edge of each of them. For the purposes of [14], this is how the recurrence versatile PLL is carried out. The filtered sequence PLL (FSPLL) described in [15] is required for this PLL. An offbeat d-q shift and the movement of normal channels are used to segregate positive groupings of voltages from the negative sequence and a few noises in the first phase of the FSPLL (MAFs). a standard reference outline has been included into the SRF-PLL to reach to the edge of the positive sequence that was extricated. As shown in Fig. 1, three FSPLLs were used in [14] to discern the borders of the three-stage framework for each stage individually. In order to keep the FSPLL from being overloaded, each FSPLL is given a single stage voltage and all other sources of information are set to zero, as follows: EA0 = (ea, (eb, and (ec), in which the network voltages are ea, eb, and ec)..

3. GENERATION OF PHASE CURRENT REFERENCES

It's seen here how the current control circles are encouraged by gaining current references. In order to manage the dc-connect voltage, iA (dynamic current) is described, while the individual responsive current amplitudes (iR- x) are determined from the hang control,

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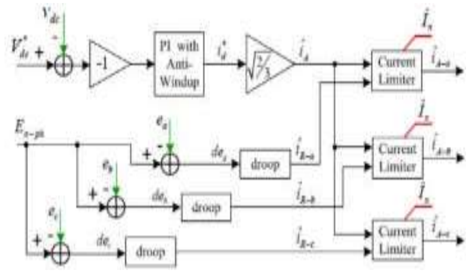
characterise as follows:

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



A constant esteem in accordance with German GCs [4] is dex, the measure of stage voltage drop from its rms esteem (En-ph), the abundance of the nominal inverter stage current (în), and dex. For voltage boosting, the infusion of receptive current at the LV side of the transformer must be no less than 2% of the nominal current for every 1% reduction in voltage [4]. Control of the dc link voltage circle is provided by an innovative relative essential (PI) controller equipped with a windup deterrent.

Reactive and active currentreferences may be obtained using this control scheme in Figure 2.

Immediately after the fault evacuation, achieve the pre-fault attributes. Figure 2's control chart shows this. The dc-interface voltage is represented by vdc, the reference voltage is represented by V dc, and the dynamic current reference is represented by i d in the dq-reference outline.

A. Constraining the Phase Currents

Controllers employ dynamic current expansion under voltage list conditions to keep up the framework's power. Meanwhile, responsive current should be injected into the problematic stages to improve the grid voltages. As a result, the amplitude stage current may rise over permitted levels, resulting in the over current assurance being triggered. A responsive current injection is needed to avoid this situation. As a result, the dynamic current's amplitudes are bound by the receptive current necessary for each step of the process (Fig. 2). Under a voltage list, responsive current is needed to improve the grid voltages. However, each stage's current can't exceed the maximum acceptable value for that stageThe inverter As a result of an overcurrent condition in one stage, the dynamic current in that stage should be limited in this manner. The limiter seen in Figure 2 is described as follows:

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

B. where x persists during the first three steps. Duplicating the dynamic and responsive amplitudes of each stage's dynamic and responsive current by the stage edge cosine and sine from the PLLs provides the true current reference. The dynamic and responsive current segments serve as the final current reference for each step. Figure 3 shows the procedure for obtaining the current reference i a for stage a's stage a's. Using the same method, current stage references are obtained for future stages.

C. Zero-Sequence Elimination from the Current References

D. Due to the three phases' ability to command their own stream, the three ebbs and

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flows may not all be equal. A zero-succession current section would be disseminated via the earth. Assuming that the ground circuit is intact, this is not possible to occur

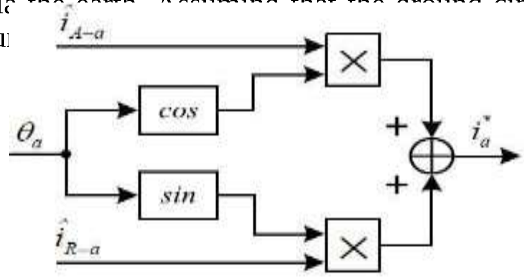

Fig. 3: Current reference generation for phase a.

is free and available. Furthermore, if the ground circuit has a low impedance, this current may not be desirable to distribute. Therefore, the zero-sequence should be removed from all current references in this paper Clarke's update (abc = 0) may be applied to the current references. The Clarke change's third component, the or zero sequence segment, is ignored in this case. It follows that if we expel the zero-succession, our current vector will be flat on the plane. Consequently, the reference current's components will be preserved. Changing the current references at each step by deleting 33 percent of the typical current component is an equivalent

$$i_a^{*'} = i_a^* - k_a i_0 \quad (3)$$

$$i_b^{*'} = i_b^* - k_b i_0 \quad (4)$$

$$i_c^{*'} = i_c^* - k_c i_0 \quad (5)$$

where:

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

way for removing $k_a = k_b = k_c = 1/3.$ (7) the zero-grouping.

