Dc Link Voltage Balance Of Grid Integrated Pv Module Using Pi-Awt

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Abstract: ***The purpose of this paper is to investigate the performance of a PV-based grid-connected system. In the suggested arrangement, there are two phases in the conversion process. The conversion of alternating current voltage to direct current voltage is the first stage. It is decided to use the usual two-level converter at this point. The second stage consists of converting the direct current voltage to alternating current voltage using a typical two-level voltage source converter (VSC). A control technique based on the Anti-windup tuned PI (PI+AWT) is being developed to govern the dc link voltage at VSC of the second stage conversion. The proportional resonant controller is used to control the current signals and also to regulate the reference signals in the pulse width modulation (PWM) scheme, which is described in detail below. The sinusoidal pulse width modulation (PWM) technique is used to regulate VSC switches. The suggested controller's performance is evaluated under three different conditions: continuous irradiation, change of irradiation, and three-phase fault. MATLAB/SIMULINK is used to calculate the parameters of the results.***

Keywords: **PV; PWM; PI; AWT; PR**

1. INTRODUCTION

Renewable energy sources have got a lot of responsiveness in the last twenty years because of the rising costs, limited reserves, and negative impact on the environment of fossil fuels [1]. In the last two decades, a wide range of solar power techniques have been developed, improving conversion efficiency and lowering the cost of solar power generation [1]. This industry continues to move forward despite photovolatic efficiency and controllability going up in recent decades, as well as its tighter integration with the grid [3]. The deficiency of grid integrated solar power in power system applications are the power system stability and power quality which reflects on power unbalance and voltage control [6-8]. The suitable control algorithms are required to overcome the challenges in grid integration of solar power [9]. Various control technique used for this purpose is addressed in [10]. The active and reactive power control method [11] Conservative power theory [12] has adopted for control of grid integrated PV system. The voltage control of dc link is the key issue in grid connected voltage source converters [13]. The PI and Fuzzy Logic Controllers are the methods used for the balancing of dc-voltage [14-15]. The PI controller is generally used for the balancing of dc-voltage [16-17]. Power smoothing control methodologies are addressed in [18-19]. In this paper, the PI tuned Anti windup Technique (AWT) is projected to regulate the dc voltage.

2. MODELING OF THE SYSTEM

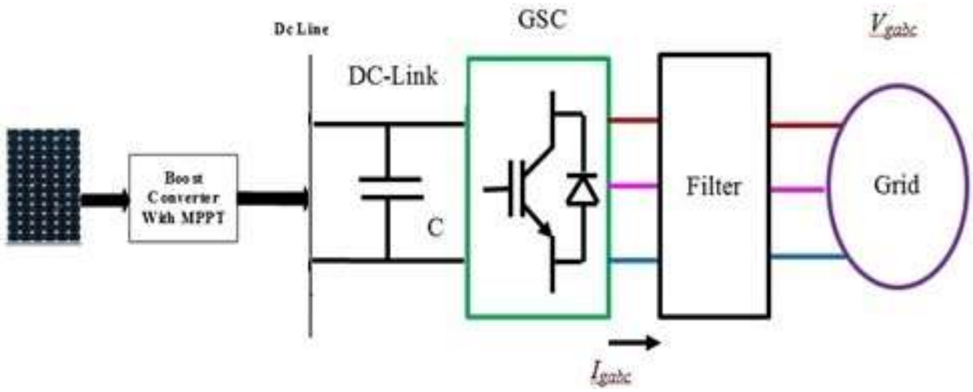


Figure 1. Block diagram of system

The equivalent circuit of PV cell is show in Fig. 2. The PV cell modeling [14] can be described by the following equations:

$$I = I_L - I_D \left\{ e^{\frac{q(v+IR_s)}{nkT}} - 1 \right\} \quad (1)$$

The PV power at time t is calculated by [15]

$$P_{pv}(t) = S_r(t) * a * \eta \quad (2)$$

The total PV system power calculated by

$$P_t(t) = Np_v * P_{pv}(t) \quad (3)$$

The PV model includes following parameters:
IL = Light generated current (A)
ID = Reverse saturation current of diode (A)
v = Operating voltage of array (V)
k = Boltzmann constant (J/°K)
n = No. of series connected cell
T = Temperature (°K)
Rs = Equivalent series resistance (Ω)
Rsh = Equivalent shunt resistance (Ω)
q = Charge on electrons
a = Ideality factor
η = System efficiency
Sr = Solar irradiation during time (t)
Npv = Total no. of solar module

