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Performance Analysis of Single and Two stage voltage source inverter Based Grid-Connected PV plants with Ride-Through Capability under Grid faults

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Abstract: In this paper Grid-connected distributed generation sources interfaced with voltage source inverters (VSIs) should be disconnected from the grid under: 1) unreasonable dc-link voltage; 2) excessive ac Currents**;** and 3) loss of grid voltage synchronization. The control of single-and two-phase grid connected VSIs in photovoltaic (PV) power plants are created to address the issue of inverter disengaging under different grid issues. low-voltage ride through (LVRT), or flaw ride through (FRT), at times under-voltage ride through (UVRT), is the capacity of electric generators to stay associated in brief times of lower electric system voltage.
Key terms: DC–DC converter, fault-ride-through, photovoltaic (PV) systems, power system faults, reactive power support

Introduction

FAULT STUDIES are imperative in extensive scale grid connected renewable energy systems and have been reported in the specialized writing. In any case, the majority of these thinks about concentrated on grid connected wind power plants. On account of grid connected photovoltaic (PV) power plants (GCPPPs), Specifically, a three-phase current-source inverter (CSI) setup was explored under different shortcoming conditions, in which the output currents stay constrained under a wide range of flaws because of the usage of a present source model for the inverter. In any case, this configuration lead to may prompt instability under dynamic conditions. Three-phase voltage source inverters (VSIs) are utilized as a grid-connected power transformation systems. Because of the expanding number of these systems, the control of the VSIs is required to work and backing the grid in light of the grid codes (GCs) during voltage disturbances and unbalanced conditions.

Among a few studies for unbalanced voltage lists, a technique was introduced to mitigate the peak output currents of a 4.5-kVA PV system in non faulty phases. Another displayed a proportional-resonant (PR) current controller for the present limiter to guarantee sinusoidal output current waveforms and over-current. In any case, in the said contemplates, reactive power backing was not considered. A study managing the control of the positive and negative series was performed. Two parallel controllers were actualized, one for every arrangement. The study showed the active restrictions of utilizing this control series because of the deferrals created in the present control circles. A study was reported for the control of the dc side of the inverter, which demonstrates the effect of different sorts of deficiencies on the voltage what's more, current of the PV array.

Considering FRT procedures for grid-connected VSIs, a few research has been done on wind turbine applications furthermore on VSI-based high-voltage direct current (HVDC) systems. Some of these studies depend on passive control, e.g., crowbar and chopper resistors though others depend on active control plans. Although both classes can give FRT ability, the detached strategies have the disadvantages of requiring extra parts and scattering huge force during the voltage list forms. In the use of GCPPPs with the setups of single-stage change (single-stage transformation implies direct association of the PV source to the dc side of the VSI), some examination were done assessing the FRT issues of both air conditioning and dc sides of the inverter under lopsided voltage conditions. In any case, in the application of a two-phase transformation (which means a dc–dc change or pre regulator unit exists between the PV source and VSI), no paper so far has proposed a far reaching system to secure the inverter during voltage sags while giving reactive power backing to the lattice. All the plans and changes for the inverter in both the single-and two-phase transformations need to suit different sorts of flaws and address FRT ability taking into account the GCs. PV inverter detachment under grid issues happens because of essentially three components: 1) excessive dc-link voltage; 2) excessive ac currents; and 3) loss of grid voltage synchronization.

The control system presented for a single-stage transformation is utilized, despite the fact that the voltage sag location and reactive power control is adjusted in view of person estimations of the grid voltages. The primary target of this paper is to present new control methodologies for the two stage change in GCPPPs that permit the inverter to remain associated with the grid under different sorts of flaws while infusing reactive power to meet the required GCs.

