Design of a Single-Phase Inverter for Solar Energy Conversion System

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Abstract. Since the calculation of the active and reactive power is considered an essential topic nowadays, the novel method is focused on these calculations with omitting the PLL that will decrease the complexity of the control process. To get the maximum photovoltaic (PV) output, the maximum power point tracker (MPPT) algorithm has been integrated with the proposed method. MATLAB/SIMULINK has been used to show the performance of the proposed method. The simulation outcomes verify the advantage of the novel method by improving the total harmonic distortion (THD) and the system stability regardless of load changes.

Keywords: Power Conversion, PLL, SVPWM, Single-phase inverter, THD

Introduction

Nowadays, active and reactive power is considered an essential topic in the industry. Aside from environmental advantages, photovoltaic systems are considered a perfect source for real and reactive power [1]. PV systems connect to the utility in several ways, such as stand-alone, grid-connected, and hybrid systems. Grid-connected configuration is mainly used to inject active and reactive power into the utility, but other ways are used for another purpose [2,3]. A study presented an adopted algorithm that contained a double-loop control strategy to improve the solar panel output. Furthermore, the MPPT algorithm was integrated with the proposed method to get optimal current from the PV systems [4-5].

Since solar power systems are widely sprinkled into the utility, some control methods should be applied. Converters are the main parts that will be controlled in this scenario. They are divided into DC/DC converters and DC/AC inverters [6]. This work will focus on inverters. Designers look for high efficiency and economic models to control PV inverters[7-8]. This paper aims to monitor and control system stability and keep the THD lower than the maximum limit. Although the three-phase instantaneous power theory allows power to be calculated without a synchronization unit, most control techniques in the literature require synchronization information [9-11]. In order to acquire more output stages without increasing the number of switches, some asymmetric multi-level inverter topologies are shown in[13-14]. Many PWM approaches have recently emerged, classified into two categories: sine wave PWM (SPWM), which can be used in single-phase or multi-phase inverters, and multilevel space vector modulation, exclusively utilized in multi-phase inverters [15-17].

Typically, the PV grid inverter has encountered three key issues: harmonics, matching maximum power tracking to grid needs, and fulfilling synchronization with the grid using national coding This As indicated in the figure, the study offers a novel design version of a PV inverter. In Fig. 1.a to address such issues with the following significant contributions:

- As shown in section 3, synchronizing control is based on RMS voltage principles and adjustable phase difference leading angle of the inverter to achieve a high power factor.

System structure

1. Three-level inverter

Multilevel inverts are widely used in the power electronics field. Figure 1 shows a single-phase three-level neutral-point-clamped (NPC) inverter. A PV panel is presented by E in this paper. The inverter consists of two capacitors C_1 and C_2, two legs with each having four IGBT switches, four clamped diodes, L-C_3 low pass filter, and system load R_L. The output current and voltage are i_{ac} and V_{ac} Respectively.

2. Design of the Controller

To calculate the instantaneous power, adjust the voltage and current to the synchronous rotary frame. The following equations show the real and

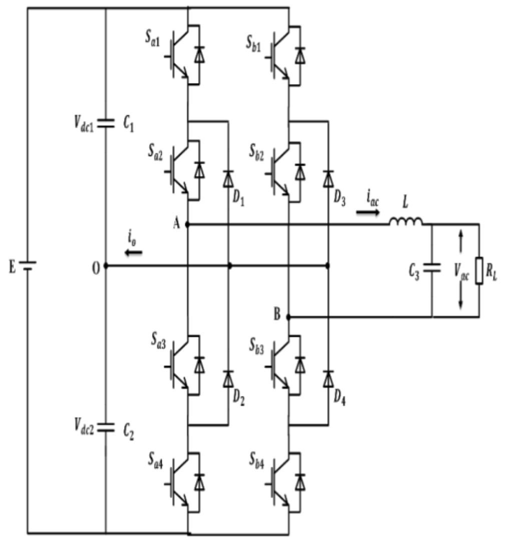

Figure 1. Single-phase three-level NPC inverter.

reactive power that is used to build the proposed control strategy.

$$v_{abd} = v_{sm} - L\frac{di_{ac}}{d_t} - R_L i_d - \omega L i_q \quad \text{and}$$

$$v_{abq} = -L\frac{di_{ac}}{d_t} - R_L i_q - \omega L i_d \qquad (1)$$

The steady-state value is integrated with PI-DPC, as shown in (2)

$$\begin{Bmatrix} v_{abd} = -[K_{pp} + \frac{K_{PI}}{s}]\,(P^* - P) + V_{ds} \\ v_{abq} = \left[K_{Qp} - \frac{K_{QI}}{s}\right](Q^* - Q) + V_{qs} \end{Bmatrix} \qquad (2)$$

3. SVPWM Algorithm

The three-phase inverter SVPWM algorithm was used in this work to generate suitable switching signals. This algorithm is programmed to dependon several inputs: MPPT output, the voltages of the balance capacitors C_1 and C_2, i_{ac}, i_{sm}, sampling time T_sAnd the outputs from equation 12. The output of this algorithm will drive the switches, as shown in Figure 2.

