# RESILIENT SOLAR PV SYSTEM WITH FLEXIBLE DC LINK VOLTAGE ADJUSTMENT FOR ENHANCED POWER QUALITY IN WEAK GRID CONDITIONS

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**ABSTRACT:**
In this paper, a solar photovoltaic array (PVA) output unit which is linked to a utility grid with poor distribution is presented. In adopting an incremental conductance (InC) technique to manage the boost converter, the PVA power is maximized. Distortions, imbalance, voltage sag and voltage swell can all affect an unstable grid. These grid voltage shortcomings are prevented from affecting the regulated grid currents by the grid voltage filtering (GVF) stage used in the implemented control system. Additionally, any DC offset in the voltage signal is neutralized by the GVF. Flexibility in controlling the DC link voltage prevents over modulation operating in poor grid conditions. The grid power quality is maintained in strong unbalanced voltage circumstances due to the flexible regulation. The system functions efficiently irrespective of the grid voltages, load currents or PVA power fluctuate. For quickly determining the load current weights, DC link voltage variations at load fluctuations are avoided. For system validation, the system capacity to function in difficult operating conditions is demonstrated.
**Keywords:** power quality, adjustable DC link voltage, PV production, and weak grid.

## INTRODUCTION :

Clean energy sources such as solar photovoltaic (PV) energy have grown in popularity as a result of the deteriorating global energy situation and growing awareness of the harmful effects of burning fossil fuels [1]. Distributed generation (DG) plants are quickly adopting PV array (PVA) based generation since it is practical for tiny generating units [2]. In order to get around the need for battery storage for reliability issues, it ends to be grid interactive [3]. In order to maintain PVA's continuous operation at the maximum power point (MPP), the generated PV power that exceeds the prevailing load needs can be delivered to the grid. The MPP is the operational point at which the PVA produces peak power. Nevertheless, this point continues to alter as the surroundings change. The scientific literatures are extensively examined the MPP operation, which is crucial [4]. To achieve this, the work which is being discussed employs a boost converter it is controlled by an incremental conductance (InC) methodology. This approach provides real-time information on the MPP with far less computing effort. The voltage source converter (VSC) and the PVA can be decoupled by the boost converter, allowing the VSC DC link voltage to be independently adjusted. Applying this property represents the effort which can be considering delivers.

In many distribution networks, an unstable grid issue occurs. As a result, there is distortion or imbalance in the voltages. Variations can also happen in the voltage magnitude. At such circumstances, the grid currents produced by traditional PV systems [5] are not balanced and distortion-free. These harmful effects are eliminated from the sustained grid currents by the two-

 

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stage grid voltage filtering (GVF) approach used in the proposed study. A large percentage of the input signal harmonic voltages are eliminated together with the DC offset elimination using the third order generalized integral (GI) [6]. Nevertheless, if its output voltages are not balanced, the system can tolerate undesired grid currents. Consequently, a first order sequence filter (FOSF) [7] is utilized to quickly extract positive sequence voltages and further eliminate harmonic voltages.
The distribution network is now more likely to suffer from nonlinear loads [8]. For the maintenance of distortion-free and balanced grid currents, in addition to situations with uneven loads or unbalanced voltage, the proposed solution improves the grid power quality. The grid's measured power factor remains at unity. These operations continue even when PVA generation is not present.
A fixed reference value is used by the traditional systems [9–10] to maintain the DC link voltage. The usage of variable reference value in [11] results in the enhanced functioning. Nonetheless, the average grid voltage is taken into account. For very imbalanced grid voltages that can arise in the modern distribution network, the calculated reference is deemed inappropriate and results in over modulation operation. Through the use of a flexible reference control, which determines the reference value based on the phase with the highest swell voltage, the work that is being presented achieves a sufficient DC link voltage to provide the necessary control over the grid currents. The results that are shown assess the alleged advantages.

**CONFIGURATION OF THE SYSTEM:**
In Fig. 1, the system configuration is shown. The boost converter is responsible for providing the decoupling between the PVA and the DC link capacitor. Interfacing inductors smooth the VSC currents as they communicate with the grid at the point of interconnection (POI). At the point of attraction, there exist nonlinear local loads. With an RC filter, the VSC switching disturbances are reduced.