II. GRID CODES

As the German GCs are the most comprehensive codes for the different power levels of PV installations and coordination advancements, this paper takes after these codes as a basis for the exchanges. During voltage sags, the GCPPP should support the grid voltage by injecting reactive current. The amount of reactive current is determined based on the droop control defined as follows:

$$i_{qref} = droop|de_L|I_n \tag{1}$$

$$for\ \frac{|de_L|}{E_n} \geq 10\% and droop \geq 2$$

Where droop is a steady value, de_L is the measure of voltage drop, and In is the rated current of the PV inverter in dq organizes, i.e., $I^1_n = \sqrt{3}In$, where In is the appraised rms line current of the inverter. The measure of voltage drop de_L is acquired based on the most reduced rms estimation of the line-to-line voltages of the three phases at the terminal of the GCPPP, i.e., e_L min appeared in Fig. 1.The rms voltage is acquired utilizing the following expression:

$$e_{Lrms} = \sqrt{\frac{1}{T_w}\int_{t-T_w}^{t} e_L^2\,dt}, with T_w = \frac{T}{2} \tag{2}$$

Where e_L is the instantaneous line-to-line voltage, T_W is the window width for the rms value estimation, and T is the grid voltage period, which is equivalent to 20 ms for a grid frequency of 50 Hz. The subsequent control graph for the reactive current generation is depicted in Fig. 1.

III. CASE STUDY FOR A SINGLE-STAGE CONVERSION

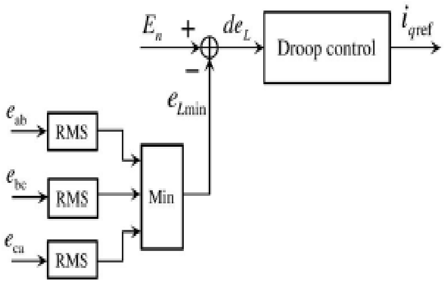


Fig. 1. Droop control diagram for the reactive current reference provision.

A. Grid Voltage Synchronization

In grid-connected inverters, one important issue is the voltage phase angle detection. This is normally performed by phase locked- loop (PLL) system in view of a synchronous reference outline PLL (SRF-PLL), known as ordinary PLL. The traditional PLL arrangement does not perform well under unbalanced voltage sags and thus may prompt the inverter being separated from the grid. A few strategies were proposed to extricate the voltage phases precisely under lopsided voltage conditions. The strategy in light of moving normal channels (MAFs) presented is connected, which was additionally utilized as a part of appearing exceptionally attractive execution. In this strategy, the positive sequence of the voltage is extricated from the grid by method for a perfect low-pass channel. At that point, the angle of the positive grouping is recognized.

B. Excessive AC Current

Commercial grid-connected inverters have a maximum ac current quality indicated. In the event that any of the streams surpass such esteem, the inverter is disconnected from the grid. Under grid voltage sag, the d-segment of the current (in the SRF) increments in light of the fact that the controller needs to keep up the dynamic power infused into the grid and grid voltages are briefly diminished. Notwithstanding the expansion of the d current segment, the inverter needs to infuse reactive current during the shortcoming to meet the FRT requirements. The measure of reactive current is according by load control given in (1). Since the d and q current segments expand, this may lead the over-current protection to separate the inverter from the grid.

C. Excessive DC-Link Voltage

If the active current reference is restricted, i.e., $i_{dref} < i^1_{dref}$, the produced power from the PVs is more than the infused power into the electrical grid. As an outcome, some energy is at first accumulated into the dc-link capacitor, expanding the dc bus voltage as appeared in Fig. 5(c). In a solitary stage GCPPP, as the dc-link voltage increases, the working point on the I−V curve of PV array moves toward the open-circuit voltage point (V_{oc}), which drives the PV current to diminish, as appeared in Fig. 6. The power generated by the PV panels is reduced because the operating point is taken away from the maximum power point (MPP) and in this manner; less active current is injected into the ac side. This happens until the GCPPP achieves a new steady state where the dc-link voltage quits expanding. In this manner, single-stage GCPPPs are self-protected since the produced power is decreased when the dc-link voltage increases under ac shortcomings. It should to be said that the inverter needs to withstand the most pessimistic scenario of the dc-link voltage,
Which is produced when the voltage gave by the PV modules achieves the open-circuit value (V_{oc}) under the maximum solar radiation expected on the generation site. Henceforth, the number of PV modules connected in series (n_s) must be restricted in the outline of the GCPPPs so that the dc-link voltage is never higher than the maximum acceptable estimation of the inverter($V_{dc\text{-}max}$)

