# Design of a novel control hysteresis algorithm for photovoltaic systems for harmonic compensation

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**ABSTRACT**

Solar photovoltaic (PV) system design and integration with an existing AC grid is growing very fast in recent years and used by many of them as they are pollution-free, structure is limited and maintenance free. From the factors considering, the performance of PV system depends upon the inverter output voltage tested for linear, non-linear, with harmonic, and without harmonic loads. Generated due to the nonlinear loads. Better inverter control techniques are developed to maintain grid power quality. This article discusses the analysis and comparison of pulse width modulation (PWM) converters with unique and state of the art nonlinear control schemes and various modulation approaches. The primary objective of this research is controlling an active filtering (AF) hysteresis PWM converter with no sensors. A simple structure with hysteresis current control method total harmonic distortion (THD) is lower when compared with the sinusoidal pulse width modulation (SPWM) method. The said claims are supported by employing computer simulations using MATLAB/Simulink and different control approaches, such as proportional plus integral and artificial neural network controllers.



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## 1. INTRODUCTION

Discussions on analogue component differences, noise-handling ability, ease of connection to other digital systems, the ability to execute advanced control schemes, the ability to modulate controllers with commonly used software, and the advanced heartbeat width balance dilated cardiomyopathy (DCM) module pulse width modulation (PWM) are found in the literature [1]–[8]. Numerous studies have discussed digital current mode approaches for DC-to-DC converters [9]. Some studies have also attempted to reduce computational time delays by studying dead-beat current regulation [10], [11]. The discovery that the work ratio needs to be changed only once for every two shift cycles led to the development of an algorithm for model predictive digital current programming [12]. If this problem can be resolved within a few cycles, the primary goal can be considered to have been achieved. A proper modulation mechanism will make it possible to design the control rule to enable it to function with any variable of interest. It also works with valley, pinnacle, and normal current control methods. These strategies not only consider recurrent prescient control or non prescient control [13]–[16] but also require accurate sensing of high-speed inductor currents. Here, we start with a no sensor digital mean current mode control approach in DC-DC choppers, which operate mostly in the continuous mode for conduction (CCM). The primary objective of the suggested control strategy is to obtain the best possible results. This is done using the low-pass channel capacity to determine the normal inductor current depending on information and yield voltages that change over time and subsequently direct the inductor current utilizing the current of a voltage controller as a reference.

## 2. PULSE WIDTH MODULATION INVERTER

With the purpose of expanding the latest control methods of voltage-fed converters, DC/AC and AC/DC source/power-side inverters, also known as PWM converters (i.e., synchronous converters), were considered gate turn-off thyristors (GTOs) and insulated gate bipolar transistors (IGBTs) which are primary components of AC/DC converters, have a similar classification and operation procedure as that of diodes. IGBTs and GTOs can sum sinusoidal steady-state currents, which are given in addition to a complicated and conventional method known as PWM. The method also estimates the in-line situations with pulses obtained from the width modulated method to allow central control of power switches. The new technology for changing voltage-fed AC/DC rectifiers interconnected for the power electric grid is represented in Figure 1. The electric power main network for the majority of the diode rectifiers obtained in the technology for the PWM voltage converter is three-phase (battery energy storage system) [17].

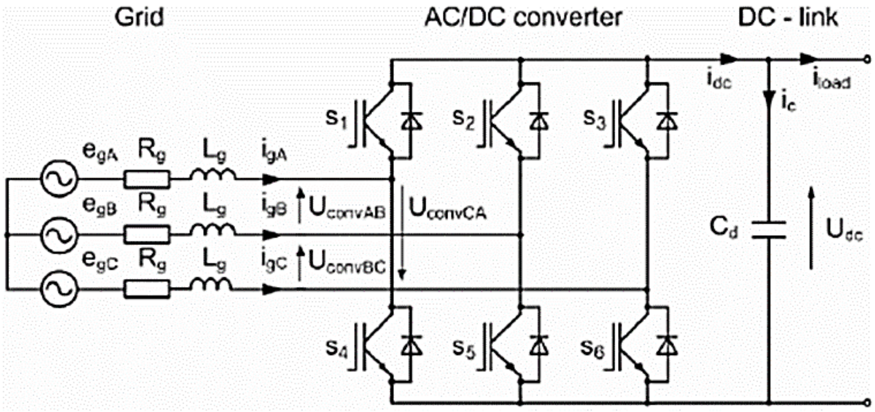



Figure 1. Voltage source of the AC/DC line-side converter

The bridge of the PWM rectifier consists of six fully controlled IGBT transistors coupled to the supply line through three-phase symmetrical line inductors. It is necessary to decrease and regulate the voltage drop across a line choke to deliver sinusoidal line currents. In (1) provides a representation of the pulses of the converter in second order using three-phase (A, B, C) Cartesian coordinates. The states of electronic switches in terms of binary [1, 0] associated with the three-phase rectifier phases are denoted by Sa, Sb, and Sc.