Figure 3 shows the circuit diagram, including a PV panel, DC capacitors, a three-level inverter, and the proposed control method. In addition, a MATLAB/SIMULINK model is developed to show the advantages of the proposed method.

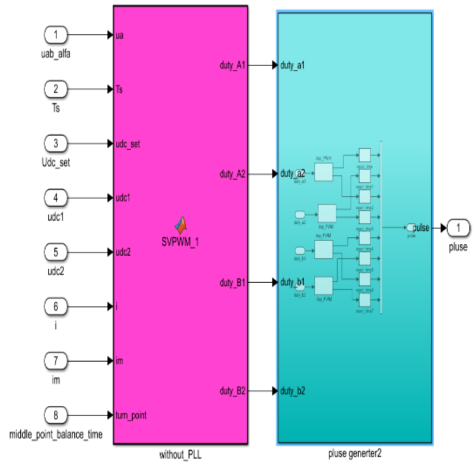

Figure 2. circuit of SVPWM

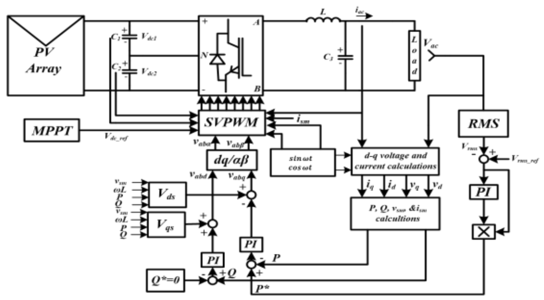

Figure 3. circuit diagram, including a PV panel, DC capacitors, a three-level inverter

Simulation Results and Discussion

Figure 4 shows the Simulink diagram for the strategy, which displays the active and reactive power calculations. These calculations are done by using the customized DPC-PI controller and integrated with SV-PWM Figure 5 presents the waveforms and dynamic response of AC current and voltage, irradiance, and PV voltage. Both irradiance and load are varying. The solar irradiance is changed multiple times, as shown in the figure below. The model outcomes show the stronger of the suggested method; Figure 5 presents the stability of the novel method regardless of the irradiance and load changes.

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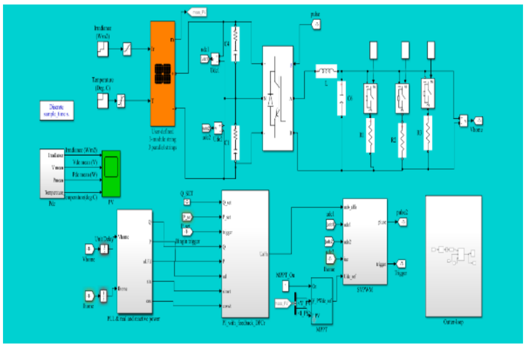

Figure 4. System Simulink

The figures show that the proposed method has THD less than the previous method [6], 1.23% for the proposed method and 5.95% for the previous strategy. The standard PI-DPC with PLL is tested in fig. 6 to compare the performance of DPC with and without PLL. In this test, the previous method estimates real and reactive outputs and performs the PLL. As shown in Figures 4 and 5, the present harmonic components using the proposed method are smaller than those using the traditional PI-DPC method with PLL[12]. The comparative analysis results indicate that the proposed methodology can achieve excellent evaluation and control accuracy. To further evaluate the system stability of DPC with and without the PLL module, the conventional DPC is tested and shown above using [7] to calculate power and realize PLL. The findings demonstrate that the line current harmonics are high in the traditional DPC than in the proposed technique. As a result, the proposed method outperforms the traditional PLL method in terms of control performance.

Temperature and radiance are the variables used in the simulations. First, the Space Vector Pulse Width Modulation model for three-level single-phase inverters has been introduced and combined with the P&O MPPT algorithm. Then, the suggested technique evaluates algorithmic modifications based on each scenario's combined aspects. Following that, a MATLAB/SIMULINK model is created to test the efficacy of the suggested technique based on the previously mentioned SVPWM and DPC-PI controller algorithms. Figure 6 and Table 1 demonstrate how the simulation system is created based on the circuit design and its parameters.

