BIDIRECTIONAL AC/DC CONVERTER USING FEED-FORWARD CONTROL FOR PV SYSTEMS

S.Vinodhini [a], Mr.S.Bharathkumar [b]

[a]Department of electrical and electronics Engineering,
M.A.M College of Engineering,Trichy
[b]Department of electrical and electronics Engineering,
M.A.M College of Engineering, Trichy

Abstract

The simplified pulse width modulation (PWM) strategy for the bidirectional ac/dc single phase converter in a micro grid system is proposed. A high efficiency isolated bidirectional ac to dc converter is proposed to control the bidirectional power flows ant to improve its power conversion efficiency. The number of switchings of the proposed simplified PWM strategy is one fourth that of the conventional unipolar PWM and bipolar PWM. Based on the novel simplified PWM strategy, a feasible feedforward control scheme is developed to achieve better rectifier mode and inverter mode performance compared with the conventional dual loop control scheme. The proposed simplified PWM strategy with the proposed feedforward control scheme has lower total harmonic distortion than the bipolar PWM and higher efficiency than both unipolar and bipolar PWMs. Furthermore, the proposed simplified PWM operated in the inverter mode also has larger available fundamental output voltage V_{AB}than both the unipolar and bipolar PWMs. The simulation results verify the validity of the proposed PWM strategy and control scheme.

Key words: Bidirectional ac/dc converter, simplified pulsewidth modulation (PWM) strategy, total harmonic distortion (THD).

Corresponding Authors: svinome1991@gmail.com; Phone No--+919600777849

1. INTRODUCTION

DC Distribution system is one of the important future power systems to save energy and to reduce CO2 emission because it can improve the efficiency of systems due to the reduction of the number of power conversion stages. Especially, the DC distribution system for a residential house using dc home appliances can allow the flexibility of merging many renewable energy sources because most of the output of renewable energy source is DC. In order to balance the power flow and to regulate the DC bus voltage, the dc distribution system requires an isolated bi-directional ac-dc converter to interface between dc and ac grid. It usually consists of a non isolated bi-directional ac-dc rectifier for grid – connected operation and an isolated bi-directional dc-dc converter to interface dc bus and dc link of the rectifier. The single-phase non isolated bi-directional rectifier typically consists of a conventional full-bridge structure. It has two

sinusoidal pulse width modulation (SPWM) methods such as a bipolar and the unipolar switching modes. One of the disadvantages of the bipolar switching mode is the need of large inductor to reduce the input current ripple because the peak tp peak voltage of the inductor is more than twice the unipolar switching mode, inductance foe a continuous current mode (CCM) power factor correction (PFC) operation can be reduced. The unipolar switching mode rectifier using conventional switching devices including a normal anti parallel diode causes high reverse recovery current and turn-on switching noise. The switching and the conduction losses in the bi-directional rectifier are the main cause of decreasing power conversion efficiency.

The fluctuation nature of most renewable energy resources, like wind and solar, makes them unsuitable for standalone operation as the sole source of power. A common solution to overcome this problem is to use an energy storage device besides the renewable energy resource to compensate for these fluctuations and maintain a smooth and continuous power flow to the load. As the most common and economical energy storage devices in medium-power range are batteries and super-capacitors, a dc-dc converter is always required to allow energy exchange between storage device and the rest of system. Such a converter must have bidirectional power flow capability with flexible control in all operating modes.

The single-phase ac/dc pulse width modulation (PWM) converter is widely used in many applications such as adjustable-speed drives, switch-mode power supplies, and uninterrupted power supplies. The single-phase ac/dc PWM converter are usually employed as the utility interface in a grid-tied renewable resource system, as shown in Fig. 1.To utilize the distributed energy resources (DERs) efficiently and retain power system stability, the bidirectional ac/dc converter plays an important role in the renewable energy system. When DERs have enough power, the energy from the dc bus can be easily transferred into the ac grid through the bidirectional ac/dc converter. In contrast, when the DER power does not have enough energy to provide electricity to the load in the dc bus, the bidirectional ac/dc converters can simultaneously and quickly change the power flow direction (PFD) from ac grid to dc grid and give enough power to the dc load and energy storage system. There are many requirements for ac/dc PWM converters as utility interface in a grid-tied system; for instance, providing power factor correction functions, low distortion line current, high-quality dc output voltage, and bidirectional power flow capability. Moreover, PWM converters are also suitable for modular system design and system reconfiguration. In this paper, a novel PWM control strategy with feedforward control scheme of a bidirectional single-phase ac/dc converter is presented.