The usual component i0 will be zero or low during the adjusted activity. Regardless, when the voltage list is skewed, the fundamental element may be of significant importance. The new references i 0 a, i 0 b, and i 0 c may have different first quality after applying (3)–(7).

In this manner, the receptive regions of the non-broken stages may develop, leading to a voltage that exceeds the cutoff points. In this manner. Below is an explanation of an optional solution to keep a strategic distance from this problem. Changing the current references, which rely on the start of a responsive current infusion at each step, is essential to the suggested sequence, since it leaves untouched the references for any phases in which there is no receptive current infusion. Zero-sequences are no longer necessary when stages A and B are both non-defective under an unbalanced voltage hang, since the current references of alternative stages are changed.

kb + kc = 1 Disposal zero-sequences are divided across the two broken phases of this letter, kb=1 and kc=2.

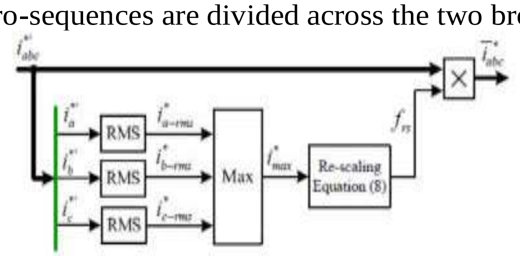

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Fig.4: Control diagram for re-scaling the current reference to avoid over currents

E. Second Current Limiter

An overcurrent may be created as soon as the zero-succession segment is ejected from the existing reference amplitudes. In order to keep the stage current at or below the maximum value (In), a method to measure the rms estimate of the ebbs and flows should be implemented. This may be done with the accompanying condition:

$$i^{*}_{x-rms} = \sqrt{\frac{1}{T_w}\int_{t-T_w}^{t} (i_x^{*'})^2 \, dt}, \qquad (8)$$

which is the estimate of the stage current x, which is the three stages (x 2 fa; b; and cg), and Tw is the window-width utilised for the estimation of the rms figuring, often T=2 or T, T being the framework voltage period (T = 1=freq). I x-rms The maximum current I max) and the nominal incentive (In) are compared. The current values are rescaled by a factor frs described

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

The final current references are set as:

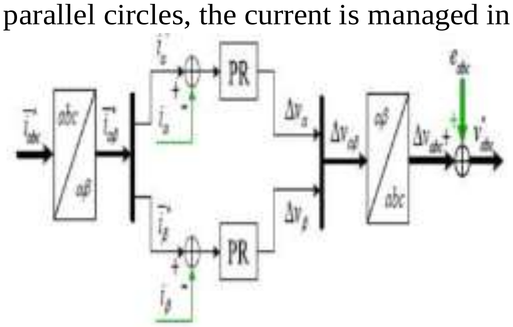
as: if it exceeds In.

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

Figure 4 depicts the suggested method for rescaling the current. When the subscript "abc" is used, it refers to the three stages of the framework, such as ia, ib, and ic. Two limiters are used in the process of constructing the stage's current references. Fig. 2 shows that the dynamic current must be limited in order to provide adequate space for the infusion of the receptive currents. After the zero-sequence disposal, all current references must be rescaled. This method is being suggested here completely out of left field and has never been examined before.

4. CURRENT CONTROL LOOP

5. Using two parallel circles, the current is managed in a stationary edge. Traditional



relative indispensable (PI) controllers fail to eliminate lasting state errors when managing sinusoidal waveforms because their control factors are sinusoidal. Fig. 7 depicts the current's command outline. The current sources cited in this control overview were used to compile it (10).

Fig. 5: Current control loop with PR controllers.