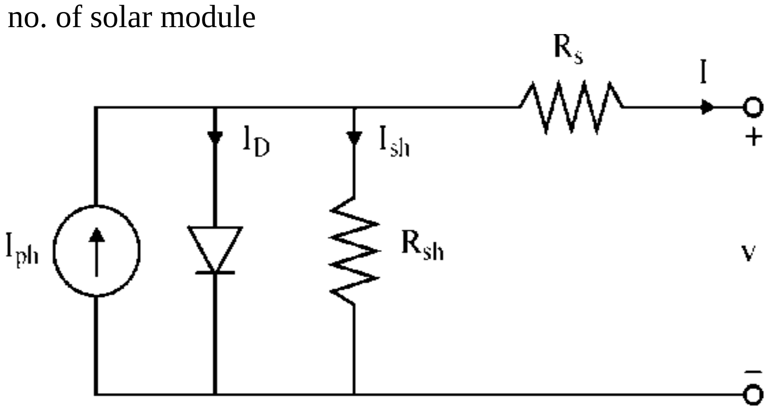


Fig. 2 The equivalent circuit of PV cell

Considering zero sequence components in a 3-phase system is not necessary because there is no circulation path. Eq.(4) depicts the three-phase balanced voltages.

$$\begin{bmatrix} V_{ga} \\ V_{gb} \\ V_{gc} \end{bmatrix} = V_m \begin{bmatrix} \sin \omega t \\ \sin(\omega t + 120^0) \\ \sin(\omega t - 120^0) \end{bmatrix} \quad (4)$$

Control systems enable an increase in the efficiency and quality of output power from a PV energy conversion system. They are closed-loop feedback systems that control switching elements in active power conversion stages. Initially, the voltage can be sensed and controlled using an active rectifier and a proportional integral (PI) controller. Second, the grid-side inverter PWM signal can be used to regulate a system. It can be adopted to keep DC link at a constant voltage, which will decouple the grid from power fluctuations caused by irradiation variations.

