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

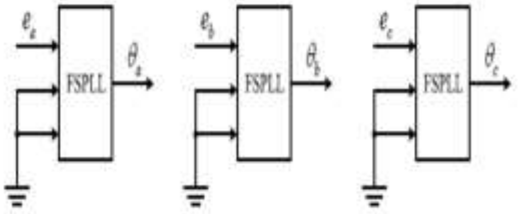
Liane Moriarty, Helen Garner

Abstract:
To successfully fulfil grid code demands for framework-associated solar power plants, free present control of each period of a three-phase voltage-source inverter under unbalanced voltage sags is presented. GCPPPs are supposed to enhance network voltages by injecting reactive current during voltage lists in accordance with current grid codes. 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. The European Network of Transmission Framework Operators released in 2012 mandated that a transmission framework administrator be allowed to propose a need for unequal current infusion. Controlling individual phases and injecting unbalanced currents into the grid during voltage droops are part of this project's grid code maintenance.

INTRODUCTION

V-Source Inverter (VSI) regulation in the context of unequal voltage droop has been widely discussed by specialists. Dynamic power control methods have been the subject of considerable investigation, and two systems have been shown to provide the current references for VSIs [1, 2]. VSIs, like typical power plants with synchronous generators, should maintain their connection during voltage drops and boost grid voltages by injecting responsive current [3], [4]. This is critical for coping with a flaw. [5] Over-voltages in the non-flawed stages may be caused by the infusion of an adjusted receptive current to aid with voltage hangs [5]. As a result, a variety of control mechanisms have been suggested for new framework codes (GCs), which call for the injection 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]. For this reason, a disconnected control parameter is utilised to assess the response power injected by means of positive and negative successions. The responsive power reference and the control parameter were renewed with the explicit purpose of restoring the lowered voltage amplitudes in [8], which included a broader speculation of previous research. There was also a study in [9] that provided a technique for setting the positive and negative succession power references in light of a proportional impedance grid model to avoid stage over- and undervoltages. As a result, the new current references were re-examined in light of the previous responsive power references. One of the first examples of an uncoupled two-fold synchronous reference outline current controller is [10]. the ability to independently adjust the dynamic and receptive intensity of positive and negative sequences. There was a discrepancy between the current references, though. The new requirement of the European Network of Transmission is based on the unique regulation of current and voltages of the three stages. If TSOs are allowed to propose a need for uneven current infusion, then so are system operators [11]. Until now, only a handful of academic journals have ever explored or discussed this notion. To improve the levels with imbalanced responsiveness, [12] included some exploring. What is certain is that the approach described in that research did not apply to all possible voltage lists.

Here, we offer a control approach for individual stage current regulation under imbalanced voltage lists. To determine the receptive current at each step, the voltage drop



at that stage is taken into account. This implies that no responsive current infusion occurs at the stages that aren't damaged. It is necessary to know the voltage edge of each step in order to implement this method. Because of this, the stage bolted circle (PLL) introduced in [14] is used. Fault ride-through (FRT) must be taken care of, thus the framework current, which includes both dynamic and receptive current ebbs and flows, is controlled in order to protect GCPPP from air conditioning overebbs and flows. Two methods have been presented to prevent controllers from attempting to infuse a zero sequence into the grid since the framework current is described arbitrarily at each stage. In this study, the suggested control approach was tested on a miniaturised GCPPP linked to a low voltage (LV) programmable air conditioning power supply (PACS). The remainder of this message is organised as follows: Section II explains how to disentangle the synchronisation approach.

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

just the grid voltage stage points. 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. In Section IV, the resounding (PR) controllers are used to regulate the grid current. Section V presents the experimental results of a shrunken research facility model using the suggested control approach. In Section VI, the most important aspects of this letter are laid forth in detail.