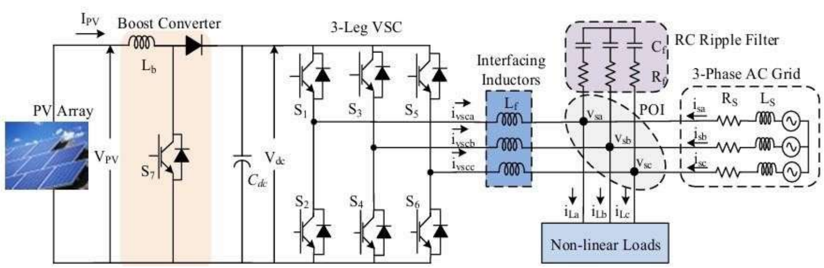

Fig. 1. System configuration

**ALGORITHM FOR CONTROL:**
The boost converter is controlled in real time for peak power harvesting, GVF stage, and VSC switching pulse creation as an element of the control approach. **Switching of Boost Converters:**
The PVA is limited to operating at its peak power by the boost converter. According to the InC technique, the PV voltage (VPV) and current (IPV) are measured and the following relations are applied.

$$If\ \frac{dI_{PV}}{dV_{PV}} > -\frac{I_{PV}}{V_{PV}} \Rightarrow D = D_P - \Delta D$$
$$If\ \frac{dI_{PV}}{dV_{PV}} = -\frac{I_{PV}}{V_{PV}} \Rightarrow D = D_P$$
$$If\ \frac{dI_{PV}}{dV_{PV}} < -\frac{I_{PV}}{V_{PV}} \Rightarrow D = D_P + \Delta D \quad (1)$$

Where ΔD is the designated update size, D and Dp are the duty ratios for the current and previous iterations, respectively.
**VSC control:**

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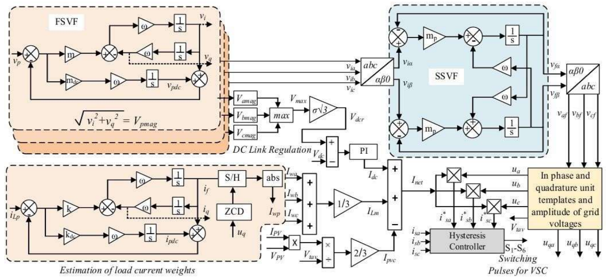



Fig. 2. Control of VSC.

Fig. 2 is an illustration of the VSC control structure. The corresponding phase voltages are obtained by converting a pair of line voltages as [8].

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 2 & 1 \\ -1 & 1 \\ -1 & -2 \end{bmatrix}\begin{bmatrix} v_{ab} \\ v_{bc} \end{bmatrix} \qquad (2)$$

In poor grid circumstances, the aforementioned voltages are distorted and out of balance. The first stage voltage filter (FSVF) eliminates the distortions and DC offset in (2). The second stage voltage filter (SSVF) receives the FSVF output after it becomes converted to the α-β domain as

$$\begin{bmatrix} v_{i\alpha} \\ v_{i\beta} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} v_{ia} \\ v_{ib} \\ v_{ic} \end{bmatrix} \qquad (3)$$

In the SSVF, the negative sequence voltages are attenuated. Its output is returned to the domain of a-b-c as,

$$\begin{bmatrix} v_{af} \\ v_{bf} \\ v_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} v_{f\alpha} \\ v_{f\beta} \end{bmatrix} \qquad (4)$$

There is no DC offset, imbalance, or distortion in these voltages. In-phase, quadrature, and average voltage amplitude templates are computed as follows:

$$V_{tav} = \sqrt{2(v_{af}^2 + v_{bf}^2 + v_{cf}^2)/3} \qquad (5)$$

$$u_a = v_{af}/v_{tav}, u_b = v_{bf}/v_{tav}, u_c = v_{cf}/v_{tav} \qquad (6)$$

$$\begin{bmatrix} u_{qa} \\ u_{qb} \\ u_{qc} \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{\sqrt{3}}{2} & \frac{1}{2\sqrt{3}} & -\frac{1}{2\sqrt{3}} \\ -\frac{\sqrt{3}}{2} & \frac{1}{2\sqrt{3}} & -\frac{1}{2\sqrt{3}} \end{bmatrix}\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \qquad (7)$$