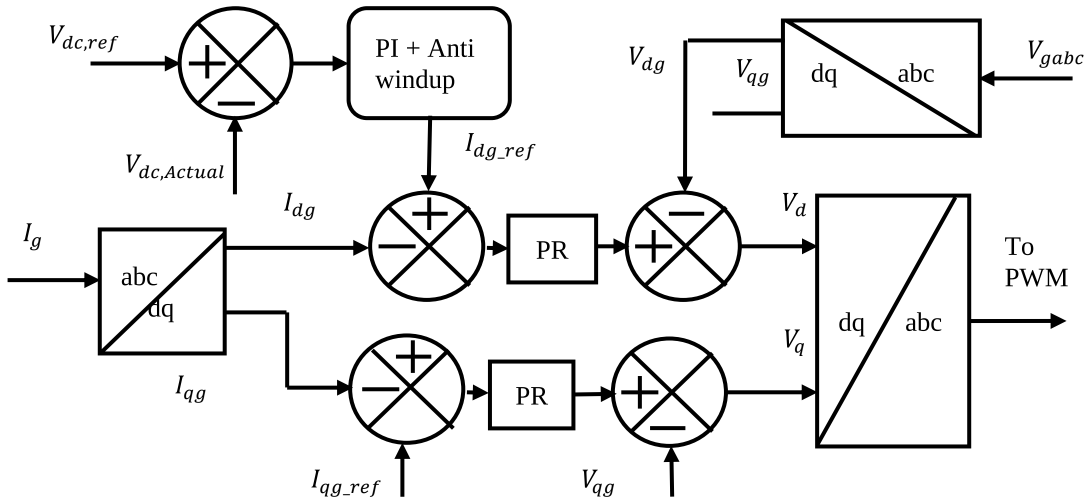


Figure 3. Control block diagram of GSC

The goal of the grid side converter (GSC) is to keep the dc-link voltage constant. Fig.3 depicts the block diagram for control of GSC. The current reference (Idg_ref) is generated using PI+AWT method. The GSC output current is converted from abc signal to dq signal and this current components are compared with reference currents of I_{dg_ref} and I_{qg_ref}. This design is made up of one outer voltage loops and two inner current loops, which are connected together. The dc-link voltage loop provides the reference d-axis component of grid current. It is necessary to match the reference and measured dc-link voltages, and vector control is used to minimise errors. The reference d-axis grid current is produced by the PI+AWT controller. Inner proportional-resonant (PR) controller produces d-q axis grid voltage from d-axis reference grid current and actual d-axis grid current. Park transformation is adopted to convert the d-q voltage components into natural abc grid components. The actual three-phase abc grid voltage components are then sent to the PWM generator, which generates the firing pulses to the VSC. Figure 4 depicts the PR controller's block diagram. The PR control method has a high gain at the resonant frequency, which ensures that presented a little steady-state inaccuracy between the actual and reference signals. The PR controller is composed of a proportional and a resonant term.

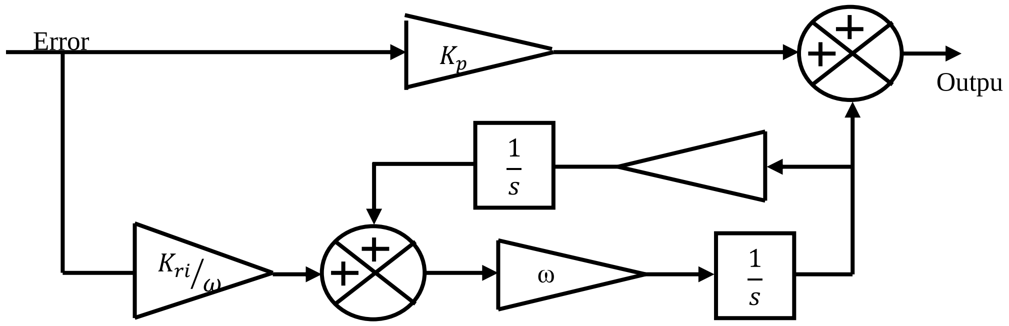


Figure 4. Block diagram of PR current controller

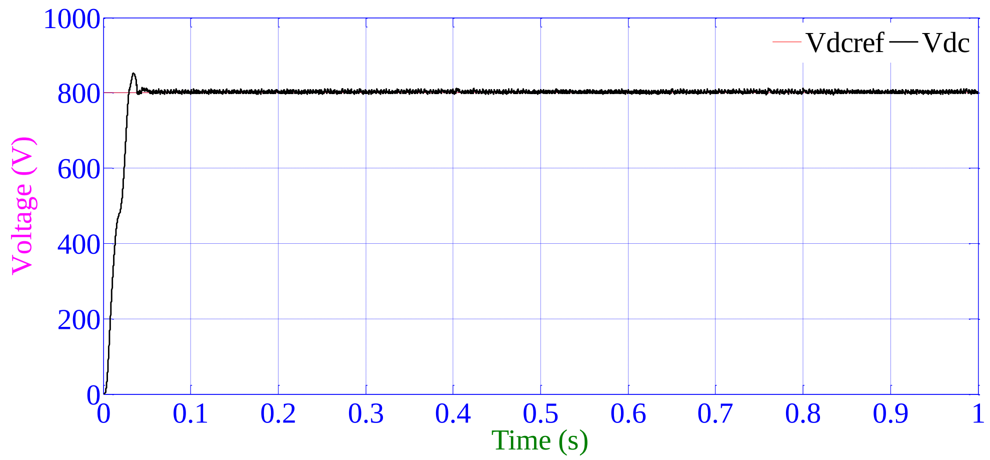
3. Simulation Result and Analysis

The performance of proposed grid connected PV system is analyzed using Matlab/ simulink. The proposed work is simulated in three cases such as constant irradiation, variable irradiation and three phase fault condition. Table 1 contains the simulation parameters.