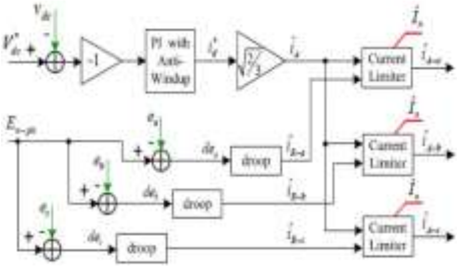
SINGLE-PHASE PLL PHASE EXTRACTION FOR THREE-PHASE SYSTEMS

The suggested method relies on removing all grid voltages from the stage edge before it can be used to freely adjust the stage current. The recurring versatile PLL is implemented in accordance with the study in [14]. As mentioned in [15], this PLL is based on the sifted sequence-based PLL (FSPLL). 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 synchronous reference outline is included into the FSPLL.

PLL (SRF-PLL) to remove the positive sequence that was previously trapped. An example of how this was done is shown in Fig. 1. Three FSPLLs were used in [14] to identify the boundaries between the three stages of the three-stage framework. All other information sources are set to zero: ea0 = (ea; 0; 0),eb0 = (eb; 0; 0,ec0 = (ec; 0; 0), in which the network voltages are the network voltages, respectively.

GENERATION OF PHASE CURRENT REFERENCES

In this section, we'll go through how to gather current references in order to strengthen the current control rings. When managing the dc connection voltage, the amount of dynamic current (iA) is measured to determine how much power is available for each responsive current amplitude, which is defined as: iR-x.



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. The infusion of receptive current at the LV side of the transformer must be no less than 2% of the nominal current per % of the voltage drop if the esteem 2 for hang is to be used [4]. Control of the dc link voltage circle is provided by a relative essential (PI) controller equipped with a hostile windup innovation that matters.

FIG. 2: Control diagram for obtaining active and reactive currentreferences, as shown.

Immediately after the fault evacuation, achieve the pre-fault attributes. Fig. 2 shows this in the control chart. Vdc is the voltage on the dc-interface, V dc is its reference esteem, and i d is the dynamic current reference in the dq-reference outline.

Constraining the Phase Currents

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

The controller extends the dynamic current to maintain the framework's power supply in the event of a voltage list circumstance. Meanwhile, responsive current should be injected into the malfunctioning stages to assist the grid voltages stabilise. To put it another way, the amplitude stage current may rise over the maximum allowed level, triggering the over current protection. In order to avoid this situation, the framework voltages need the injection of receptive current. As a result, the dynamic current's amplitudes are bound by the receptive current needed at each step of operation (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 stage. The inverter is the key component. In this method, the dynamic current in that stage should be regulated because of an overcurrent in one stage. Figure 2's current limiter is described as following:

For phases a, b, and c, x remains. Cosine and sine of the PLL stage edge are multiplied by the dynamic and responsive current amplitude for each stage to get a real current reference. The dynamic and responsive current segments are used to provide the final current reference for each step. For step a, Fig. 3 shows the procedure for obtaining the current reference, i a, as shown. Using the same method, current stage references are obtained for future stages.

Zero-Sequence Elimination from the Current References

When current is allowed to flow freely between stages, it's possible that there will be no zero-amplitude oscillations. Zero-succession current would be dispersed across the earth as a result of this. If the ground circuit is intact, then this will never happen.

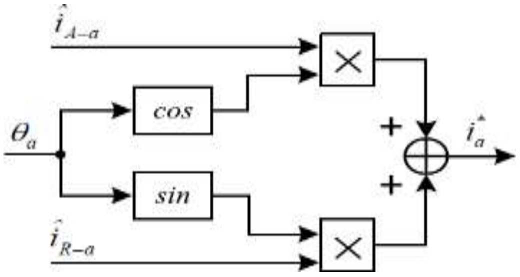


Fig. 3: Current reference generation for phase a.

