IMPROVED POWER QUALITY FOR A SINGLE-PHASE AC-DC HYBRID MICRO-GRID

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ABSTRACT

The modelling and simulation of the power flow control strategy of a single-phase AC-DC Hybrid Micro-Grid is presented in this paper (HMG). A full bridge IGBT structure that is a regular H-Bridge inverter/rectifier is included in the HMG system topology that has been proposed. This structure contains two AC and DC zones that are separated from one another by a bidirectional interlinking converter (BIC). In accordance with the principles outlined in the DQ transformation theory, the switching pattern of the BIC is derived from two power control loops and one voltage loop (Vdc). This control strategy enables the controlled transfer of both active and reactive power between the HMG and the public AC Grid. The transfer can take place in a controlled manner. In addition to this, this is carried out in both directions by working with a bidirectional converter in modes that either rectify or invert the signal. MATLAB-Simulink is used to carry out the implementation and testing of the simulation model.

Keywords: Hybrid AC-DC micro grid, bidirectional interlinking converter (BIG), constant power control, single-phase micro grids.

I. INTRODUCTION

In order to ensure that the power supply to the consumers in a hybrid AC-DC micro grid is uninterrupted at all times, it is necessary to design a stable conversion system that is able to initiate the islanding procedure in the event that an unanticipated event takes place [1, 2, 3]. The development of an energy flow control system that contributes to the power factor correction/compensation (PFC) for the local AC distribution public grid at the point of common coupling (PCC) by reactive current injection methods [4, 5], and [6] is another important aspect of modern HMG. Because of the limited amount of reactive power that is available, a single residential HMG may only have a negligible impact on the PFC calculations carried out at the PCC for a regional public grid. An increased number of HMG working with this strategy in a particular local public could mean a more significant impact on the quality of the power that is distributed if the power factor at the common coupling point is compensated. This is because the strategy works to compensate for the power factor. The control strategy that is used in references [7], [8], [9], and [10] proposes a DQ synchronous reference frame control for single-phase systems. This is accomplished by converting alternating current (AC) signals into direct current (DC) signals, which is the form of processing that is the most efficient. Some applications [11], [12], and [13] make use of this transformation by utilising three control loops for the active-reactive power and output DC voltage, respectively. In contrast to these applications, the current work focuses on the capability of this method to adjust the phase of the current that is fed into or injected from the AC Grid in order to compensate or correct the power factor at PCC. This capability is highlighted by the fact that this method can operate either in the rectifier mode or the inverter mode.

II. LITERATURE SURVEY

[1] Fatemeh Ghalavand, Ibrahim Al-Omari, Hossine Kazemi Karegar and Hadis Karimipour, (2018), "Hybrid Islanding Detection for AC/DC Network Using DC-link Voltage,". Islanding is a critical and unsafe condition which may cause serious problems for smart grid operation. This paper proposes a new method for islanding detection in hybrid AC/DC network from DC side. The proposed method uses variation in energy production and energy storage in DC-link voltage for DC islanding detection. The proposed method is applied on a AC/DC microgrid including Photovoltaic (PV) modules, Combined Heat and Power (CHP) generation units. Simulation results under various disturbance caused by AC fault short circuits, and motor starting verify the accuracy and efficiency of the proposed method.

[2] Gongxin Qi, Alian Chen and Jie Chen, (2017), "Improved Control Strategy of Interlinking Converters with Synchronous Generator Characteristic in Islanded Hybrid AC/DC Microgrid,". In this paper, an improved control strategy of interlinking converters for hybrid AC/DC microgrid operated in islanding mode is proposed, which applies synchronous generator model to the converters. This enhanced scheme adopts direct frequency control method to realize active power sharing and improves the transient frequency stability by using synchronverter technology. Unlike existing droop control methods of interlinking converters that mostly just focus on power sharing, this scheme can not only maintain proportional power distributed between DC and AC sub grid, but also regulate the AC sub grid voltage directly to improve its poor frequency stability during AC side loading transitions in autonomous operation. It's noteworthy that this scheme can also keep the AC-side loads working uninterruptedly during AC sub grid faults events by using voltage-controlled method. Moreover, any additional energy storage or inverters are not required to assist interlinking converters for microgrid frequency regulation. The effectiveness of this modified control method is verified by offline time-domain simulation and real-time experiment in MATLAB/Simulink and OPAL-RT digital platform respectively.