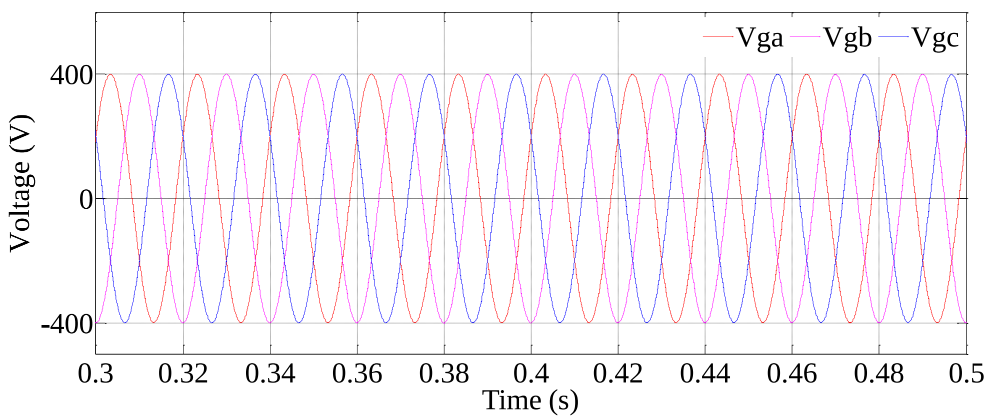
Table 1: Simulation parameters

Description	Value
DC link Capacitor	4700 μF
Reference DC voltage	800V
Switches	IGBT
Switching frequency	7000Hz
Filter inductance	6 mH
Voltage	400V (r.m.s)
Frequency	50 Hz
Source resistance	0.01Ω
Source inductance	2μH

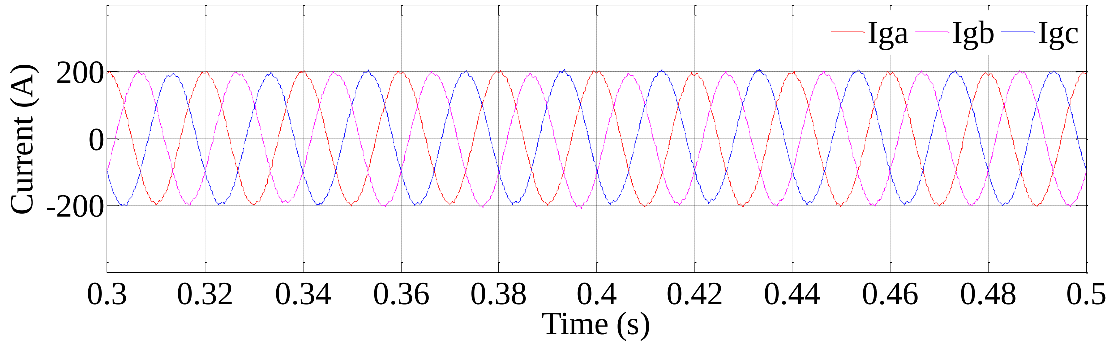
The first case simulation response curves are illustrated in Fig. 5. In the first case, the DC link voltage is regulated and there is no difference between reference and actual voltage is observed using proposed controller and is illustrated in Fig. 5 (a). That shows the actual value is perfectly tracking the reference value. The response curves of voltages and currents of Grid are presented in Fig. Fig. 5 (b). The response curves of grid voltage and current are presented in Fig.5 (c) using proposed controller. All grid voltages and currents are sinusoidal and balanced using proposed controller.