2. BIDIRECTIONAL AC TO DC CONVERTER

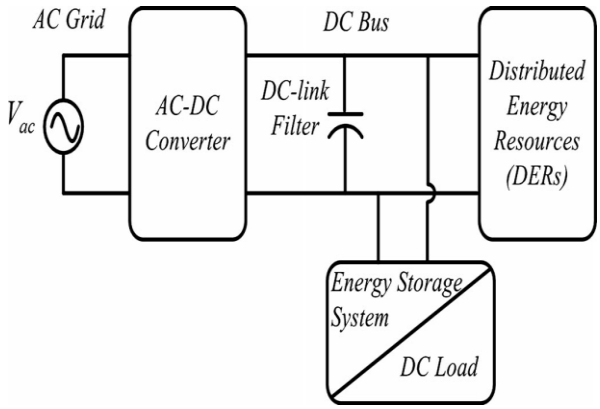

Figure 1 – Distribution energy system

The single-phase ac/dc pulse width modulation (PWM) converter is widely used in many applications such as adjustable-speed drives, switch-mode power supplies, and uninterrupted power supplies. The single-phase ac/dc PWM converters are usually employed as the utility interface in a grid-tied renewable resource system, as shown in Fig 2. To utilize the distributed energy resources (DERs) efficiently and retain power system stability, the bidirectional ac/dc converter plays an important role in the renewable energy system. When DERs have enough power, the energy from the dc bus can be easily transferred into the ac grid through the bidirectional ac/dc converter. In contrast, when the DER power does not have enough energy to provide electricity to the load in the dc bus, the bidirectional ac/dc converters can simultaneously and quickly change the power flow direction (PFD) from ac grid to dc grid and give enough power to the dc load and energy storage system. There are many requirements for ac/dc PWM converters as utility interface in a grid-tied system; for instance, providing power factor correction functions low distortion line currents high-quality dc output voltage and bidirectional power flow capability. Moreover, PWM converters are also suitable for modular system design and system reconfiguration. In this paper, a novel PWM control strategy with feedforward control scheme of a bidirectional single-phase ac/dc converter is presented.

3. EXISTISNG SYSTEM: UNIDIRECTIONAL AC TO DC CONVERTER

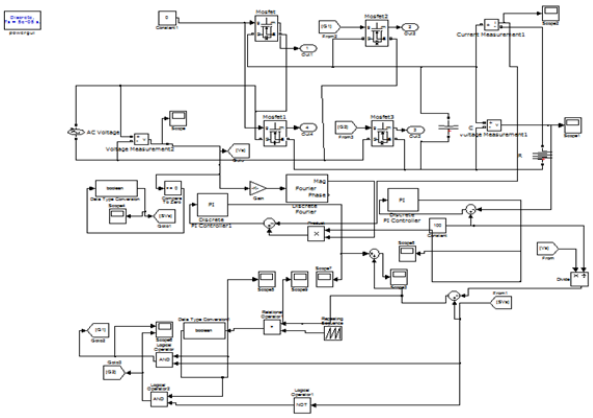

Figure 2 – Unidirectional ac to dc converter

This figure shows the matlab simulation circuit for unidirectional ac to dc converter and their corresponding ac and dc output voltages as follows.