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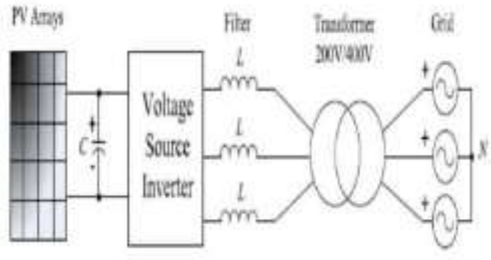
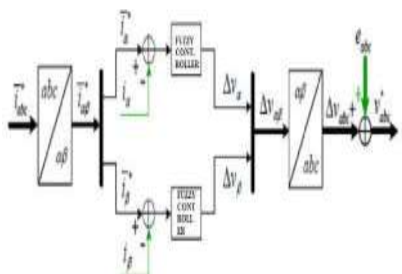


Fig. 6: Diagram of a GCPPP

CONTROLLER USING FUZZY LOGIC:



True values of variables in fuzzy logic may be any real integer between 0 and 1, making it a kind of many-valued logic. In contrast, in Boolean logic, variables may only have truth values of 0 or 1. It has been expanded to handle partial truth, where the truth value might be anywhere from totally true to completely false. Furthermore, these degrees may be handled by particular functions when linguistic variables are employed.

Fig. 7: Current control loop with Fuzzy controllers.