(a) DC link Voltage



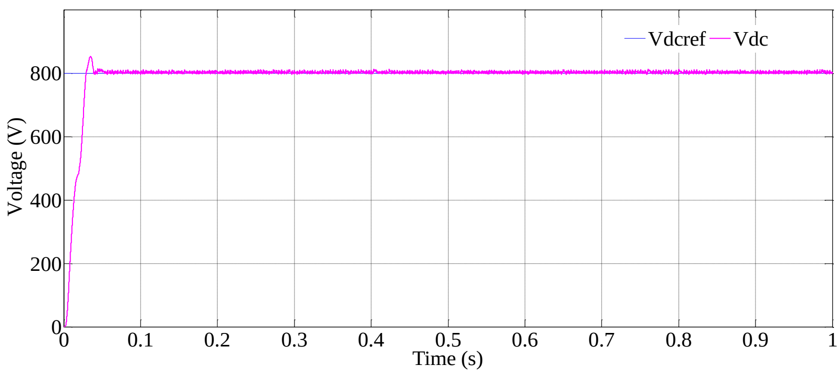
(b) Grid Voltage



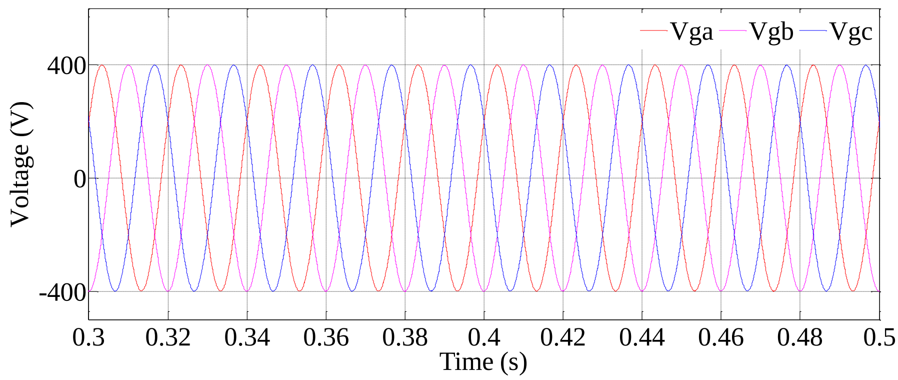
(c) Grid Current

Figure 5. Response curves of proposed controller under constant irradiation

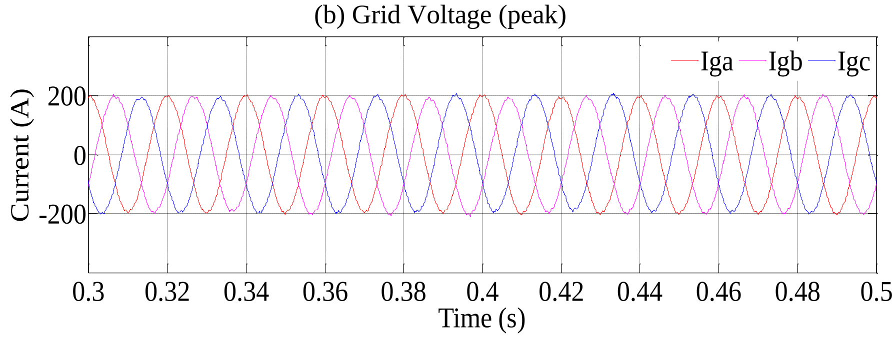
The second case simulation response curves are illustrated in Fig. 6. In the second case, the irradiation is set in different values in different times as depicted in Fig. 6 (a). The DC link voltage using proposed controller is tracking the reference voltage as depicted in Fig. 6 (a). No difference value between reference and actual voltage is observed using proposed controller. That shows the actual value is perfectly tracking the reference value. The response curves of grid voltage and current are presented in Fig.6 (b & c). All the grid voltages and currents of grid are sinusoidal and balanced using proposed controller.