3.1 AC grid voltage

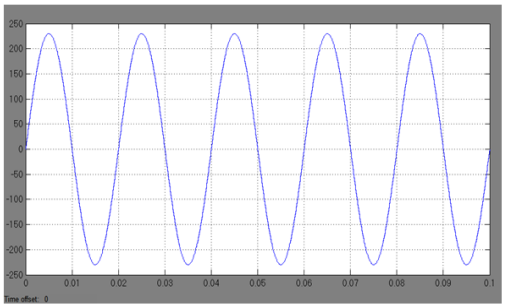

Figure 3 –AC grid voltage for Unidirectional ac to dc converter

3.2 DC grid voltage

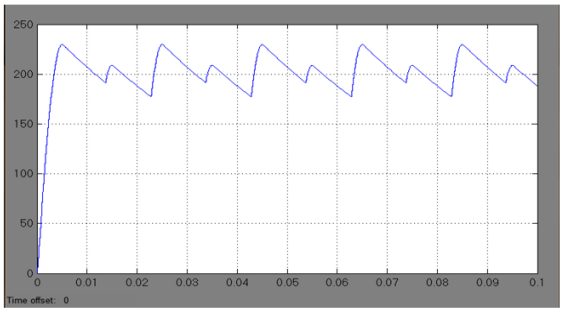

Figure 4 – DC grid voltage for Unidirectional ac to dc converter

4. PROPOSED SYSTEM : BIDIRECTIONAL AC TO DC CONVERTER

The fluctuation nature of most renewable energy resources, like wind and solar, makes them unsuitable for standalone operation as the sole source of power. A common solution to overcome this problem is to use an energy storage device besides the renewable energy resource to compensate for these fluctuations and maintain a smooth and continuous power flow to the load. As the most common and economical energy storage devices in medium-power range are batteries and super-capacitors, a dc-dc converter is always required to allow energy exchange between storage device and the rest of system. Such a converter must have bidirectional power flow capability with flexible control in all operating modes.

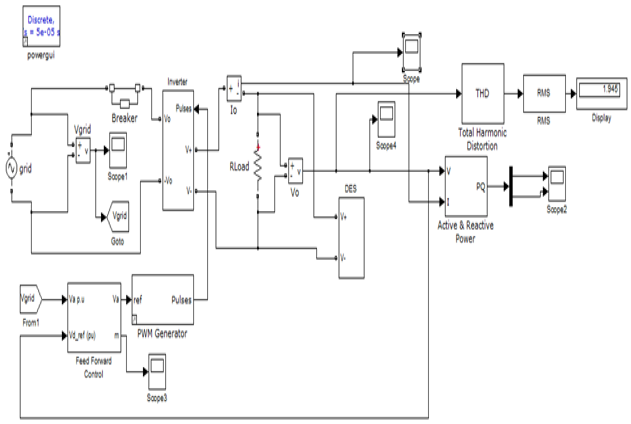

Figure 5 – Bidirectional ac to dc converter

4.1 AC grid voltage

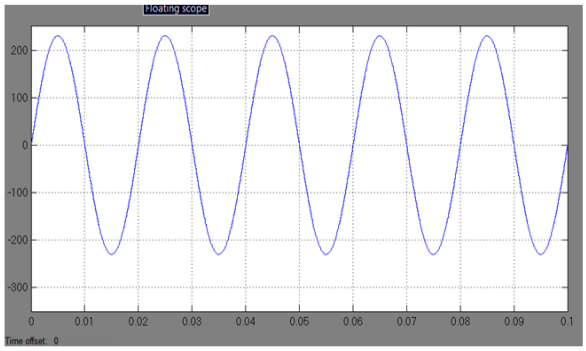

Figure 6 – AC grid voltage for bidirectional ac to dc converter

4.2 DC grid voltage

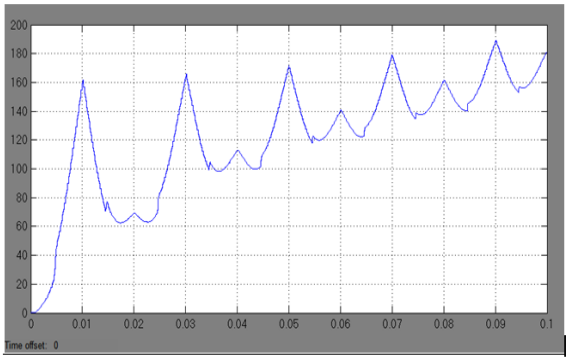

Figure 7 –DC grid voltage for bidirectional ac to dc converter

5. CONCLUSIONS

This paper presented a simplified PWM strategy using a feedforward control scheme in the bidirectional single-phase ac/dc converter. The proposed simplified PWM strategy only requires changing one active switch status in the switching period instead of changing four active switch statuses as required in the UPWM and BPWM strategies. The efficiency of an ac/dc converter operated in the proposed simplified PWM strategy is higher than that in the UPWM and BPWM strategies. Based on the proposed feedforward control scheme, both ac current shaping and dc voltage regulation are achieved in both the rectifier and inverter operating modes. In addition, the proposed simplified PWM operated in the inverter mode has larger available fundamental output voltage V_{AB} than both BPWM and UPWM, and the THD of the proposed simplified PWM is less than that of BPWM, and close to that of UPWM. Finally, the prototype system was constructed and tested using the MATLAB . Both the simulation and experimental results verify the validity of the proposed PWM strategy and control scheme.

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