[3] A. Hina Fathima, N. Prabaharan, K. Palanisamy, Akhtar Kalam, Saad Mekhilef and Jackson. J. Justo, (2018), "Hybrid-Renewable Energy Systems in Microgrids: Integration, Developments and Control". Hybrid-Renewable Energy Systems in Microgrids: Integration, Developments and Control presents the most up-to-date research and developments on hybrid-renewable energy systems (HRES) in a single, comprehensive resource. With an enriched collection of topics pertaining to the control and management of hybrid renewable systems, this book presents recent innovations that are molding the future of power systems and their developing infrastructure. Topics of note include distinct integration solutions and control techniques being implemented into HRES that are illustrated through the analysis of various global case studies. With a focus on devices and methods to integrate different renewables, this book provides those researching and working in renewable energy solutions and power electronics with a firm understanding of the technologies available, converter and multi-level inverter considerations, and control and operation strategies.

III. METHODOLOGY

Hybrid systems

A hybrid system combines (C)PV and CSP with one another or with other forms of generation such as diesel, wind and biogas. The combined form of generation may enable the system to modulate power output as a function of demand or at least reduce the fluctuating nature of solar power and the consumption of non-renewable fuel. Hybrid systems are most often found on islands.

Hybrid Microgrid Topology

The topology of residential single-phase Hybrid Micro-Grid are shown in Fig. 1, where the two AC and DC circuits are delineated via the bidirectional interlinking converter (BIC). The AC circuit contains the AC grid, the point of common coupling (PCC), islanding switch, the AC load and an LCL passive filter. The DC circuit contains the capacitive filter (C), the DC load and the renewable sources and/or storage element (DC Source). The bidirectional interlinking H-bridge converter (BIC) ensure transfer from/to the AC and DC circuits. For the bidirectional interlinking converter, the energy management is defined by three individual operation cases. For the first two cases, the scenario allows the controlling of the reactive power and the third case is highlighting the operating at unity power factor. The Rectifier operating mode (case 1) allows the electrical energy to be transferred from the AC Grid to the DC-grid, feeding all the electrical DC consumers.

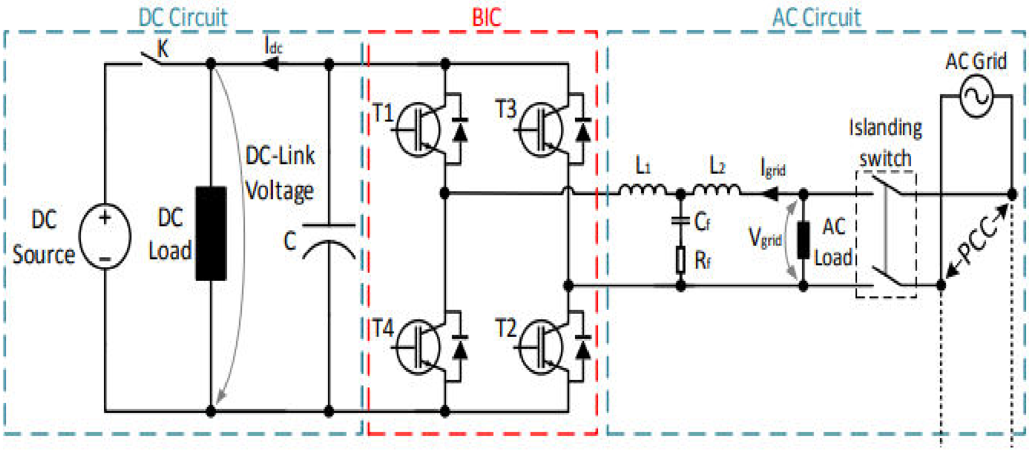


Figure 1: The hybrid microgrid topology

The AC Load is directly powered from AC Grid and DC Load and is interfaced to the DC-link Voltage by a power electronic converter. In the Inverter operating mode (case 2), the DC Source directly powers the DC load, while the AC load through the interlinking converter, at the same time allowing the energy flow in AC Grid. Inverter with islanding operating mode (case 3) is like the previous one, except that the AC-DC hybrid microgrid is islanding during to unexpected event (defect occurrence, quality condition failure, independent micro-grid operation), with no physical connection to the AC public grid. In this case scenario the DC Source ensures the power supply of both consumer's type.