The grid power quality is significantly influenced by the DC link voltage (Vdc). As a result, its reference (Vdcr) is adjusted to the grid circumstances. This strategy prevents the VSC from over modulating, which results from inadequate Vdc and degrades power quality. The voltage amplitude of each phase is provided by the FSVF as,

$$V_{pmag} = \sqrt{v_i^2 + v_q^2} \qquad (8)$$

where the orthogonal signals supplied by the FSVF are denoted by vi and vq. The greatest value (Vmax) is chosen from these and utilized to compute Vdcr in the manner described below:

$$V_{dcr} = \sigma\sqrt{3}V_{max}, \qquad \sigma > 1 \qquad (9)$$

The voltage drops caused by the VSC switches and coupling inductors is compensated for using the term "σ." The output term Idc is produced by a proportional integral (PI) regulator tracking Vdc to the reference Vdcr. When there are abrupt changes in voltages, loads or PVA power, the PI unit must quickly update the grid currents. In these situations, it is unable to react quickly. The active load current weight of each phase is determined using the third order GI, which gives the DC offset free fundamental in-phase component, in order to reduce the variances in Vdc at load perturbations. For obtaining the necessary weights (Iwa, Iwb and Iwc), a zero-crossing detector is applied to the quadrature voltage templates, a sample and hold block and a magnitude block. From that, their average is calculated as follows:

$$I_{Lm} = (I_{wa} + I_{wb} + I_{wc})/3 \qquad (10)$$

For a quicker reaction to PVA power or grid voltage disturbances, the direct contribution of PVA power to grid currents (Ipvc) is computed as follows:

$$I_{pvc} = \frac{2V_{PV}I_{PV}}{3V_{tav}} \qquad (11)$$

The ultimate weight is determined as follows:

$$I_{net} = I_{Lm} + I_{dc} - I_{pvc} \qquad (12)$$

The reference waveforms are formed as follows since it is intended to attain unity power factor at the POI:

$$i_{sa}^* = I_{net}u_a, i_{sb}^* = I_{net}u_b, i_{sc}^* = I_{net}u_c \qquad (13)$$

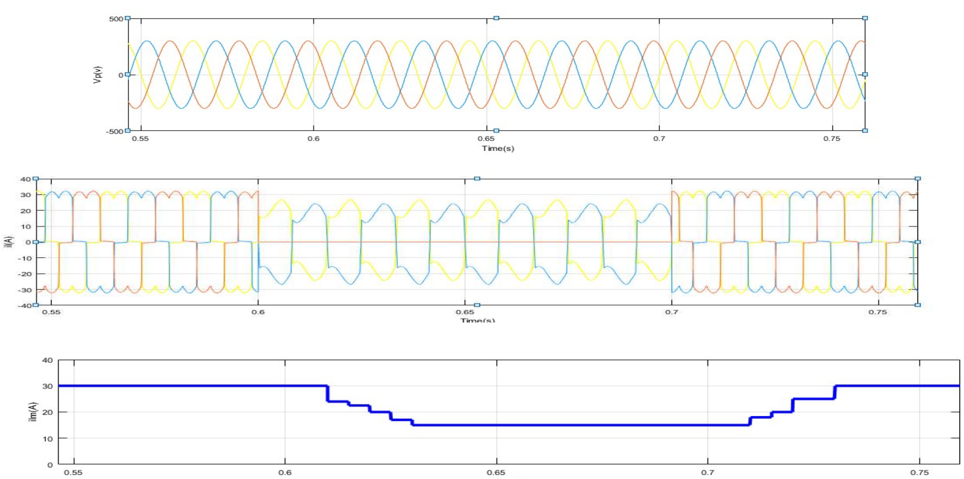
The necessary switching pulses are produced by a hysteresis controller, which attempts to bring the difference between the currents in (13) and the detected waveforms down to a certain limit.