Table I. System parameters

Parameters	Value
RMS (V)	85
T_s µs	10
f_s (kHz)	1.25
C_1 and C_2 (mF)	3.0
load R_L (Ω)	30-20

Conclusion

This work proposes new direct power control of the single-phase three-level photovoltaic inverter SVPWM without (PLL). The proposed method employs a DPC-PI controller to control inverter active and reactive power output to connect PV generation to the power grid. Since the calculation of the active and reactive power is considered an essential topic nowadays, the novel method is focused on these calculations with omitting the PLL that will decrease the complexity of the control process. The simulation results validate the novel method's advantage by improving total harmonic distortion (THD) and system stability regardless of load changes. The proposed scheme has the potential to reduce the detrimental effects of primary voltage harmonics. Compared to the traditional method, the system obtained high accuracy of calculated values in the main voltage with numerous harmonics and DC components, even under extreme conditions such as harmonic resonance in traction power grids. [12].

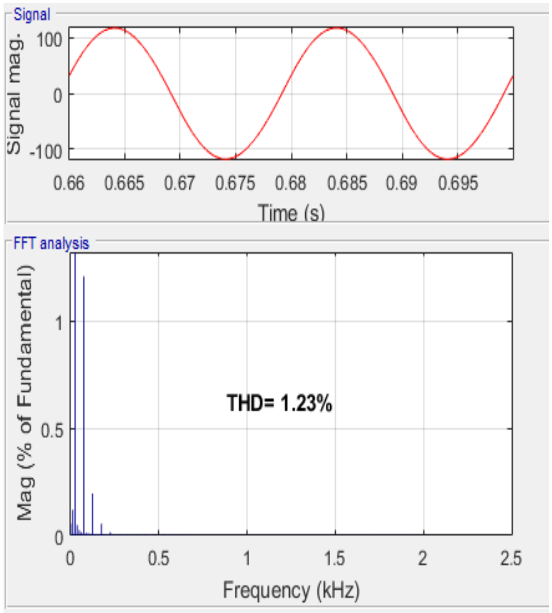

Figure 6. The THD system voltage output

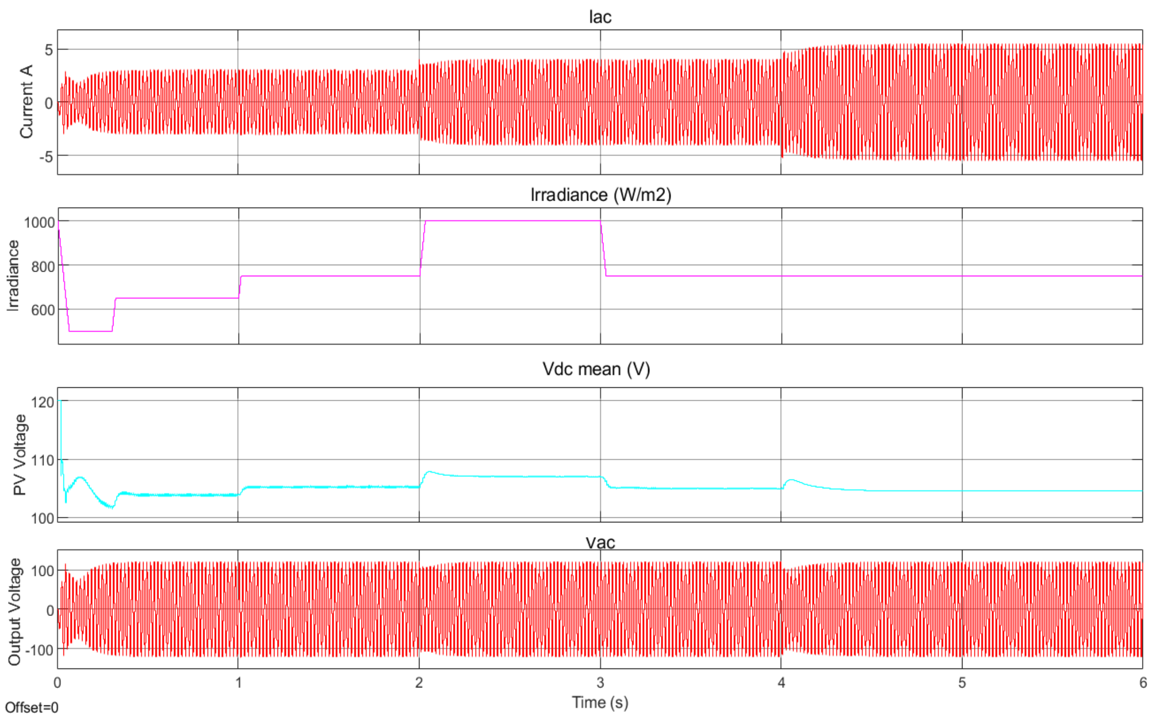

Figure 5. System Performance

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