CONVERTER CONTROL STRATEGY

The control strategy based on the reactive power control (Fig. 2) is using as measured inputs the AC voltage signal at the PCC (Vgrid), the input current (Igrid), the DC voltage (Vdc) and the DC current (Idc). These signals are also presented in Fig. 1. By applying the single-phase DQ transformation for the Vg and Ig signals, the Vd and Vq voltages and Id and Iq currents are being obtained in DQ rotation references frame. The references control signals are the DC voltage (Vdc_ref), the active power (Pref) which is obtained using to DC-link current and voltage and the reactive power (Qref) defined by the AC public grid. The outputs of this control system are the PWM signals for switching the interlinking converter transistors. The first control loop regulates the DC voltage (Vdc) obtaining the required reference for the IDC_ref DC current. This is accomplished by comparing the DC voltage (Vdc) to the required reference (Vdc.ref), obtaining a steady state error that is compensated by PI1 controller. The outputs of P-Q calculation block are measured value of the active (P) and reactive (Q) powers base on equation (1). These signals will be compared with the references for the power control (Pref, Qref) and the results are being compensated by PI2 and PI3 controllers, returning the references for the two current control loops (Id_ref, Iq_ref) [14]. The outputs of PI4 and PI5 controllers represents the signals (Vdm, Vqm), that after their Ịù transformation will become the inputs for the sinusoidal PWM generator (PWM).

$$P = V_d I_d + V_q I_q$$
$$Q = V_d I_q - V_q I_d \qquad (1)$$

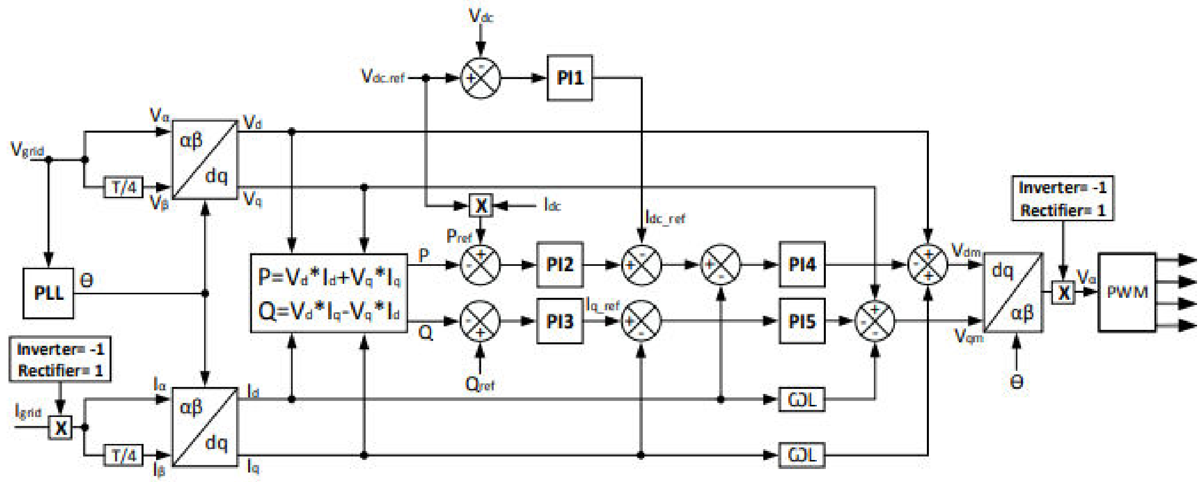


Figure 2: Control strategy schematic

IV. RESULTS & DISCUSSION

The proposed HMG system topology incorporates a full bridge IGBT structure in the form of a standard H-Bridge inverter/rectifier. Two AC and DC areas are separated by a bidirectional interconnecting converter in this setup (BIC). The BIC's switching pattern is derived from one voltage loop and two power control loops in accordance with the principles of the DQ transformation theory (Vdc). The active and reactive power can be transferred between the HMG and the public AC Grid in a controlled manner using this control strategy. The handover can happen in a managed fashion. To add, this is accomplished in both directions by employing a bidirectional converter in modes that rectify or invert the signal. The simulation model is implemented and tested using MATLAB-Simulink.