is free and available. In addition, if the ground circuit has a low impedance, this current may not be desirable. This zero-sequence should thus be removed from the current references. Clarke's update (abc = 0) may be applied to the current references. In this case, the Clarke change's third component, the or zero sequence segment, is ignored. It follows that if we expel the zero-succession, our current vector will be flat on the plane. As a result, the reference current's constituent elements are preserved. Changing the current references at each step by deleting 33 percent of the typical

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

current component is an equivalent way for removing the zero-grouping.

$$i^{*'}_{a} = i^{*}_{a} - k_a i_0 \qquad (3)$$

$$i^{*'}_{b} = i^{*}_{b} - k_b i_0 \qquad (4)$$

$$i^{*'}_{c} = i^{*}_{c} - k_c i_0 \qquad (5)$$

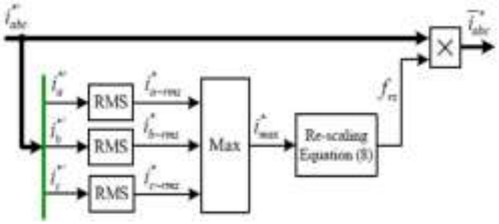
where:

$$i_0 = i^{*}_{a} + i^{*}_{b} + i^{*}_{c} \quad \text{and} \qquad (6)$$

$$k_a = k_b = k_c = 1/3. \qquad (7)$$

The usual component i0 will be zero or low during the adjusted activity. However, the fundamental portion may have a notable value in lists with imbalanced voltages. This means that after applying (3)–(7), the initial attributes of the new references may be different from those of the old ones.

If the responsive sections of the non-broken stages continue to grow, a voltage may exceed the cut off points. The following is a possible solution for avoiding this problem. As part of the suggested sequence, references to phases with no responsive current infusion would be changed while references to phases with a responsive current infusion remained unchanged. 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.



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

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

Second Current Limiter
Changing the amplitudes of the current may lead to overcurrents when zero-succession is removed from the current references. It is necessary to implement a method for determining the rms estimate of the ebbs and flows in order to keep the stage current at or below the highest value (In). This may be done with the help of the following:
When the stage current is represented by x, the window-width used for the rms calculation is Tw, which is usually T=2 or T, with T being the framework voltage period (T = 1=freq). x represents the three stages (x 2 fa; b; cg). A comparison is made between the maximum current (i max) of the three stages and the nominal incentive (In). The current values are rescaled by a factor frs described as: if it exceeds In.

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

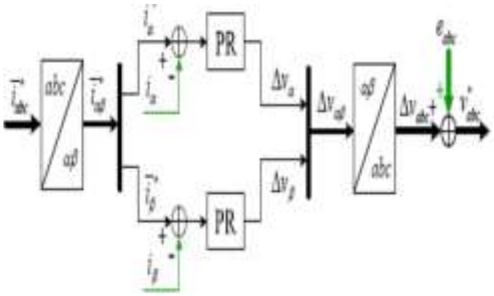
The final current references are set as:

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

Figure 4 depicts the rescaling method that has been suggested. Ia, ib, and ic are all abbreviated as "iabc" in the framework's three stage sizes, as shown by the abbreviation. Two constraints are involved in the process of establishing the stage that is now being referred to. Fig. 2 depicts the first method, which involves limiting the dynamic current to allow for the infusion of receptive current that is needed. Second, following the zero-sequence disposal, all of the existing references must be rescaled in order to complete the operation. This method has never been examined before, and it has never been discussed in any other study.

CURRENT CONTROL LOOP

Using two parallel circles, the current is managed along a stationary edge. PR controllers were used because PI controllers fail to remove lingering state errors while managing sinusoidal waveforms, which is why they were chosen for this project. Fig. 7 shows the present control outline. The current references included in this control overview are the sources of these contributions:



(10).

Fig. 5: Current control loop with PR controllers.