(a) DC link Voltage

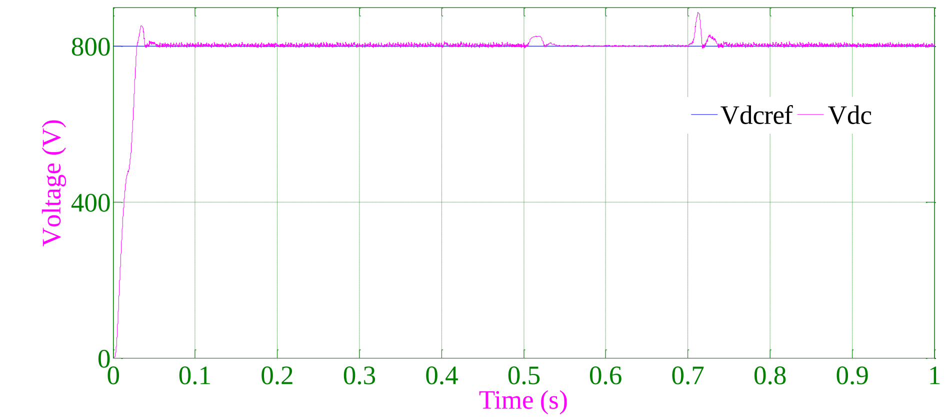


(b) Grid Voltage (peak)

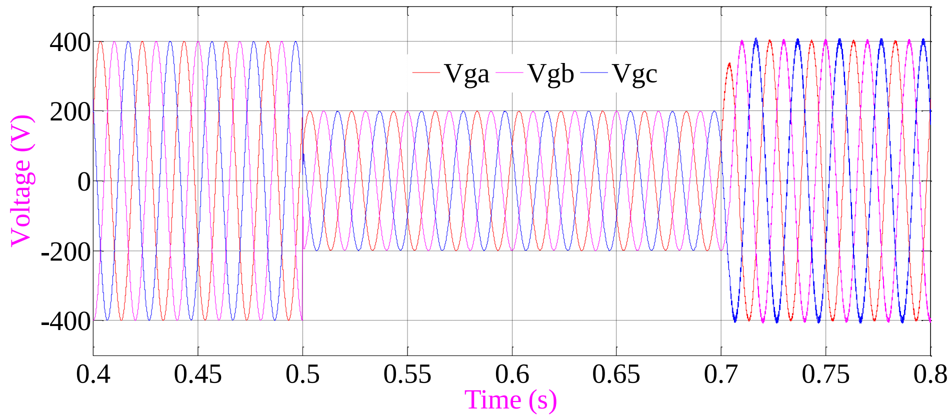


(c) Grid Current

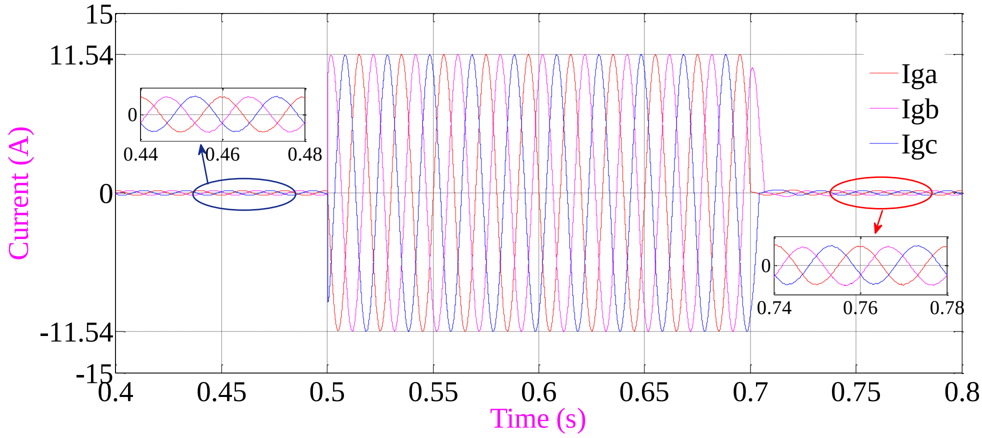
Figure 6. Response curves using proposed controller under variable irradiation