Proposed Simulink:

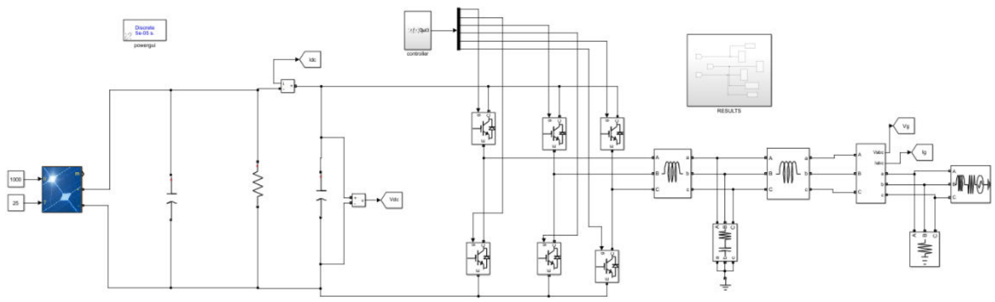
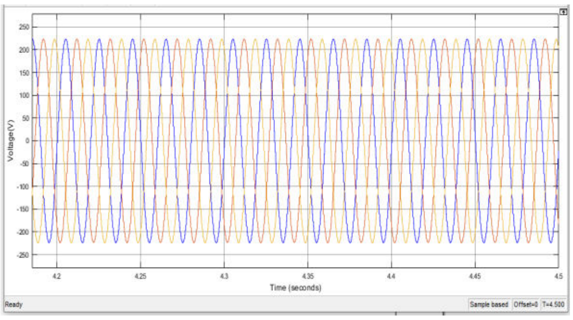
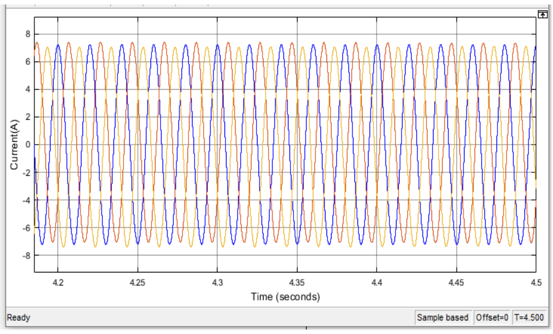


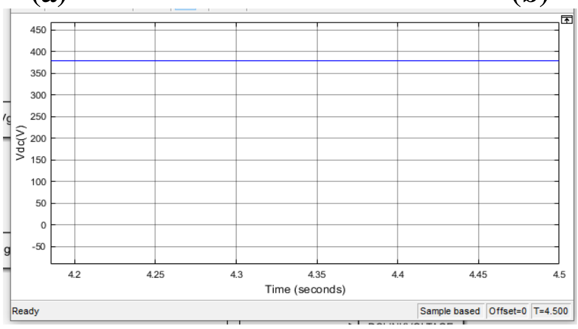
Figure 1: Proposed Simulink 5A



(a)



(b)



(c)