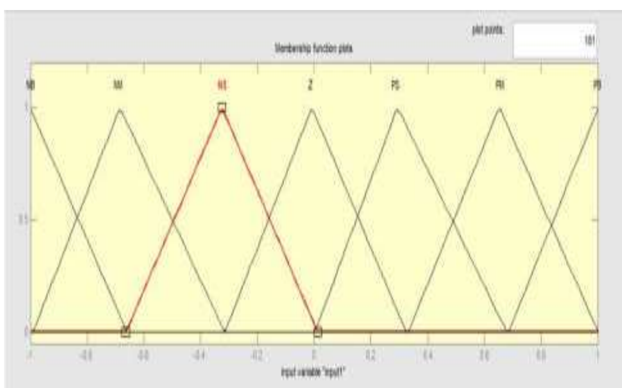


Fig.8: Membership functions of current error

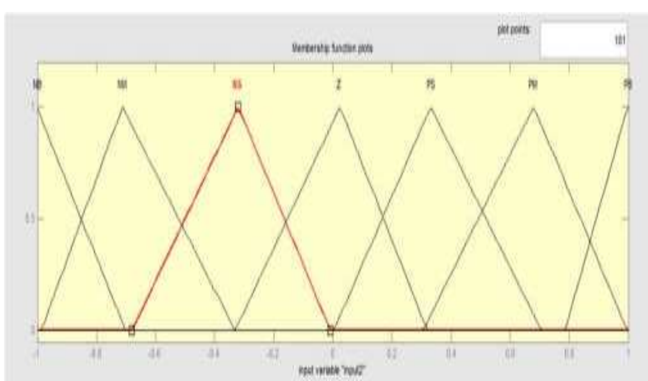


Fig.9: Membership functions of changing current error

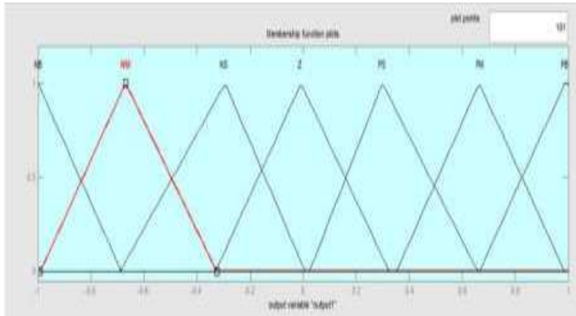


Fig.10: Membership functions of voltage error

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

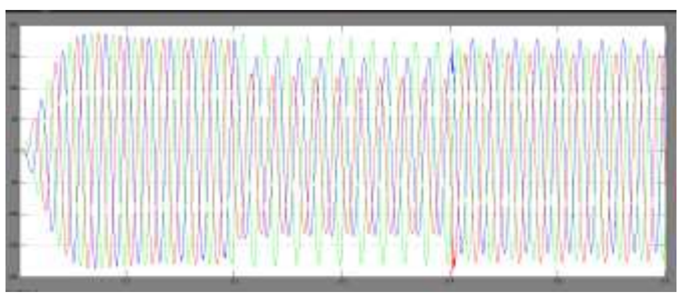


Fig.11: Grid voltages at the LV side of the transformer

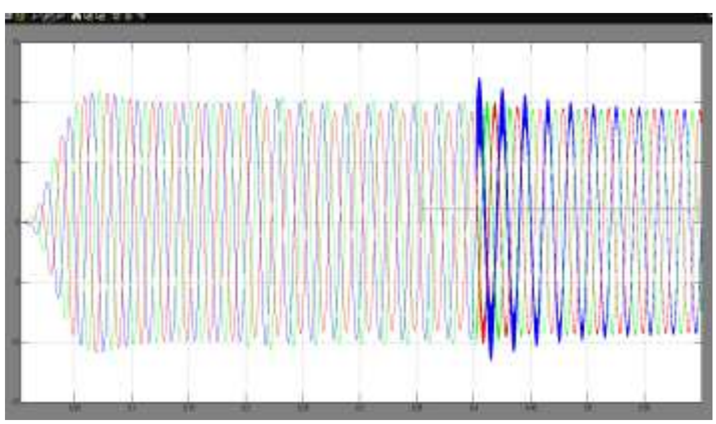


Fig.12: Output currents at the LV side

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Fig.13: Reactive current reference

SIUMULATION RESULTS USING PRCONTROLLER:

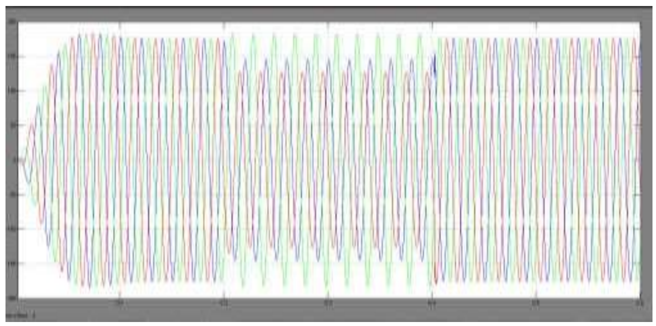

Fig.14:Grid voltages LV side of the transformer

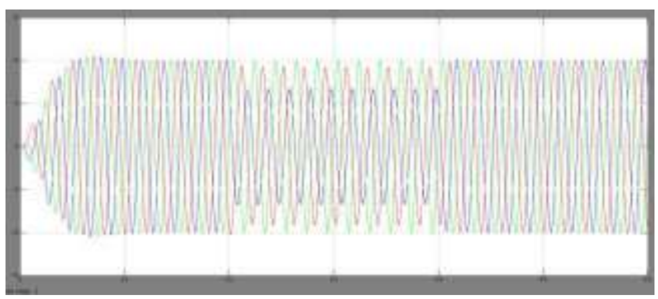

Fig.15:Output currents at LV side

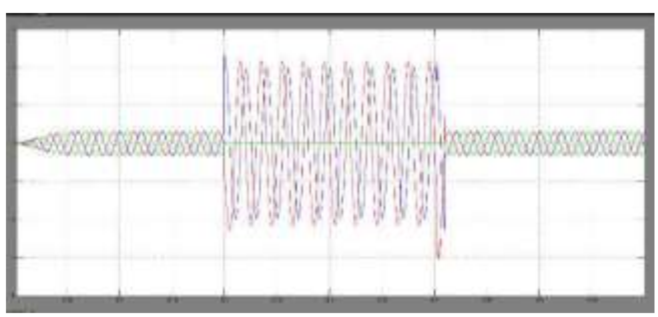

Fig.16:Generated reactive current references,

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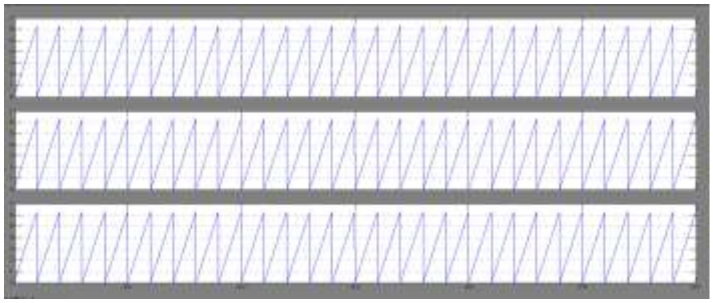