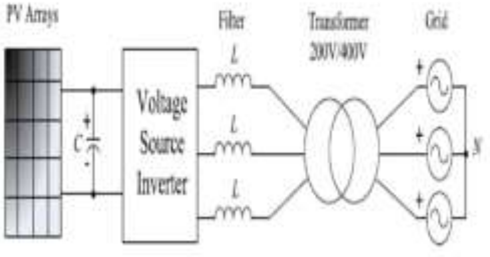


Fig. 6: Diagram of a GCPPP

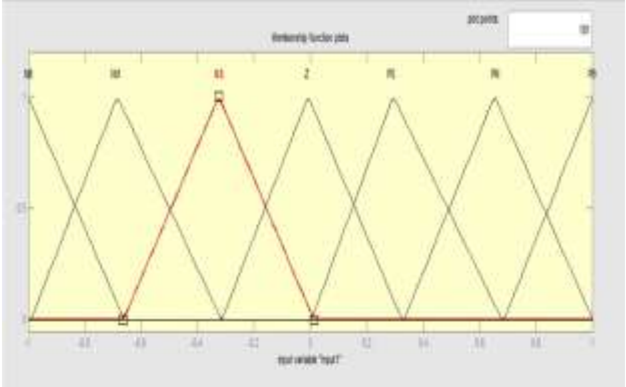
CONTROLLER USING FUZZY LOGIC:

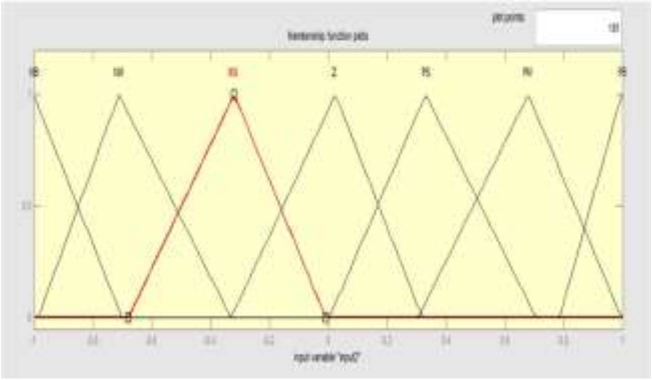
The truth values of variables in fuzzy logic may be any real integer between 0 and 1, making it a kind of many-valued logic. Boolean logic, on the other hand, restricts the truth values of variables to 0 and 1. To deal with the idea of partial truth, fuzzy logic has been developed to handle a truth value that might vary from entirely true to completely false. Furthermore, these degrees may be handled by particular functions when linguistic variables are employed.

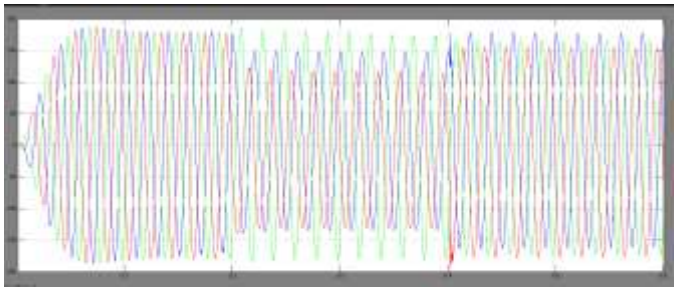
Fig. 7: Current control loop with Fuzzy controllers.

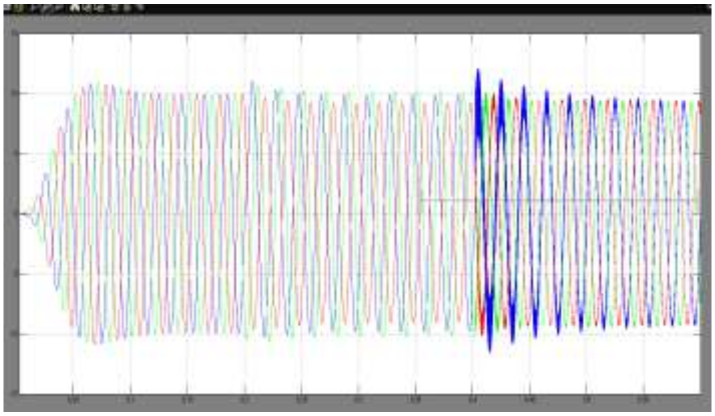
Fig.8: Membership functions of current error