$$n_s \leq \frac{Vdc-max}{Voc} \qquad (3)$$

This concept in the case of a single-stage GCPPP. An issue that may show up in view of the deviation of the MPP during the voltage list is that, after the flaw being cleared, the dc-join voltage and ac currents may take a long time to come to the pre fault values, as appeared in Fig. 5(b) furthermore, (c). The reason is that the error in the dc-link voltage produces accumulation of control activity to the essential part of the proportional-integral (PI) controller. This control activity is constrained by the present limiter and in this way it has no impact on the lattice streams. Be that as it may, when the voltage list closes, the exorbitant control activity gathered in the necessary part of the controller must be remunerated by an input mistake the other way. As an outcome, the dc-link voltage is lessened beneath the reference value. For this situation, a critical diminishing of the dc-link voltage may lead inverter losing control and be disconnected. To conquer this issue, an anti-wind-up system is connected to stop the PI controller accumulating excessive control action when it exceeds a specified value. The schematic of the anti-wind-up method Is appeared in Fig.4. which V^*_{dc} and V_{dc} are the reference also, real dc-link voltages, individually.
The enhanced results while applying the counter twist up system are portrayed in Fig. 8. For this situation, once the grid fault is cleared, the dc link voltage recovers to the pre fault value with no perceptible overcompensation.

Low-voltage ride through (LVRT)

In electric power system, low-voltage ride through (LVRT), or flaw ride through (FRT), at times under-voltage ride through (UVRT), is the capacity of electric generators to stay associated in brief times of lower electric system voltage. It is required at circulation level (wind parks, PV systems, conveyed cogeneration, and so forth.) to keep away from that a short out on HV or EHV level will prompt a far reaching loss of era. Comparable necessities for basic loads, for example, PC systems and modern procedures are frequently taken care of using a uninterruptible power supply (UPS) or capacitor bank to supply make-up power during these occasions.

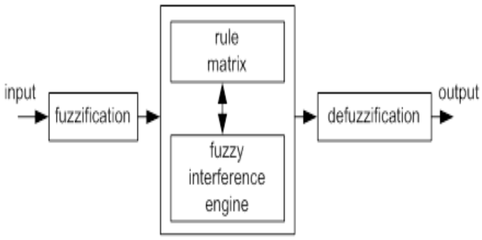
Numerous generator plans use electric current coursing through windings to create the attractive field on which the engine or generator works. This is rather than outlines those utilization changeless magnets to produce this field. Such devices may have a base working voltage, beneath which the device does not work effectively, or does as such at extraordinarily lessened proficiency. Some will remove themselves of the circuit when these conditions apply. This impact is more extreme in doubly-bolstered instigation generators (DFIG), which have two sequences of controlled attractive windings, than in squirrel-confine prompting generators which have one and only. Synchronous generators may slip and get to be shaky, if the voltage of the stator twisting goes down beneath a specific edge.

Extension

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.

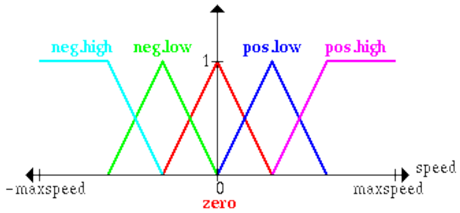
Usually fuzzy logic control system is created from four major elements presented on Figure fuzzification interface, fuzzy inference engine, fuzzy rule matrix and defuzzification interface. Each part along with basic fuzzy logic operations will be described in more detail below.



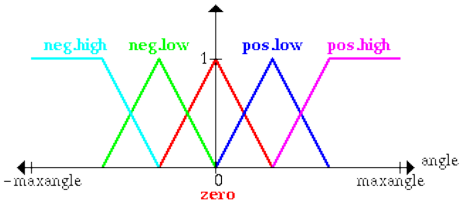
The fuzzy logic analysis and control methods shown in Figure 1 can be described as:

1. Receiving one or large number of measurements or other assessment of conditions existing in some system that will be analyzed or controlled.
2. Processing all received inputs according to human based, fuzzy "if-then" rules, which can be expressed in simple language words, and combined with traditional non-fuzzy processing.
3. Averaging and weighting the results from all the individual rules into one
single output decision or signal which decides what to do or tells a controlled system what to do. The result output signal is a precise defuzzified value.