Figure 2: Output response for proposed 5A, (a) Vg; (b) Ig; (c) Vdc

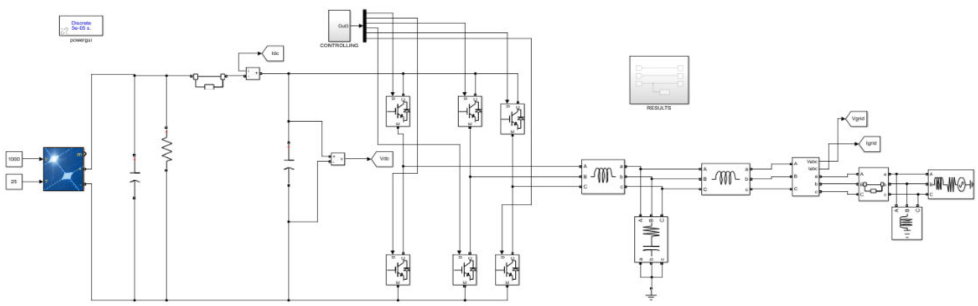
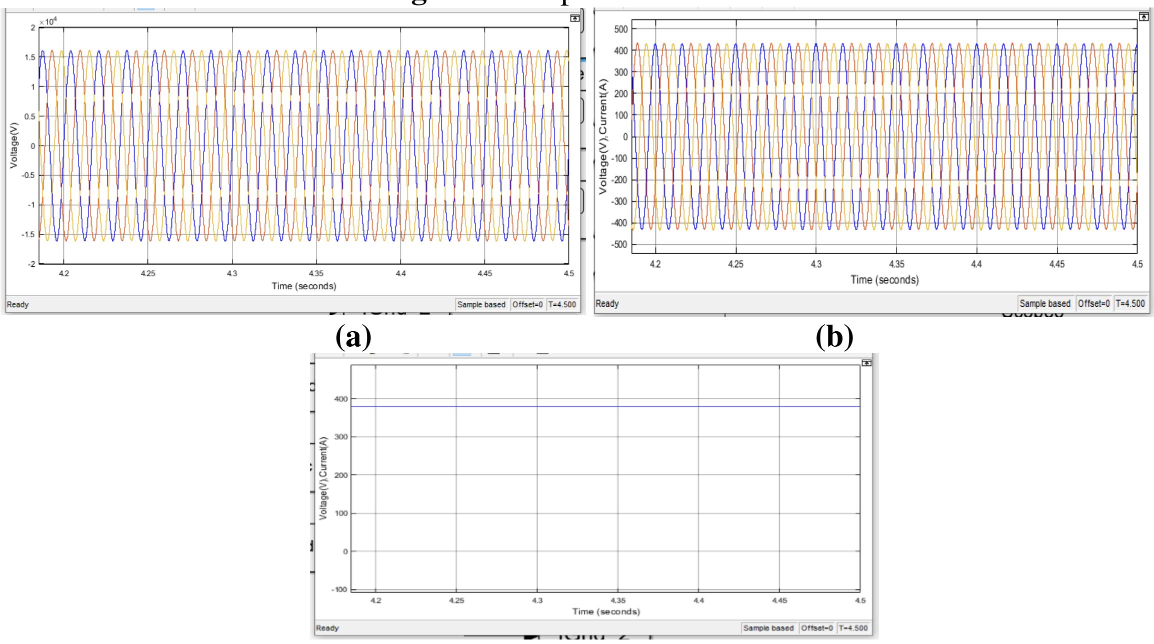


Figure 3: Proposed Simulink **5B**



(a) **(b)**

(c)

Figure 4: Output response for proposed 5B, (a) Vg; (b) Ig; (c) Vdc

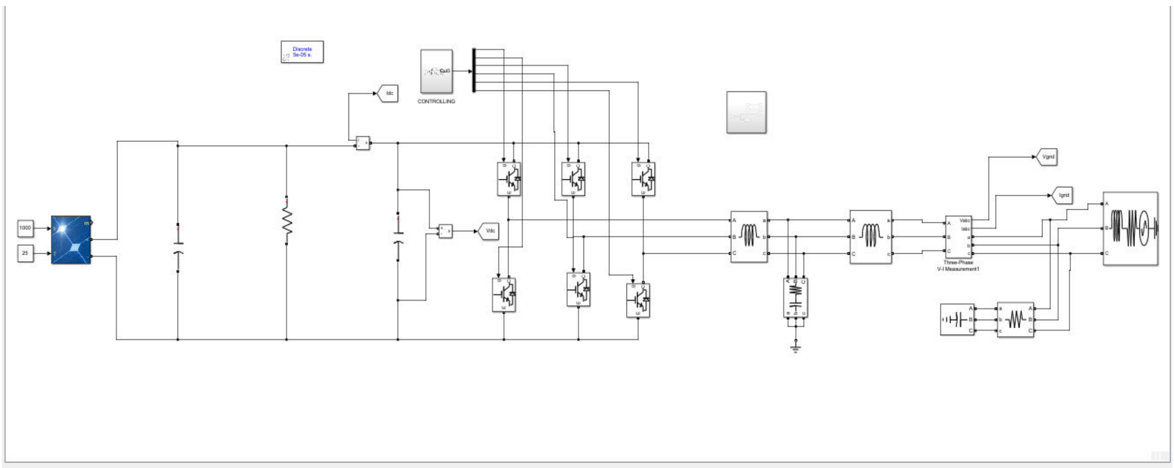
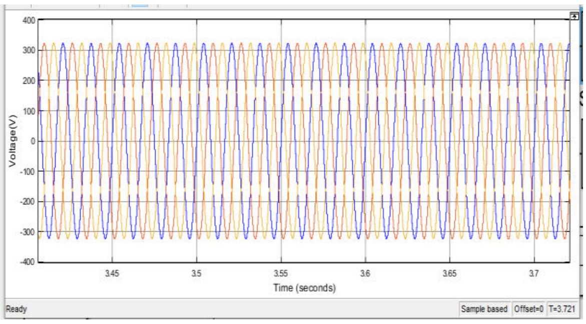
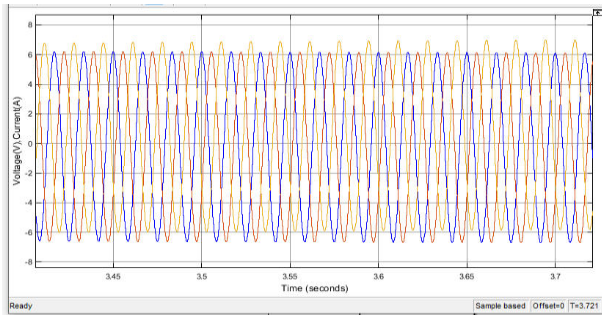