$$
\begin{aligned}
&d/dt\ (igA) = 1/Lg\ [egA - RgigA - Udc/3(2Sa - Sb - Sc)] \\
&d/dt\ (igB) = 1/Lg\ [egB - RgigB - Udc/3(-SA + 2Sb - Sc)] \\
&d/dt\ (igc) = 1/Lg\ [egc - Rgigc - Udc/3(-SA - Sb + 2Sc)] \\
&d/dt\ (Udc) = 1/Cd\ [SaigA - SbigB - Scigc)]
\end{aligned} \quad (1)
$$

## 3. APPLICATION OF PULSE-WIDTH MODULATION TO RECTIFIERS

PWM is used in AC/DC converters to alter the voltage and current amplitudes in relation to the harmonics of PWM three-phase converter input voltages. The harmonic spectrum of the line current should also be considered in this context. Modulation schemes, in general, are characterized by the linearity property's wide range, constant switching frequency, and a small effect on the generation of higher harmonics in line currents [18]. The PWM rectifier can greatly benefit from the use of the DC-link voltage. The DC-link voltage utilization factor (M) can help generate the input PWM voltage of an AC/DC converter throughout the entire control operation process [19].

Figure 2 depicts the interdependence of the rectifier sinusoidal voltage with respect to the modulation index for the DC-link current in the inner loop and the voltage considered as the reference. The change in the modulation parameter, i.e., the bandwidth, is commonly differentiated using linear and nonlinear limits. Whatever form the method outputs from source current variations is due to its nonlinearities and is unsuitable for most applications due to the DC-AC-DC rectification developing the electrical power quality [20]-[23]. The output voltage is superimposed on the triangle voltage derived from a simple resistor capacitor (RC) network linked to both the comparator (with hysteretic effect) and the converter outputs, with the feedback signal being again supplied back to the hysteretic comparator. This proposed technique has the advantages of delivering the lowest steady-state error voltage on the output as well as possessing a smooth dynamic performance for the load; this is because the hysteretic PWM controller is derived from certain characteristics and has no error amplifier. Current transients in the RC network can be obtained by selecting appropriate time-constant values [24]-[27].

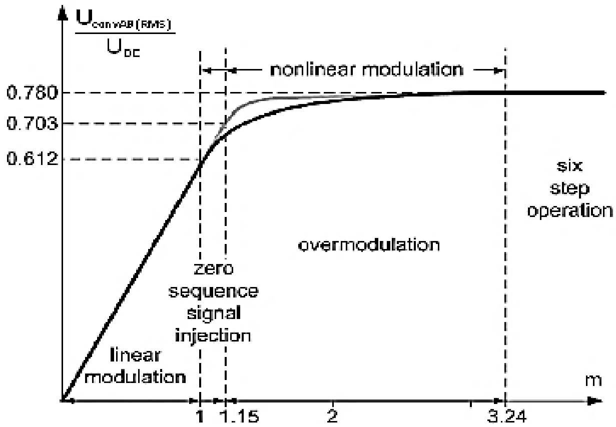



Figure 2. Range of PWM for the AC/DC line-side converters

## 4. SIMULATION MODELS, RESULTS, AND ANALYSIS

A 50 kW, 380 V, 50 Hz power supply was linked-through an AC-DC-AC power supply to the load of a 25 kV, 50 Hz power grid. Two voltage source converters ($VSC_1$ and $VSC_2$), linked through a DC connection, are powered by this power supply. $VSC_1$ is a rectifier that is linked to a 50 Hz electrical grid. Besides maintaining a constant unity power factor on the AC grid, it adopts a 680 V DC-link voltage. The PWM chopping frequency used in the calculation is 1,980 Hz. $VSC_2$ is a 50 Hz inverter attached to a 50 Hz load. It generates a frequency of 50 Hz and maintains a load voltage (rms voltage) of 380 $V_{rms}$. The PWM chopping frequency is estimated to be 2,000 Hz. The electrical circuit is discretized using discrete simulation at the rate of 2 microseconds. There are 100 microsecond sample periods for both $VSC_1$ and $VSC_2$ control systems. From Figures 3-10, both single-phase and three-phase systems are considered, control the grid-connected simulation model photovoltaic (PV) inverter. For Figure 8(a) shows grid voltage (volts) and Figure 8(b) shows current (amps) versus time (secs)