## SIMULATION RESULTS :

The PV system model and related control techniques are created using the MATLAB/ SIMULINK platform and evaluated under several unique operating conditions. Furthermore, the enhancement in power quality made possible by the DC link voltage regulation which is demonstrated can also be noted.

## TRANSIENT OPERATION AT UNBALANCED LOAD:

Fig. 3 shows the impact of load disturbance on the system. A load phase is separated at 0.6 s and reattached at 0.7 s. A quick change in the grid currents (is) causes a quick response from the mean weight of the three phases (ILm). The result retains the power balance stable and avoids significant variations in Vdc. The boost converter's quick responsiveness ensures that the PV power (PPV) remains constant. At 0.6 seconds, the VSC current of phase "a" turns sinusoidal due to the fact there is no associated load, the full output current flows to the grid.



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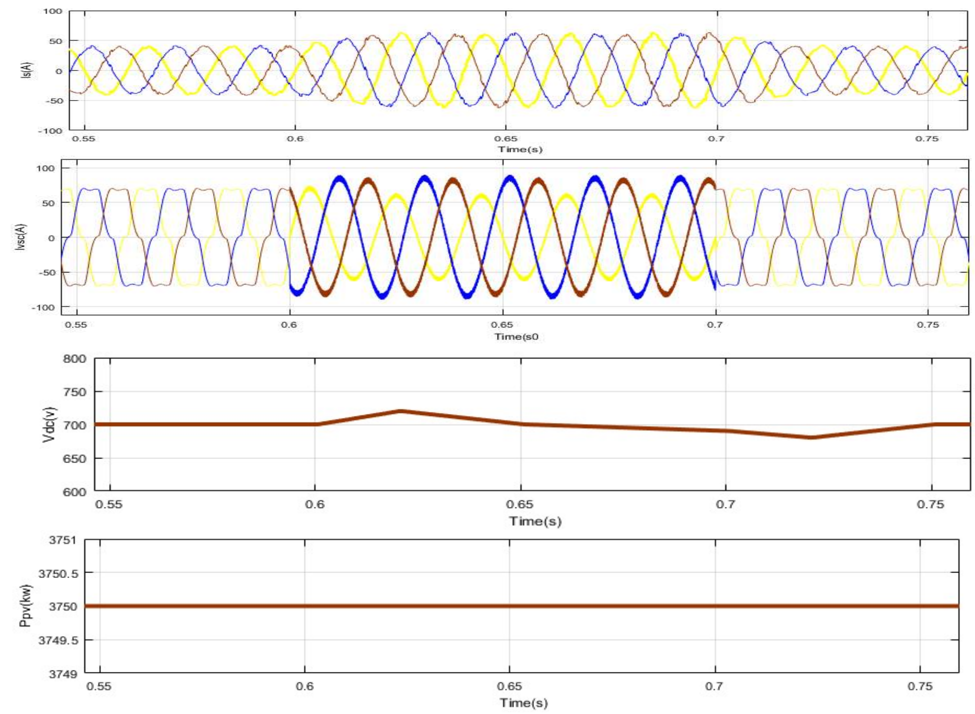
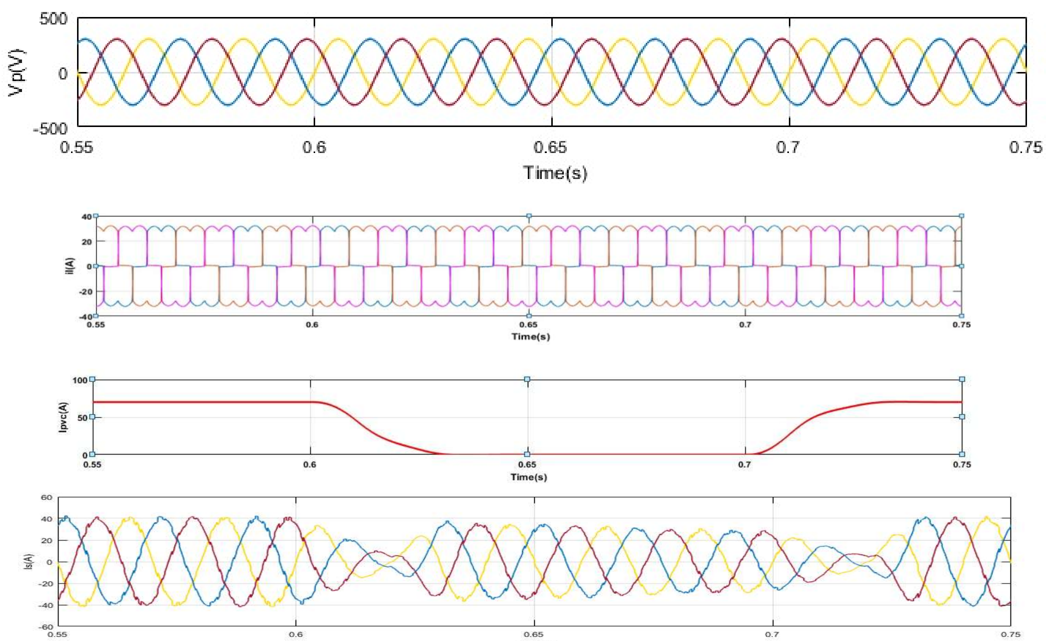