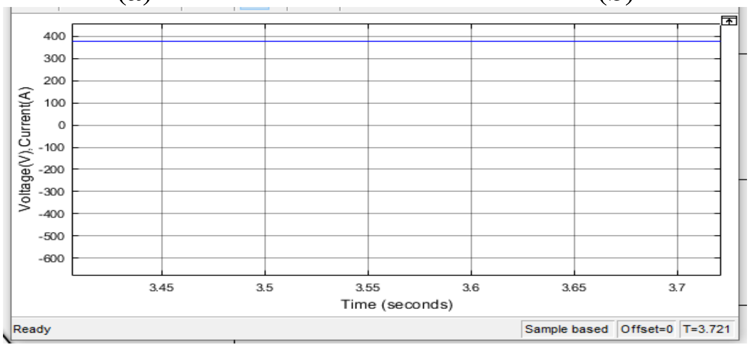
Figure 5: Proposed Simulink **5 C**



(a)



(b)



(c)

Figure 6: Output response for proposed 5A, (a) Vg; (b) Ig; (c) Vdc

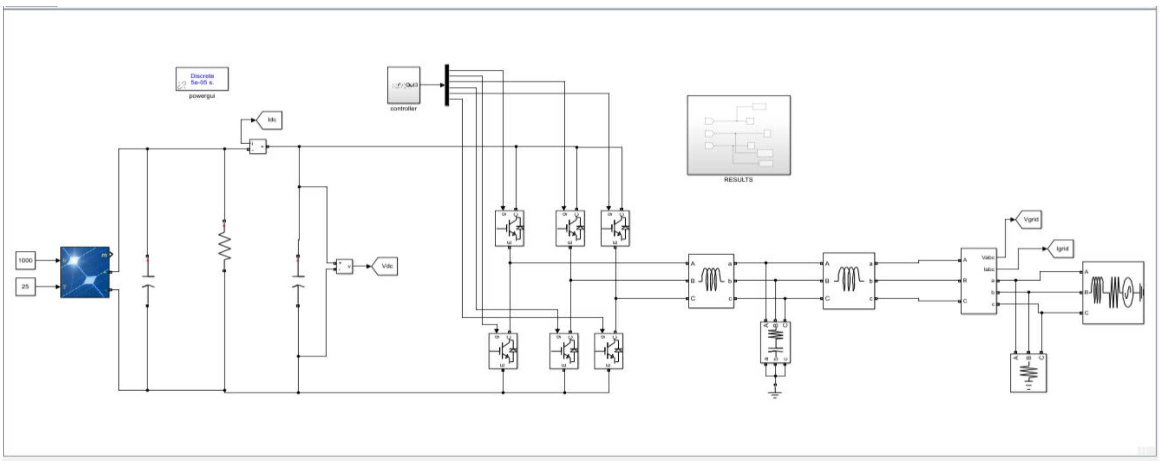
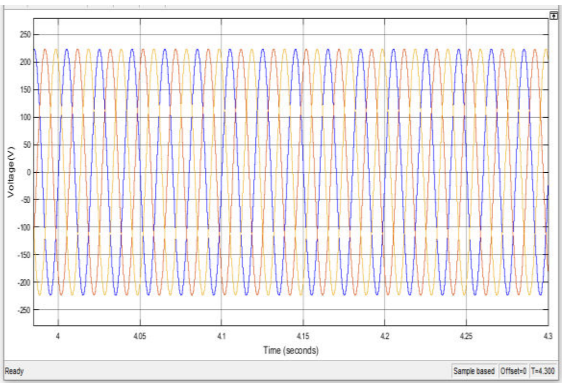
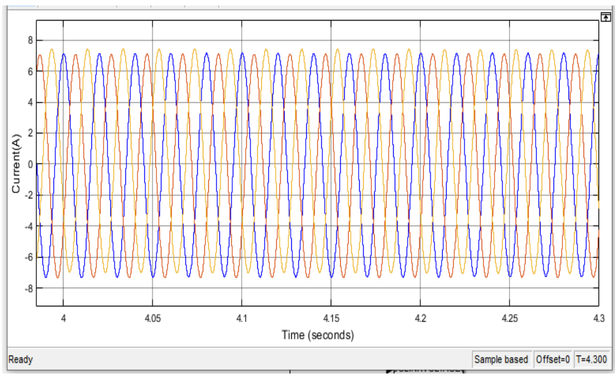