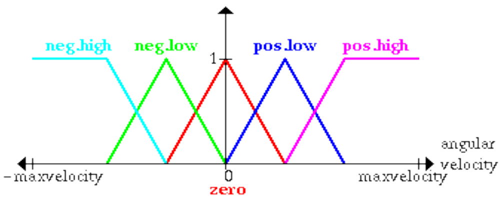
First of all, the different level of output (high speed, low speed etc.) of the platform is defined by specifying the membership functions for the fuzzy sets. The graph of the function is shown below



similarly, the different angles between the platform and the pendulum and...



the angular velocities of specific angles are also defined



Simulation results

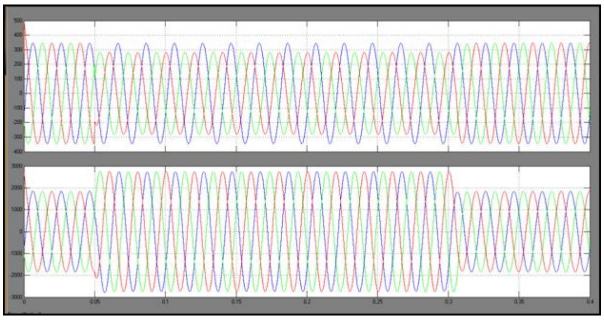


Fig. 2. (a) Grid voltages and (b) grid currents at the LV side under 60% SLG voltage sag produced at MV side of the transformer.

Fig.2 the output currents exceed the limits. This will lead to inverter disconnection, although it is not applied in this simulation. Unbalanced and distorted currents are produced because the instantaneous output power and the dc-link voltage have low-frequency ripples, and therefore, the active current reference contains low-frequency ripples as well.

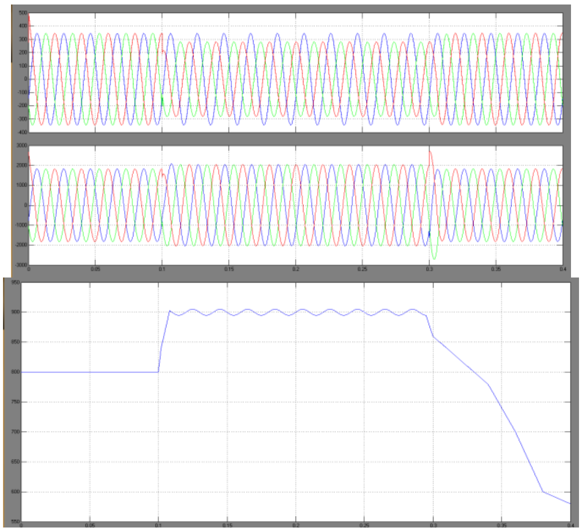
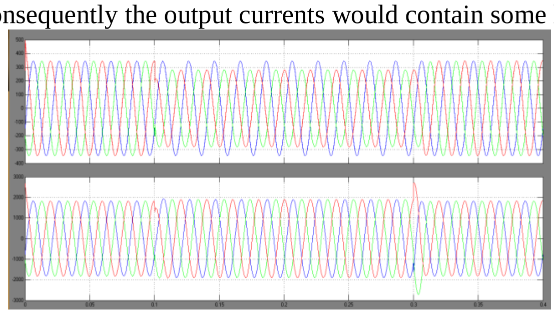


Fig. 3. Adding the current limiter to the VSI control: (a) grid voltages; (b) grid currents; and (c) dc-link voltage under an SLG-voltage sag at MV side of the transformer.

The generated currents after applying the current limiter in this example. One can observe in Fig. 3(b) that the grid currents are balanced. This is because the active current reference (i_{dref}) is limited to an almost constant value during the voltage sag. It should be mentioned that when operating with low solar radiation and/or small voltage sags, the active current reference may not be limited and therefore, it goes through the current limiter without being affected, i.e., $i_{dref} = i^1_{dref}$. As a consequence, if the voltage sag was unbalanced, the active current reference and consequently the output currents would contain some low-frequency harmonics.