Fig.17:Detected angles of phases a, b and c**,**

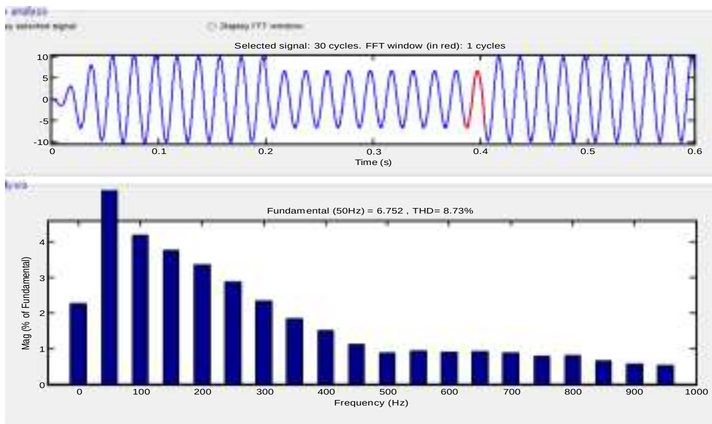

Fig.18:Current thd

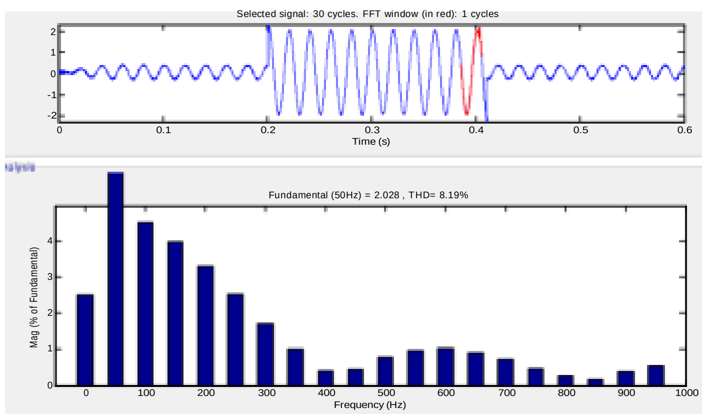

Fig.19: Reference current thd

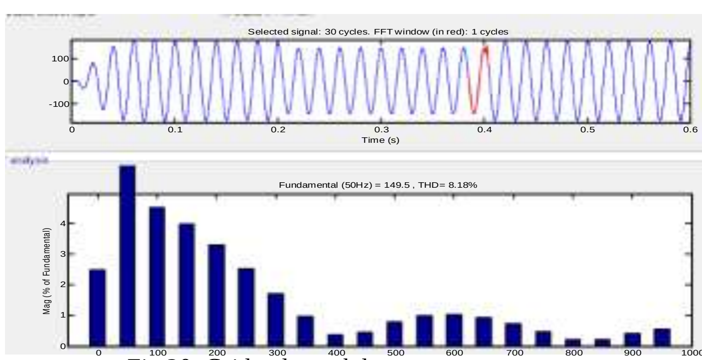

Fig.20: Grid voltage thd

SIMULATION RESULTS USING FUZZY CONTROLLER:

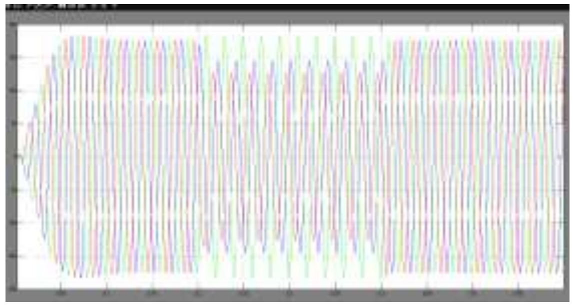

Fig.21:Grid voltages at the LV side of the transformer

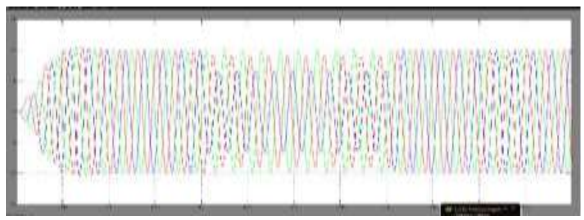

Fig.22: Generated reactive current references,

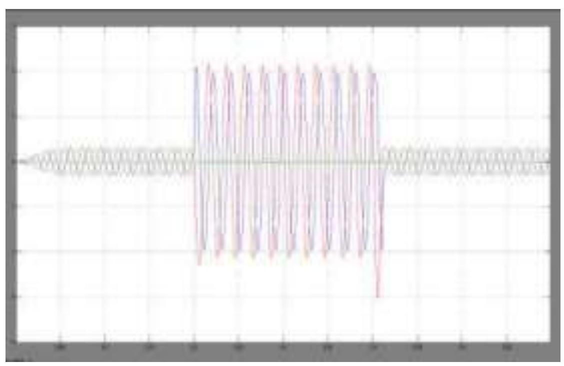

Fig.23: Output currents at the LV side

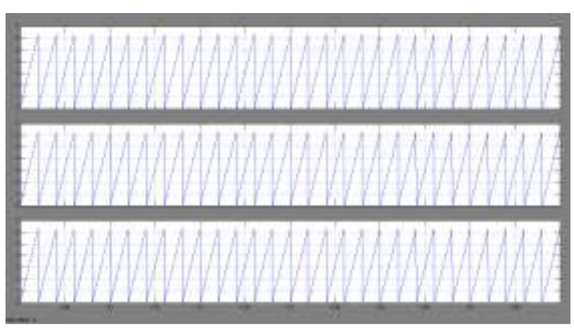

Fig.24: Detected angles of phases a, b and c,

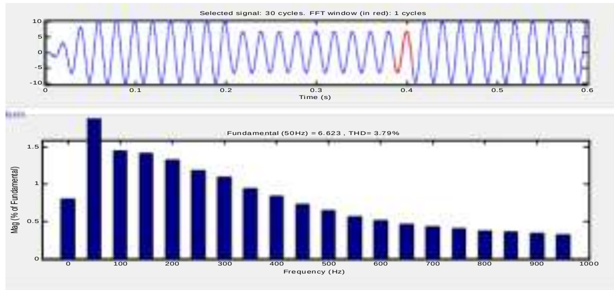

Fig.25: Current thd

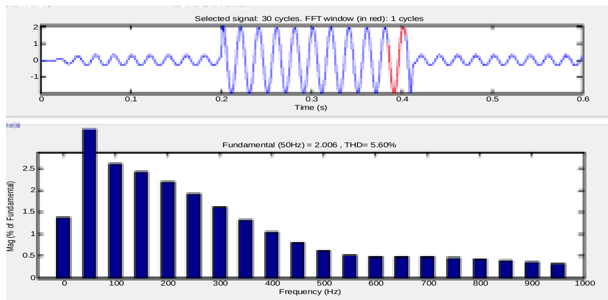

Fig.26:Reference current thd

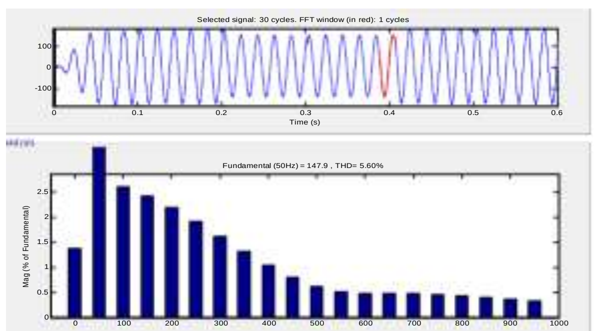

Fig.27: Grid voltage thd

5. Conclusions:

An entirely new control strategy for CPPPs has been developed in this study, based on individual management of each of the three phases. The non-faulty phases are protected against overvoltage by the separate management of the injected reactive currents into the grid. The reactive currents are calculated independently for each phase depending on the voltage drop. Depending on the quantity of reactive currents necessary, each phase's active current reference must be restricted. A zero-sequence must be eliminated from the current references produced in a three-phase system. Two options for getting rid of the zero-sequence component have been presented in this letter. Finally, it has been suggested that the instantaneous current references be rescaled in order to prevent overvoltage in the phases that are not defective while simultaneously protecting the GCPPP from overcurrents.

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10) Decoupled double synchronous reference framecurrent controller for unbalanced grid-voltage circumstances, IEEE Transactions on Power Electronics, September 2012, vol. 27, no. 9, pp. 3934–3943, (Measurement of unbalanced grid voltage using a decoupled reference framecurrent controller).

11) For all generators, the European Network of Transmission System Operator (ENTSO) "Entsoedraft network code" for grid connection requirements applies. The requirements for generators are detailed in https://www.entsoe.eu/ major projects/network code development/requirements-for-generators/Pages/default.aspx.

12) For example, at the IEEE International Conference on Industrial Technology (ICIT), asymmetrical reactive currents may be used to support grid voltage in the event of grid mistakes, as shown in the following paper: "Support of grid voltages using asymmetrical reactive currents in case of grid errors."

13) M. Bollen, Voltage Sags and Interruptions: Understanding Power Quality Problems. IEEE Press/Wiley, 2000.

14) In the IEEE Trans. Power Electron. vol. 29, no. 12, pgs. 6255–6259, December 2014, we present a three-phase frequency adaptive phase-locked loop enabling independent single phase operation.

15) A quasi-ideal lowpass filter stage and a phase-locked loop are used to build a variable-frequency grid-sequence detector that may be used to detect grid sequences with a wide range of frequencies.