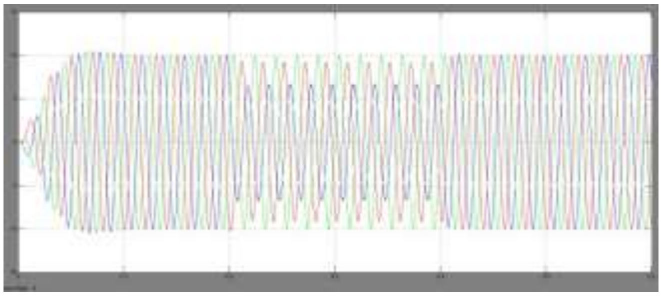
Fig.9: Membership functions of changing current error

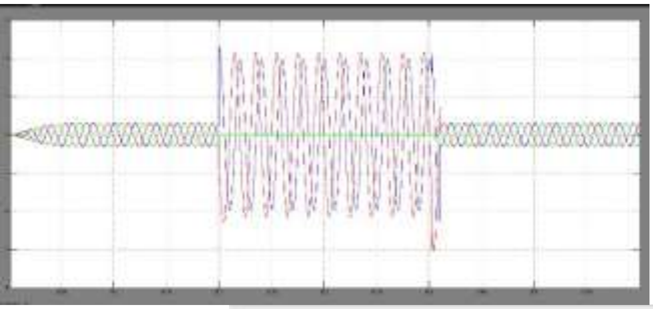












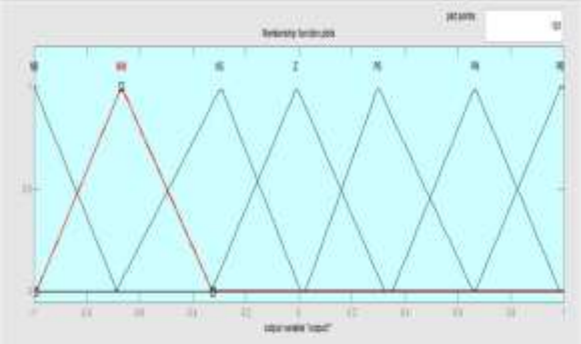


Fig.10: Membership functions of voltage error

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

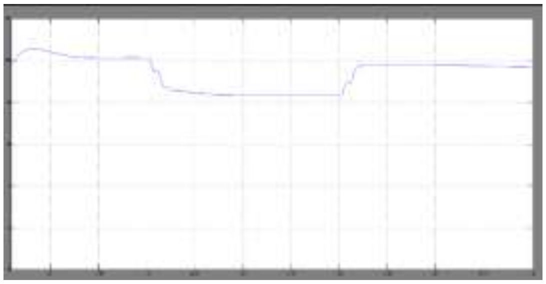


Fig.11: Grid voltages at the LV side of the transformer

Fig.12: Output currents at the LV side

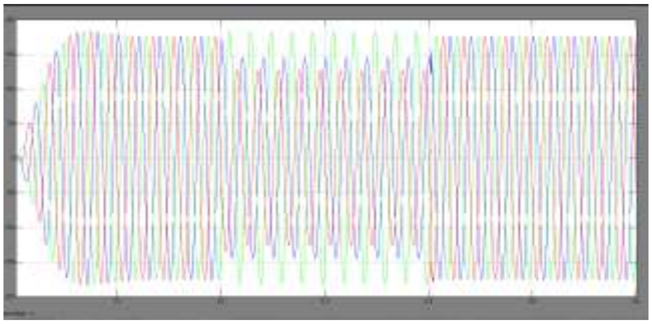