Fig.3.Performance under variations in load **Function at**

**DIFFERENT PVA POWER LEVELS:**

Fig. 4 illustrates the operation at fast PVA power fluctuations, with a total loss of PVA power occurring at 0.6 s and its restoration occurring at 0.7 s. Ipvc is a word that reflects changes in PPV and facilitates quick updates. Thus, a steady Vdc is maintained. When PPV decreases, the phase reversal occurs. This is due to the fact that the leftover PVA power is first going to the grid. It turned 180 degrees out of phase with the grid voltages (vp) as a result. However, the grid meets the load power need when PPV is reduced. In despite of the extremely nonlinear loads, the grid power quality remains unaffected because the VSC continues to inject compensating currents at the POI.



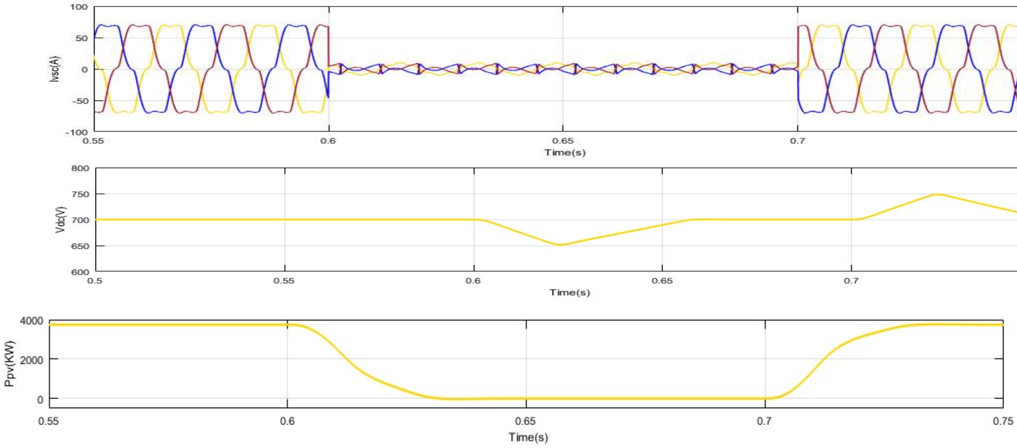



Fig.4.

Performance at PVA power gains and losses

**RESPONSE AT UNBALANCED GRID VOLTAGES:**

Fig. 5 shows the system behaviour at distorted grid voltages. After 0.6 seconds, there is significant distortion in the grid voltages. Under such circumstances, distortion-free currents cannot be sustained by traditional systems. The ripple-free Vtav is calculated and the output voltages of the GVF stage (vf) and the voltage unit templates (up) are harmonic-free. As a result, the reference grid currents are free of these flaws, stay harmonic-free and sustain oscillation-free Vdc.