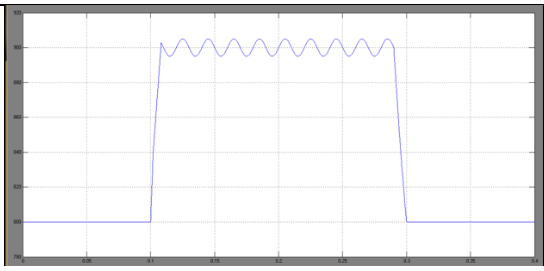


Fig.4. Application of an anti-wind-up technique to the PI controller: (a) grid voltages; (b) grid currents; and (c) dc-link voltage under 60% SLG voltage sag at MV side of the transformer.

Fig.4 In this case, once the grid fault is cleared, the dc link voltage recovers to the prefault value with no perceptible overcompensation.

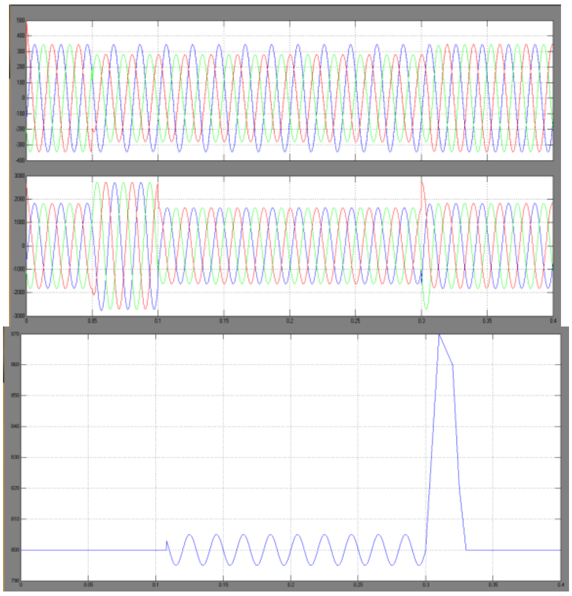


Fig. 5. Short-circuiting the PV panels: (a) grid voltages; (b) grid currents; and (c) dc-link voltage when applying a 60% SLG voltage sag at MV side of the transformer.

Some results for an SLG voltage sag with a 60% voltage drop at MV side occurred from t = 0.1s to t = 0.3 s. The generated power of the PV arrays and also the injected active and reactive power into the grid are shown in Fig.5. During the voltage sag, the dc-link voltage remains relatively constant, i_{dref} becomes almost zero with some ripples, and only i_{qref} is injected during the fault period.

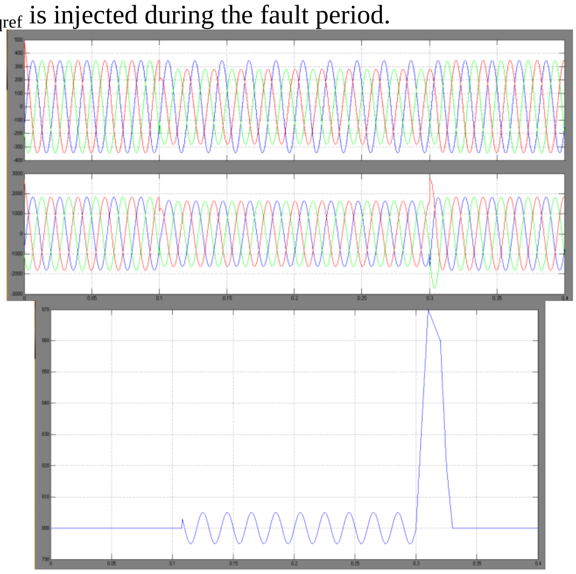


Fig. 6. Turning the dc–dc converter switch ON: (a) grid voltages; (b) grid currents; and (c) dc-link voltage

One where the diode was continuously ON and no current from the PV was provided to the dc-link. The main difference with the previous case is the transition process, as depicted in Fig. 6.