(a) DC link Voltage



(b) Grid Voltage



(c) Grid Current

Figure 7. Response curves using proposed controller under three phase fault condition

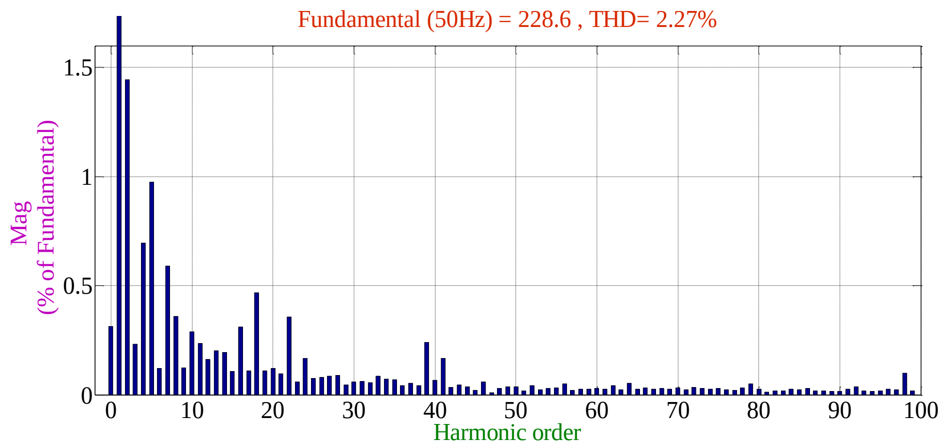
The performance of proposed controller is further extended to validate under fault condition. For this, three phase fault is applied from t=0.5sec to t=0.7sec. The actual DC voltage is accurately follows the reference voltage in three conditions as depicted in Fig.7 (a). The grid voltages are 200V during the fault condition and immediately retained the value of 400V after fault clearance which is presented in Fig. 7(b). The response curves of current are presented in Fig.7 (c) It is observed that the proposed controller have effectiveness in stabilization of currents after fault clearance compared.

Further, the comparative performance analysis has made with THD and DC link voltage regulation. FFT spectrum using conventional controller (PI) and proposed controller (PI+AWT) are presented in Fig.8 (a) and Fig.8 (b). The THD using the PI controller have recorded 2.27% while the proposed controller is 2.01%. The proposed controller has given good performance compared to conventional controller.

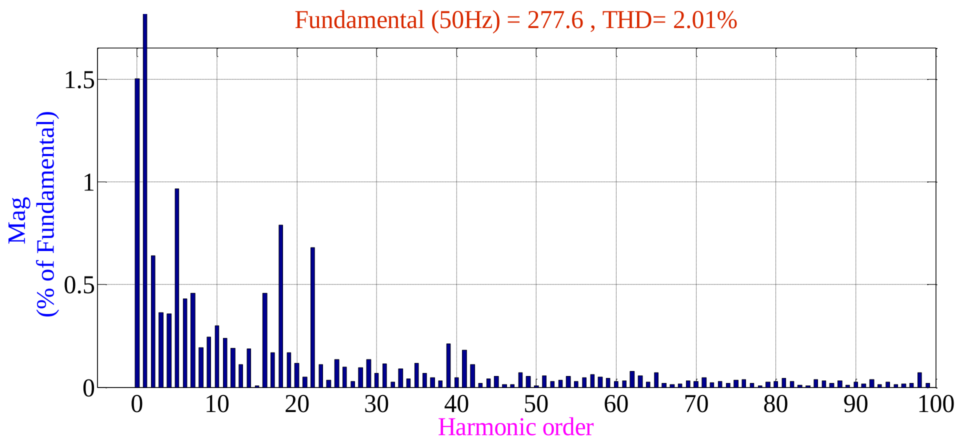
The retort of voltage in DC link is shown in Fig.9 during normal operation. The settling time and stabilization of DC voltage is achieved best using proposed controller as compared to conventional controller. The performance of PI+AWT controller is also verified under three phase fault. The response curve is presented in Fig.10. From this, it is observed that the proposed controller has performed best in all three conditions such as before fault, during fault and post fault respectively compared to conventional controller. The contrast of recital indices for both PI and PI+AWT controller is enumerated in Table 2.