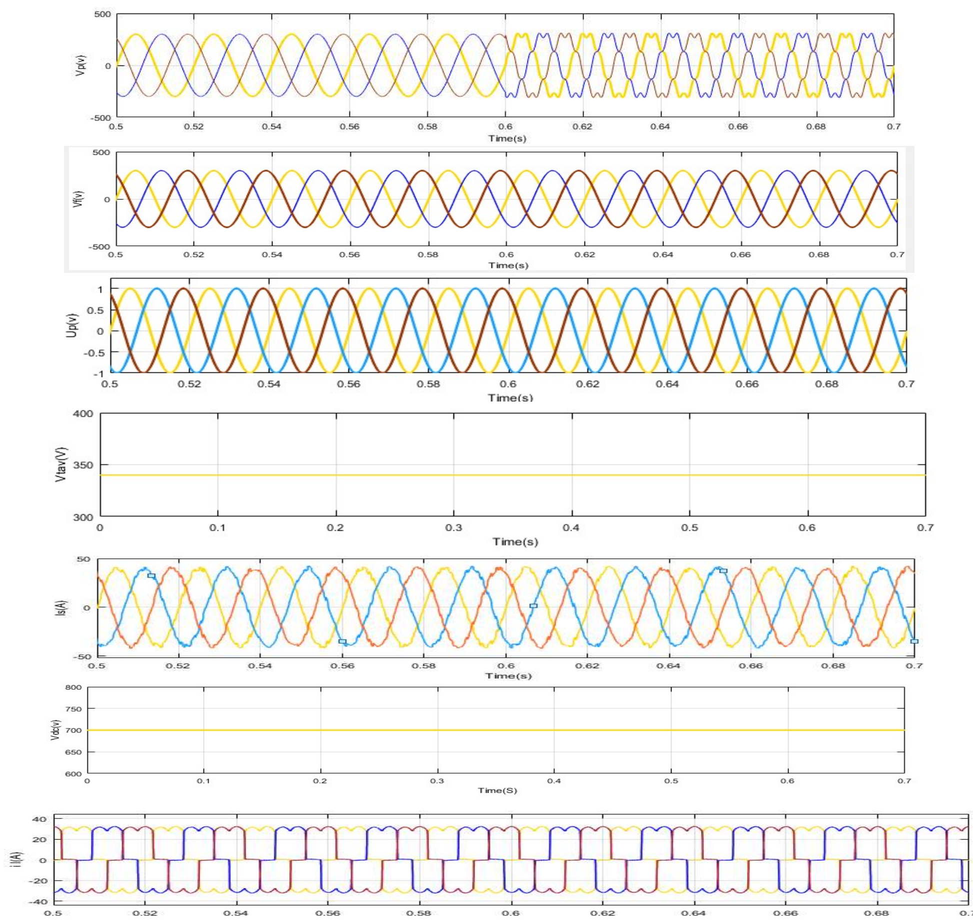



Fig.5. Performance at grid voltage distortions

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**EFFECTIVENESS OF ADAPTABLE DC LINK VOLTAGE REGULATION:**

As seen in Figs. 6-10, where the system suffers a 40% voltage swell in phase "a" alone while the other phases are at normal voltages, the provided control of Vdc performs better than the adaptive adjustment documented in the literature [11]. In contrast to traditional systems that use a fixed reference value, Fig. 6 illustrates the scenario in which the reference value of Vdc is adjusted based on the average phase voltage amplitude (Vtav) [11]. The voltage is balanced as the GVF is able to reject the imbalance. There is no effect on the unit templates either. The reference voltage acquired using Vtav in this case is inadequate and cannot stop over modulation. when a result, the power quality deteriorates when the wave-shaping is altered and harmonic currents are introduced into the grid. Fig. 7 illustrates that the load current contains a high total harmonic distortion (THD) of 22.84%, and Fig. 8 shows that the THD level is 9.28%. The IEEE 519 standard does not, however, include the harmonic content [12].