Fig.13: Reactive current reference

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,



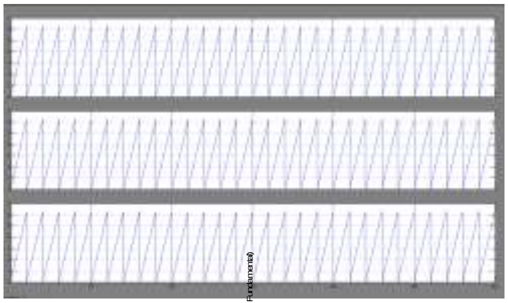


Fig.17:Detected angles of phases a, b and c,

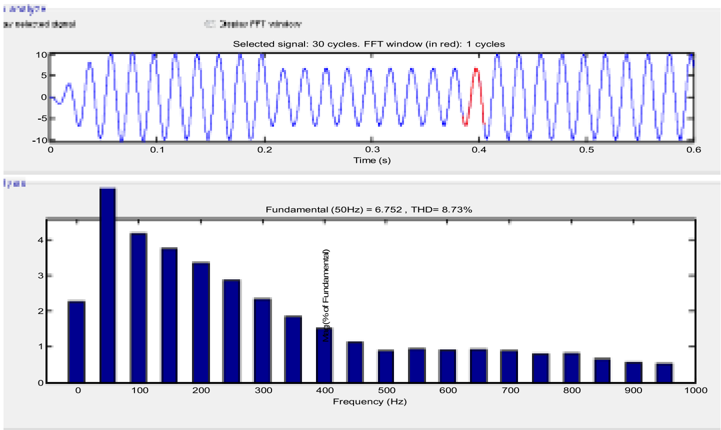
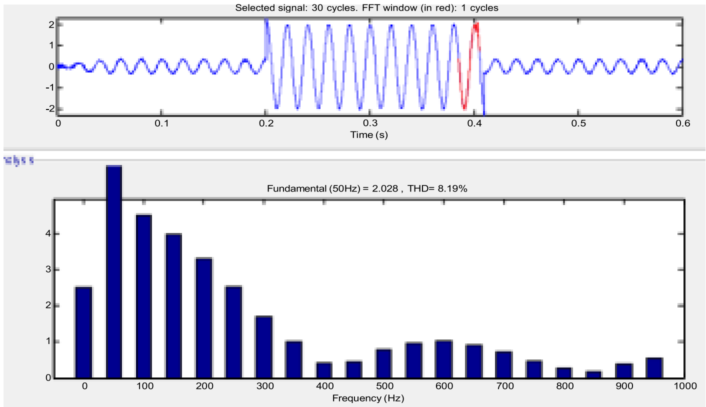


Fig.18:Current thd



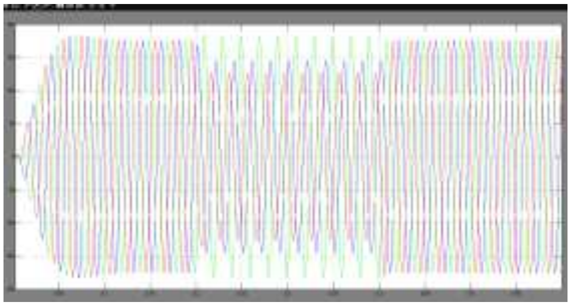


Fig.19: Reference current thd

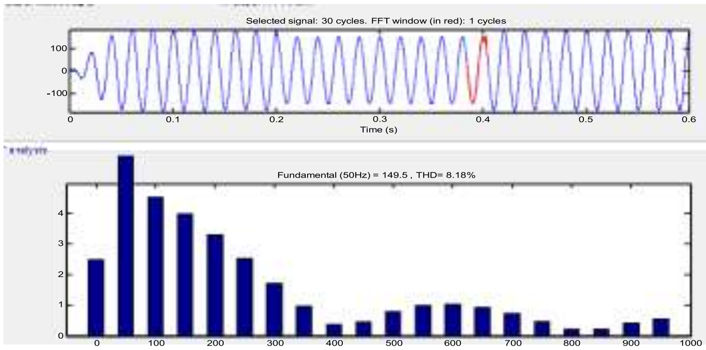


Fig.20: Grid voltage thd

SIMULATION RESULTS USING FUZZY CONTROLLER:

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

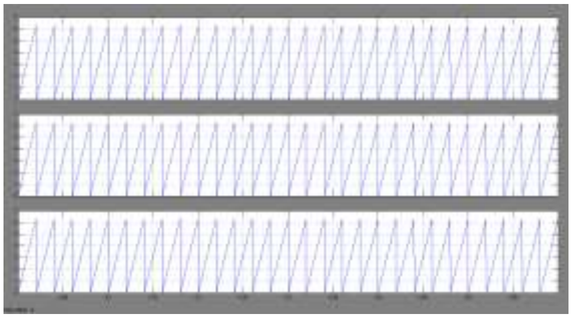


Fig.22: Generated reactive current references,

Fig.23: Output currents at the LV side

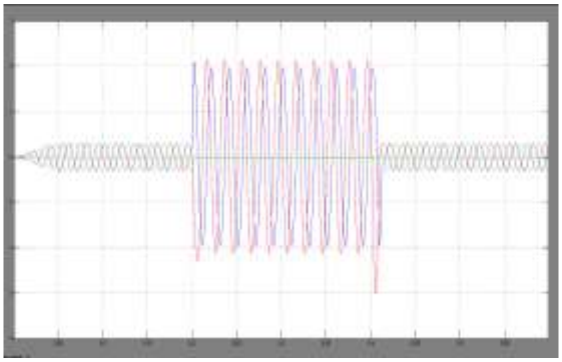
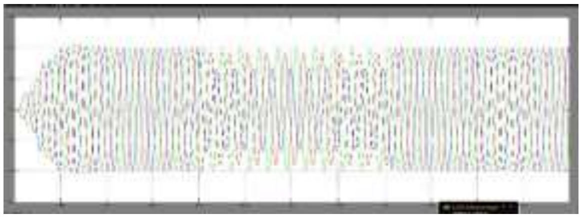


Fig.24: Detected angles of phases a, b and c,



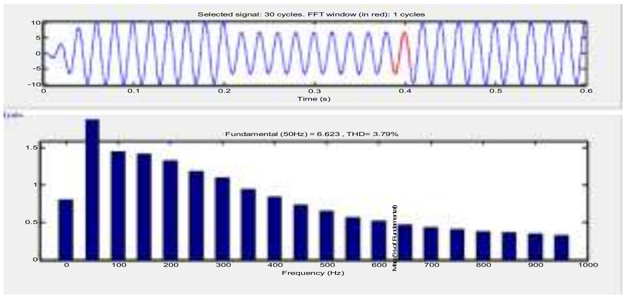


Fig.25: Current thd

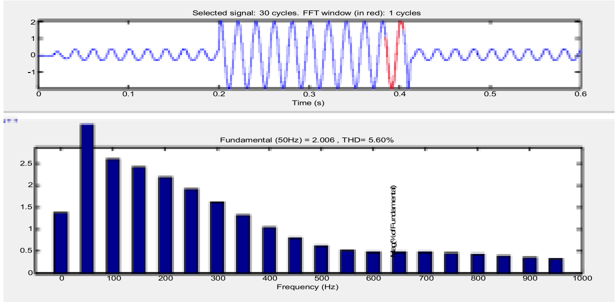


Fig.26:Reference current thd

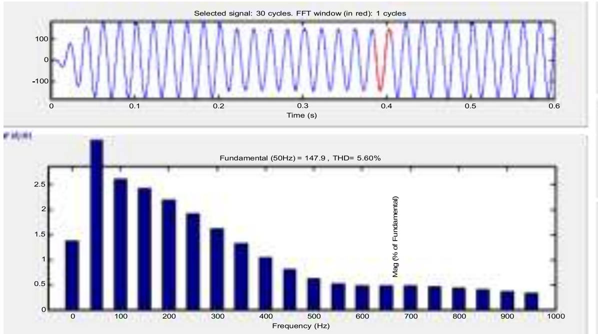


Fig.27: Grid voltage thd

Conclusions:

An entirely new control strategy for CPPPs has been developed in this study, based on individual management of each of the three phases. Non-faulty phases are protected against over-voltage due to the separate regulation of reactive currents introduced into the grid Reactive currents are calculated for each phase independently depending on voltage drop. The needed number of reactive currents dictates a limit on the active current references for each phase. In a three-phase system, the zero-sequence must be eliminated from the produced current references. To get rid of the zero-sequence component, we've put up two options in this letter. There has also been a mechanism developed for re-scaling the instantaneous current references in order to avoid creating overvoltage in the non-faulty phases while simultaneously protecting the GCPPP from over-currents.

References:

For example, in the event of a grid outage or a loss of power, a distributed power generation system (DPG) may be controlled using a flexible, active-power control strategy.

Active power management solutions for distributed generating inverters during unbalanced grid failures have been proposed by F. Wang, J. Duarte, and M. Hendrix in the IET Generation, Transmission and Distribution journal.

It is recommended that generating plants be linked to and parallel operated with the medium-voltage network in accordance with BDEW "Technical guideline" (https://www.bdew.de, June 2008).

New German grid codes for connecting PV plants to themedium voltage power grid, E. Troester, "Proc. 2nd International Workshop on Concentrating Photovoltaic Power Plants: Optical Design, Production, Grid Connection," Mar 2009. p 1–4.

"Single-stage inverter-basedgrid-connected solar power plant with ride-through capabilities across multiple kinds of grid failures," in Proc. 39th Annual Conference of the IEEE Industrial Electronics Society IECON, Nov. 2013, pp. 8008–8013. "

For three-phase distributed generating inverters operating in the presence of grid faults and with flexible voltage support regulation enabled by a single input signal, IEEE Trans. Ind. Electron., 60, no. 4, April 2013, pp. 1429–1441.

"Coordinated reactive power regulation for static synchronous compensators with unbalanced voltage sags," in Proc. IEEE International Symposium on Industrial Electronics (ISIE), May 2012, pp. 987–992.

IEC 61000-4-2, "Controlscheme with voltage support capabilities for distributed generation inverters" (IEC 61000-4-2), IEEE Trans. Power Electron, vol 28, no 11, pages 5252–5262, Nov. 2013. 8) J Miret A Camacho M Castilla L de Vicuna J Matas

At this point, the authors of "Reactivepower control for distributed generation power plants" are reporting in IEEE Trans. Power Electronics that "reactivepower control for distributed generation power plants to comply with voltage constraints during grid outages" (pp. 6224–6234).

The authors of IEEE Trans.Power Electron, vol. 27, no. 9, pp. 3934–3943, "Enhanced decoupled double synchronous reference framecurrent controller for unbalanced grid-voltage circumstances," M. Reyes, P. Rodriguez, S. Vazquez, A. Luna, R. Teodorescu, and J. Carrasco.

Eleven) "Entsoedraft network code for standards for grid connection applicable to all generators," by the European Network of Transmission System Operator (ENTSO). Accessed at https://entsoe.eu/network-codedevelopment/requirements-for-generators/Pages/default.aspx, January 2012.

IEEE International Conference on Industrial Technology (ICIT), February 2013, pp. 1781–1786; A. Uphues, K. Notzold, R. Wegener, S. Soter, and R. Griessel, "Support of grid voltages using asymmetrical reactive currents in case of grid defects," in Proc.

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

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 independentsingle-phase operation.

In the IEEE Trans. Power Electrons, vol. 25, no. 10, pp. 2552–2563, October 2010, the authors describe a "quasi-ideal lowpass filter stage and a phase-locked loop" for the detection of grid sequences.