Table 2. Comparison of performance indices

Controller	DC voltage settling time (sec)	%THD in Current signal
PI	1	2.27
PI+AWT	0.065	2.01



(a) FFT spectrum using conventional controller



(b) FFT spectrum using proposed controller

Figure 8. THD comparison

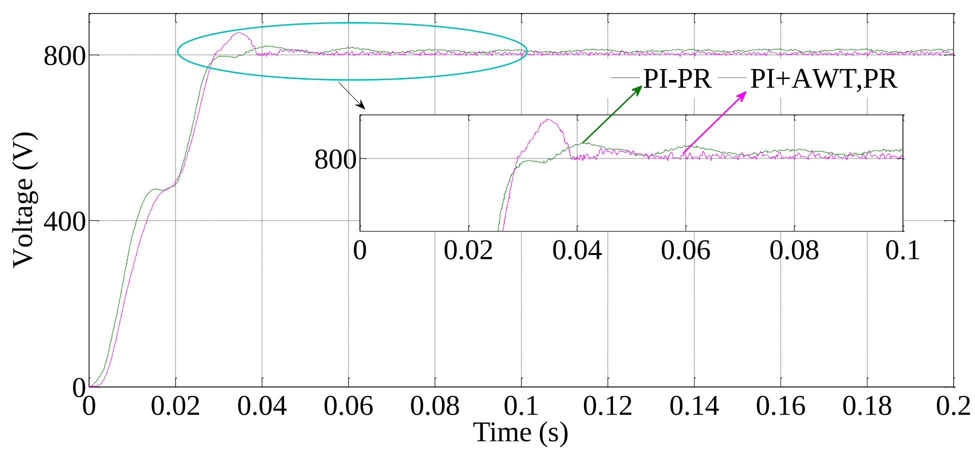


Figure 9. Comparison of DC voltage regulation during normal operation

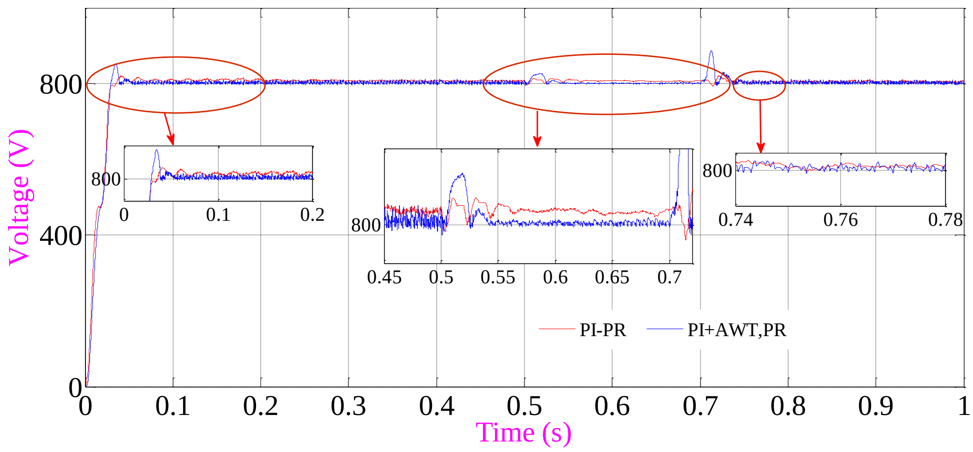


Figure 10. Comparison of DC voltage regulation during three-phase fault condition

10. CONCLUSION

The mathematical modeling of the PV and grid are described in detail. The potentiality of the proposed control scheme has been tested under constant irradiation, change of irradiation and the three-phase fault condition. From the results, it is realized that the controller side parameters has able to track its reference. The DC voltage regulation is achieved best with proposed controller in all thee-three situations including constant irradiation, variable irradiation and three phase fault.

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