Figure 7: Proposed Simulink Case: 6A



(a)



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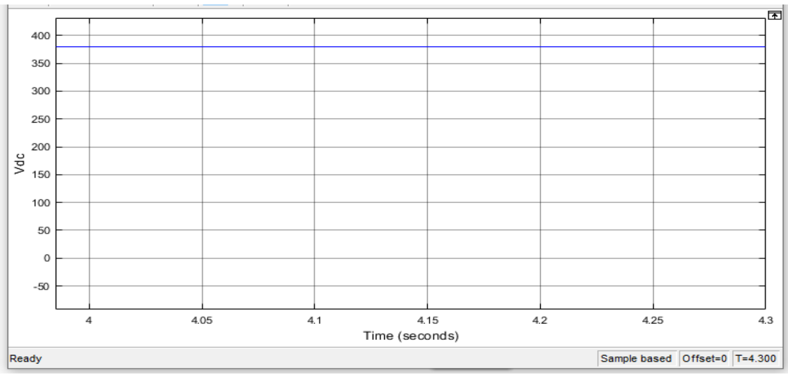


(c)

Figure 8: Output response for proposed 5A, (a) Vg; (b) Ig; (c) Vdc

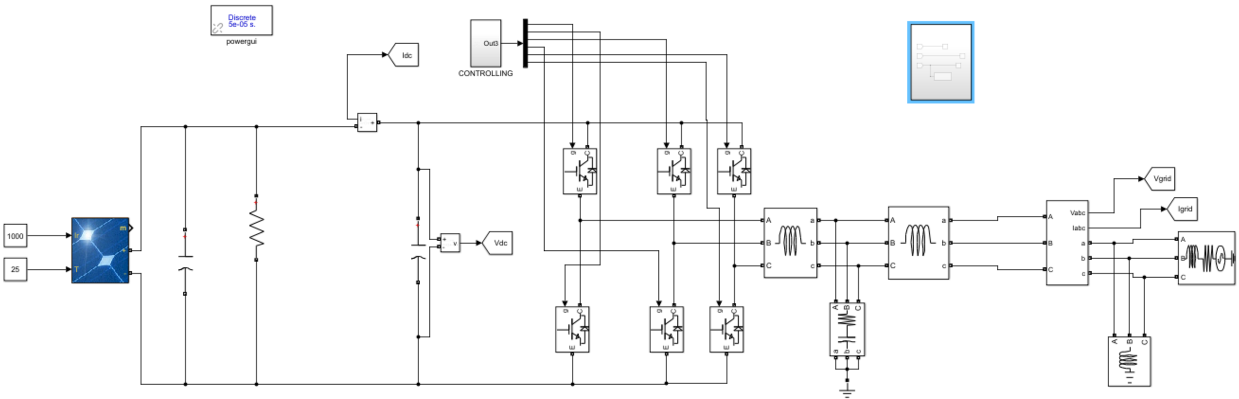
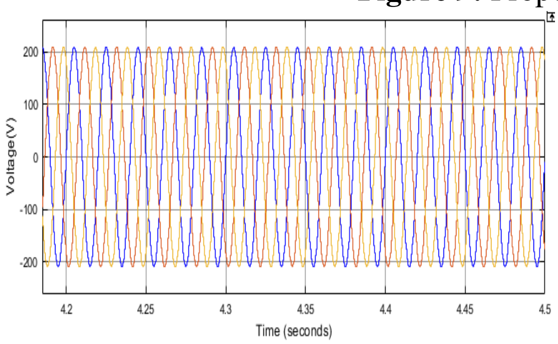