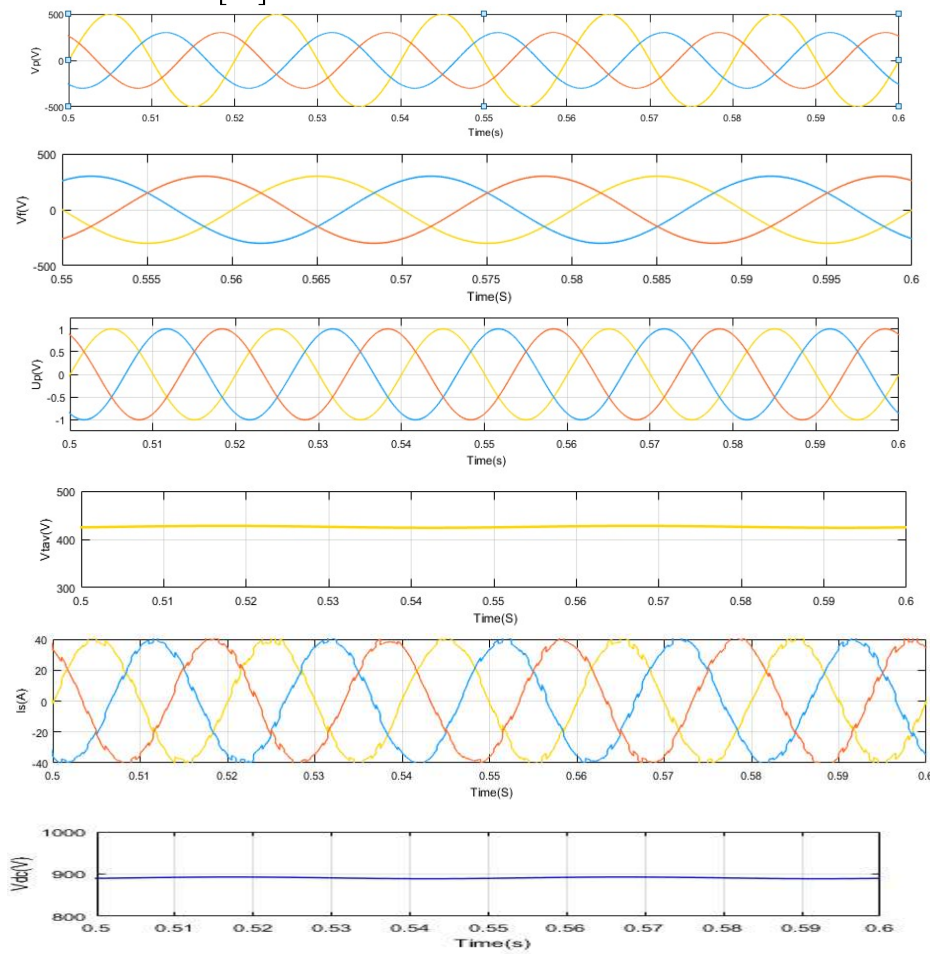


Fig.6.Performance with standard adjustment at swell in phase "a" voltage.

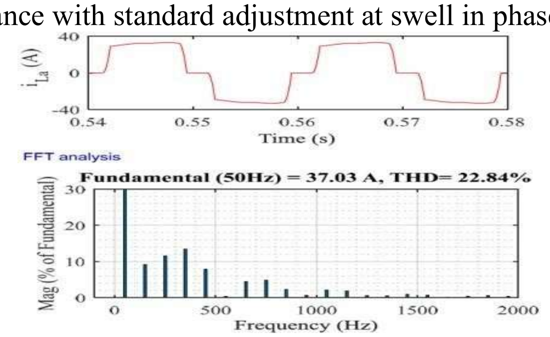


Fig.7. Harmonic structure of the load current.

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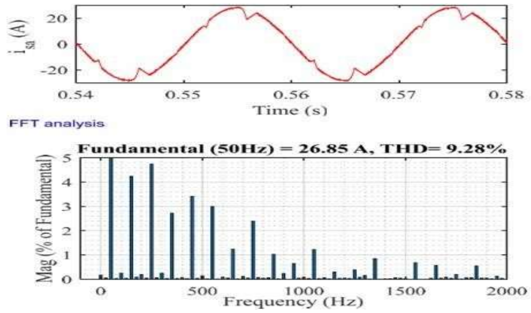


Fig.8. Harmonic content of traditional flexible control.