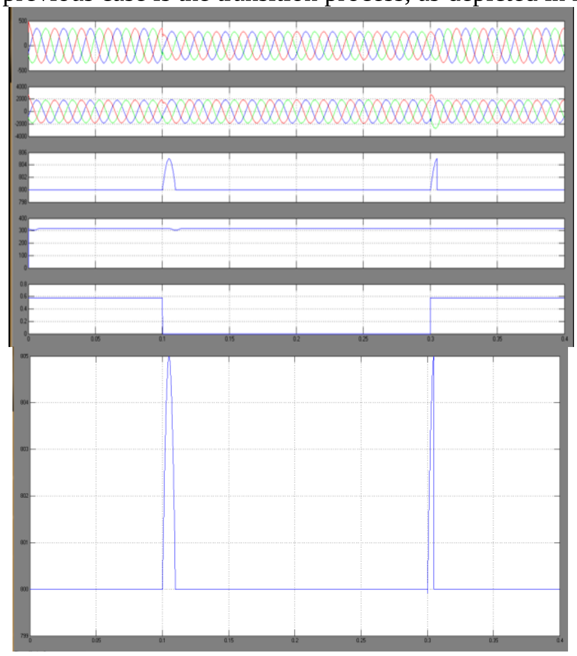


Fig. 7. Control of the dc–dc converter to produce less power under voltage sag: (a) grid voltages; (b) grid currents; (c) dc-link voltage; (d) input voltage of the dc–dc converter; (e) estimated duty cycle; and (f) actual duty cycle

As the PI controller (PI-1) is tuned to be slow in order to track the MPP during normal operation, the parameters of this controller (PI- 1) can be increased during the voltage sag in order to improve the performance of the proposed method.

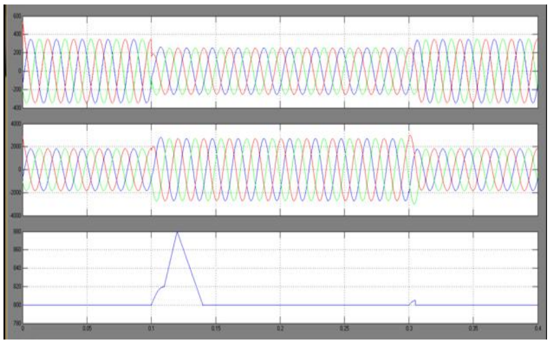
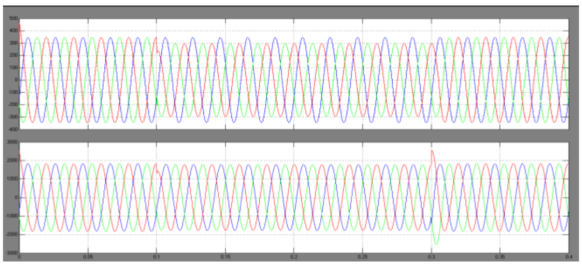
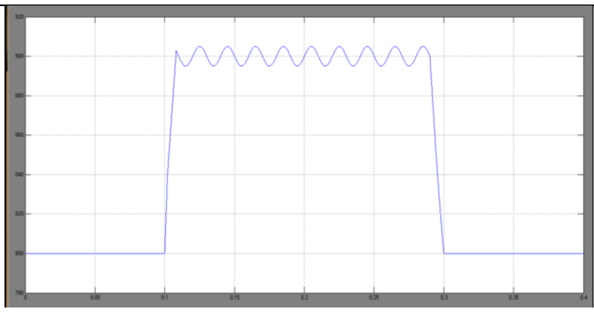


Fig. 8.Control of the dc–dc converter to produce less power under voltage sag: (a) grid voltages under a 3LG with 45% voltage sag at MV side; (b) related grid currents (c) related dc-link voltage