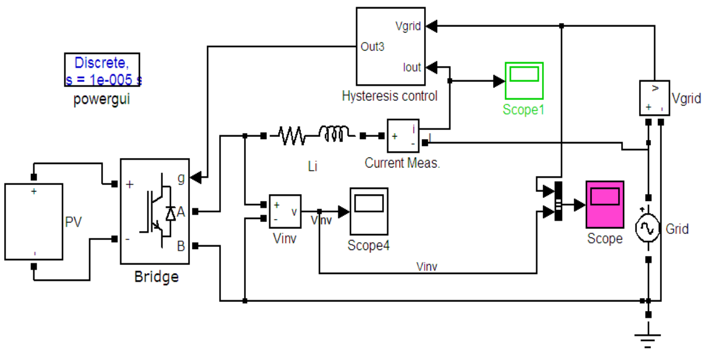



Figure 3. Grid-connected simulation model PV inverter currently controlled by single-phase hysteresis

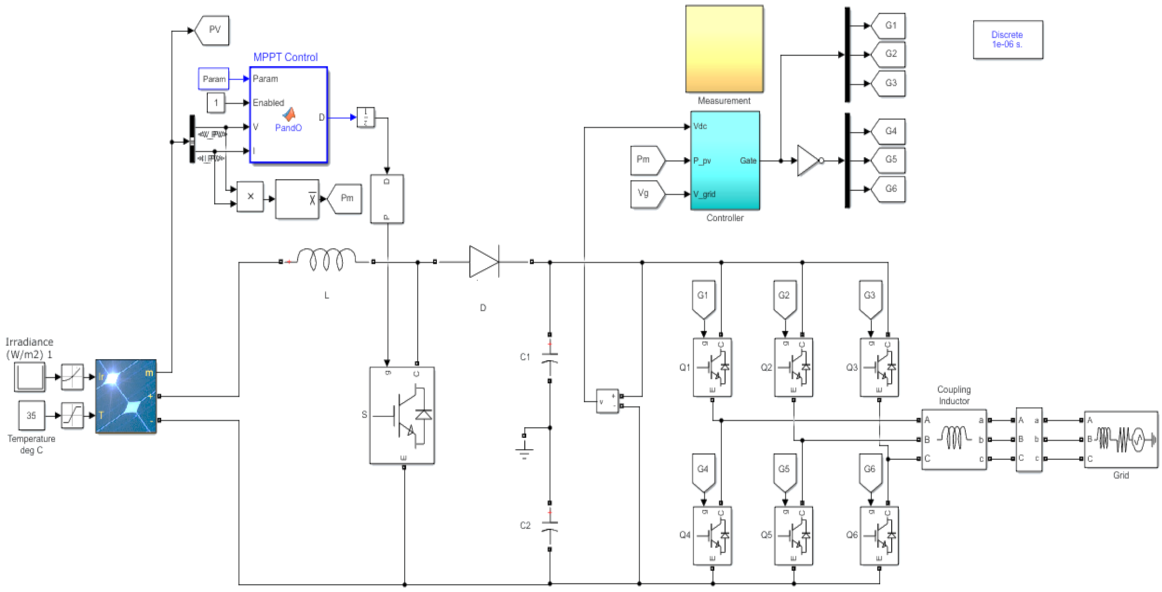



Figure 4. Grid-connected simulation model PV inverter currently controlled by three-phase hysteresis

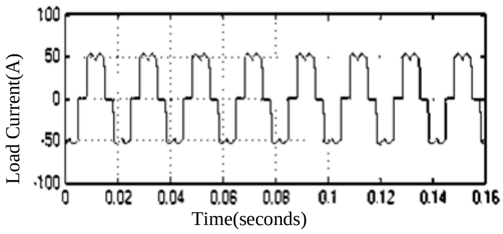



Figure 5. Load current–3 versus time (secs)