Fig. 9 shows a similar working environment for the system, but this time the proposed Vdc control approach is applied. The reference Vdc is derived using the maximum phase voltage amplitude (Vmax) which obtained from the FSVF. Thus, the VSC sustains sinusoidal grid currents and the Vdc needed for appropriate wave-shaping of it is accessible. The enhancement is supported by Fig. 10, which shows that the THD level is 3.04%, significantly beyond the acceptable ranges [12].

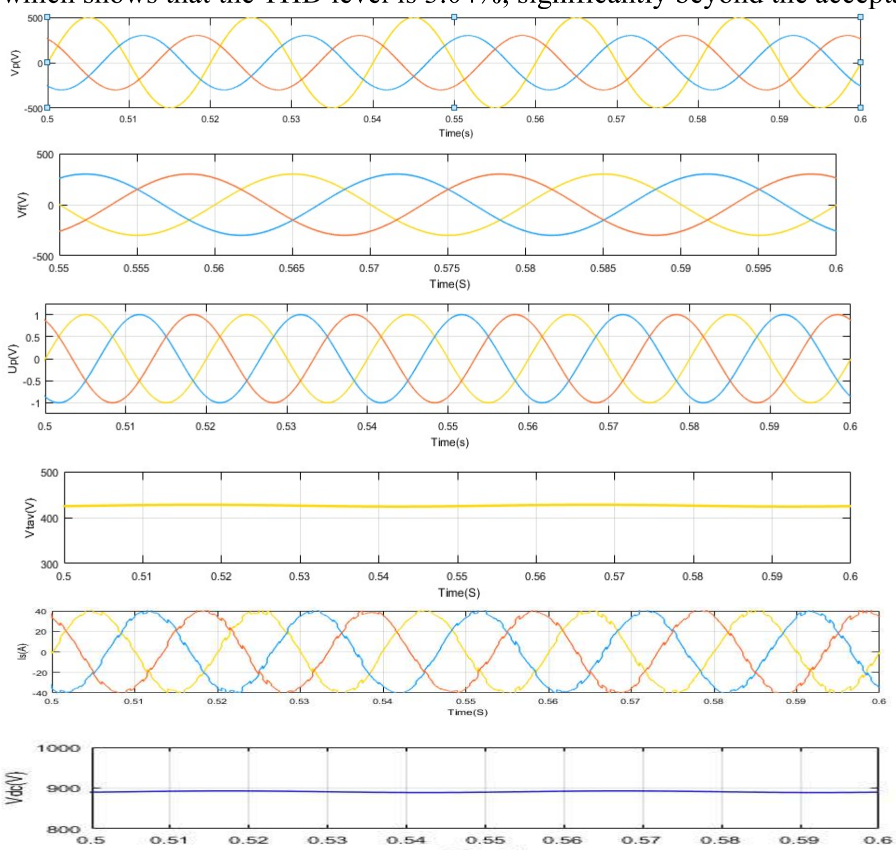


Fig.9. Response at swell in phase ‘a’ voltage with presented flexible DC link voltage control.

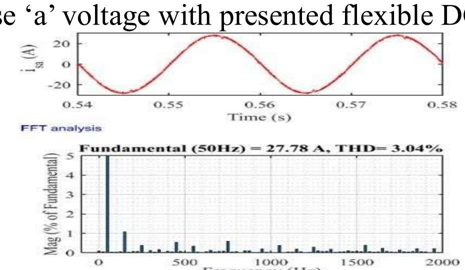


Fig.10. Harmonic content of presented flexible control.

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## CONCLUSION:

In poor grid circumstances, the grid-connected PV system continues to operate robustly. For eliminating the detrimental impact of a weak and non-ideal grid on the currents of the system regulates, the two-stage GVF results in balanced and distortion-free grid currents in difficult grid circumstances. Implementing the proposed DC link voltage handling is being shown to increase power quality compared to both the traditional and conventional adaptive techniques. It proves successful in preventing over modulation. PVA power fluctuations, nonlinear loading scenarios, fast load changes and an absence of PVA power are all used to validate the system power quality enhancement features.

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