Extension results





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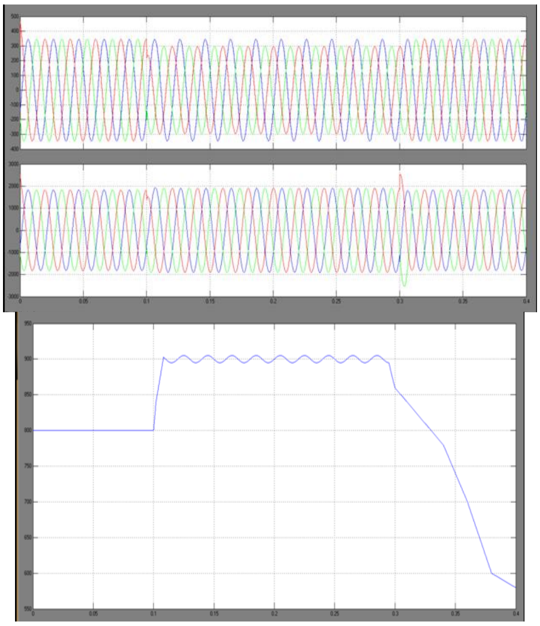

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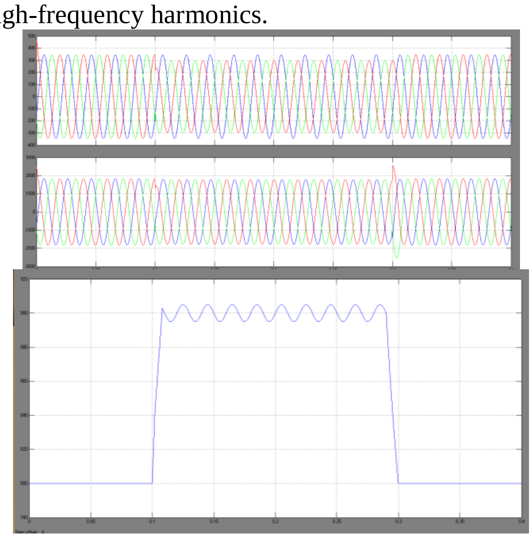
It should be mentioned that when operating with high solar radiation and/or small voltage sags. The output currents would contain some high-frequency harmonics.



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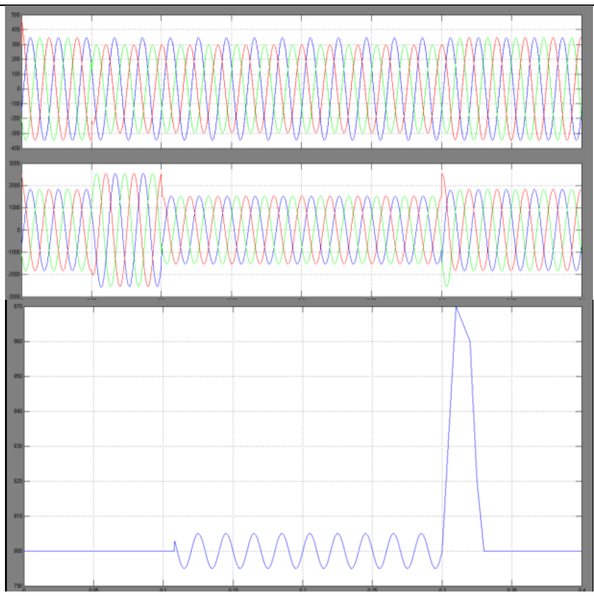

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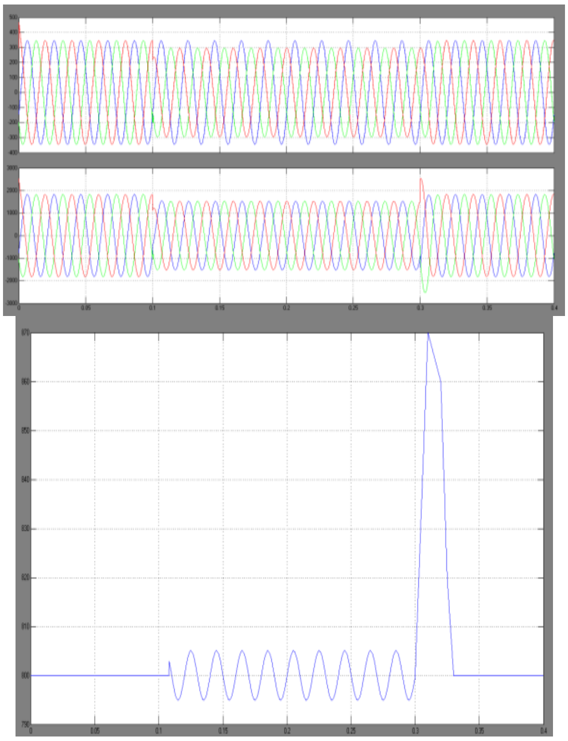