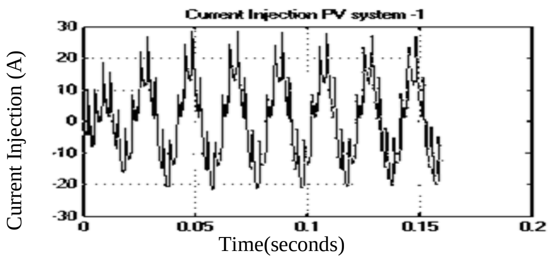



Figure 6. Current injection at PV system-1

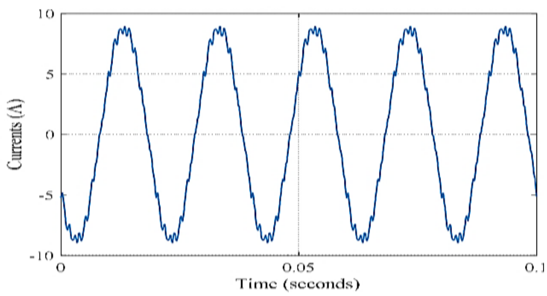
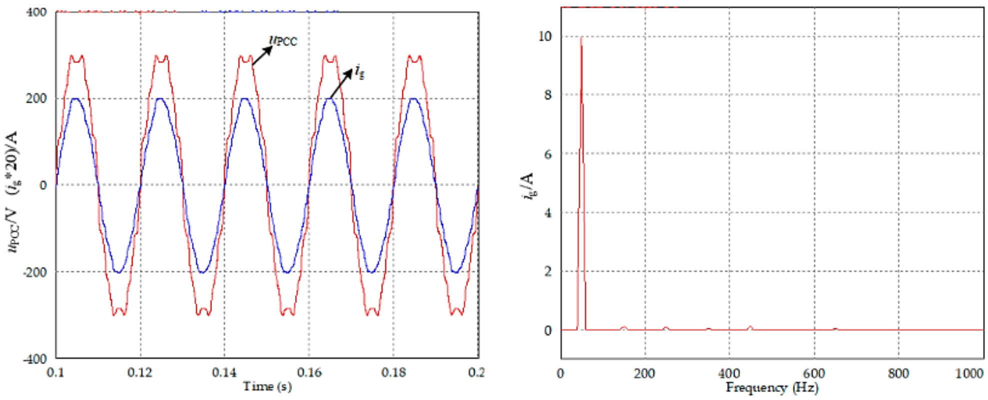



Figure 7. Current injection PV system–2 versus time (secs)




(a) (b)

Figure 8. Voltage injection: (a) grid voltage (volts) and (b) current (amps) versus time (secs)

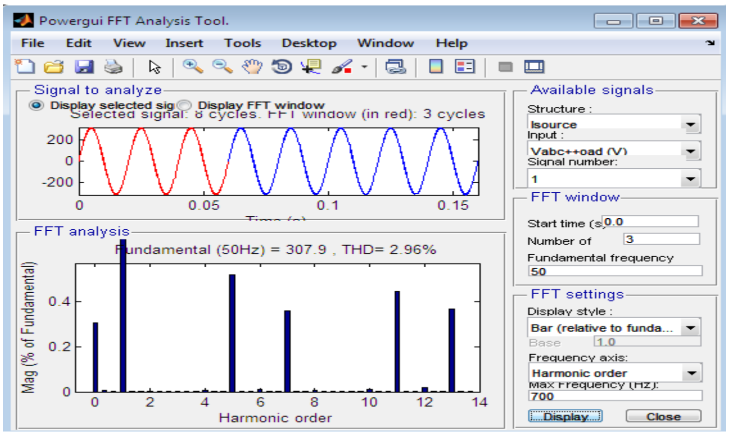



Figure 9. Total harmonic distortion (THD) of the network current in the absence of a PV system

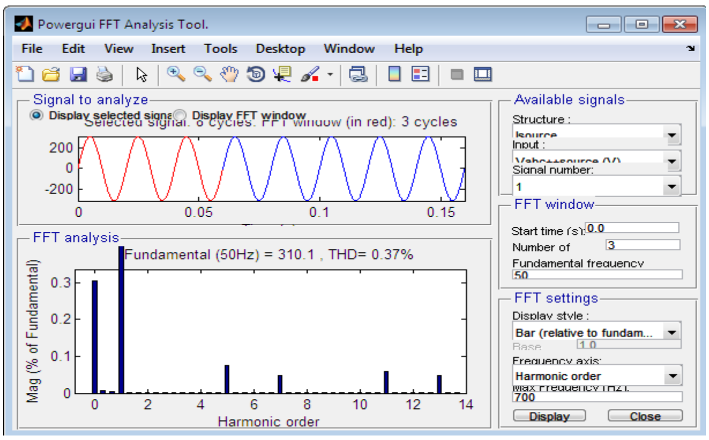



Figure 10. THD of the network current in the presence of a PV system

## 5. CONCLUSION

This paper discussed how to develop a three-stage grid-connected PV-active filter (AF) framework. A three-stage AC power system outputs the total dynamic power, current disposal, and responsive power pay. The PV system is linked by transformer of step-up to the grid utilized and supplying load and the full-bridge DC/AC inverter. Using the same procedure, a nine-panel solar panel system was designed. In this case, by considering three-phase system current reference by using SRF method. Both reactive power adjustment and active power injection were found effective, as was eliminating current harmonics. When two separate loads with differing THD receive power from the grid, solar panels with an inverter are demonstrated to be very efficient. Using the AN controller, the PV-AF system can remove harmonics and inject active energy into the network at low THD currents ranging from 2.96% to 0.34%.

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