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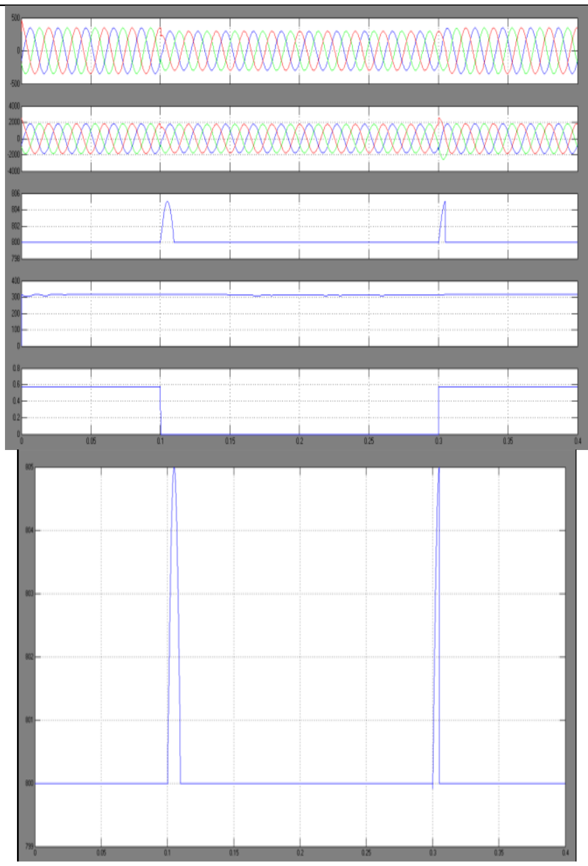

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The parameters of this controller (PI- 1) can be decreased during the voltage sag in order to improve the performance of the proposed method.

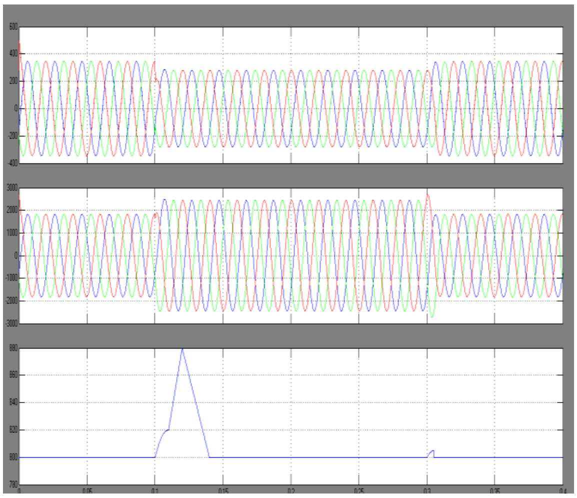

Fig. 8. Control of the dc–dc converter to produce less power under voltage sag: (a) grid voltages (b) related grid currents (c) related dc-link voltage;

Conclusion

In this project Performance requirements of GCPPPs under shortcoming conditions for single-and two-stage grid-connected inverters have been addressed. A few adjustments have been proposed for controllers to make the GCPPP ride-through perfect to faults as indicated by the GCs. These adjustments incorporate applying current limiters and controlling the dc-link voltage by various techniques. It is reasoned that for the single-stage design, the dc-link voltage is normally constrained and in this manner, the GCPPP is self-ensured, though in the two-phase design it is most certainly not. Three techniques have been proposed for the two-phase design to make the GCPPP ready to withstand any kind of flaws as per the GCs without being detached. The initial two techniques depend on not creating any force from the PV exhibits amid the voltage lists, though the third strategy changes the force purpose of the PV arrays to inject less power into the grid contrasted and the pre fault condition.

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