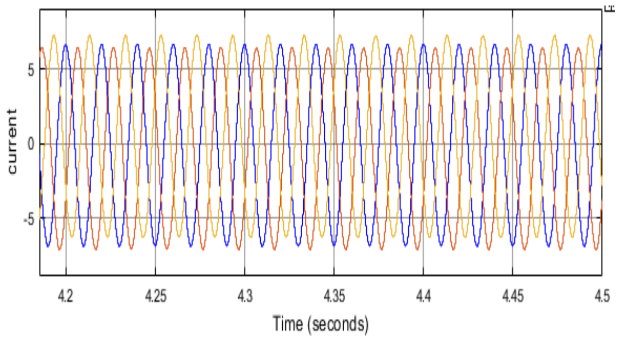


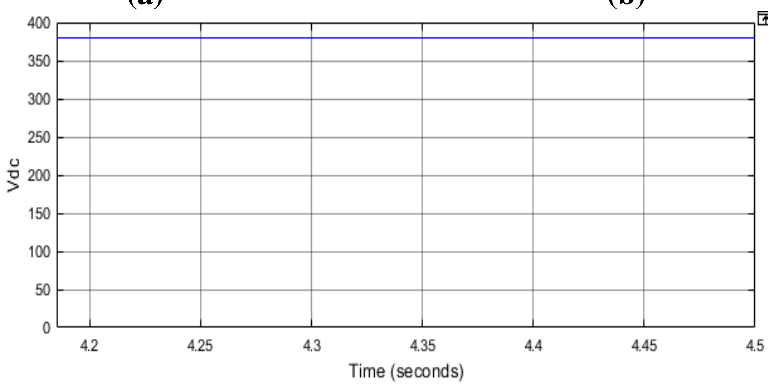
Figure 9: Proposed Simulink Case: 6b



(a)



(b)



(c)

Figure 10: Output response for proposed 5A, (a) Vg; (b) Ig; (c) Vdc

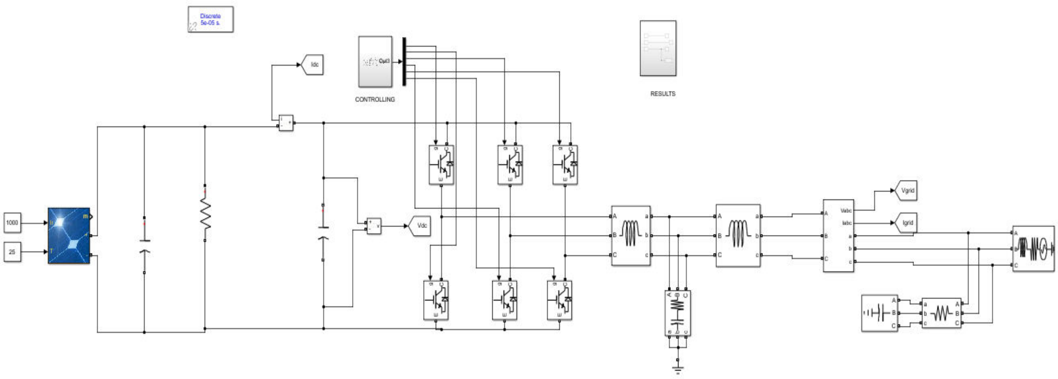


Figure 11: Proposed Simulink Case: 6-C

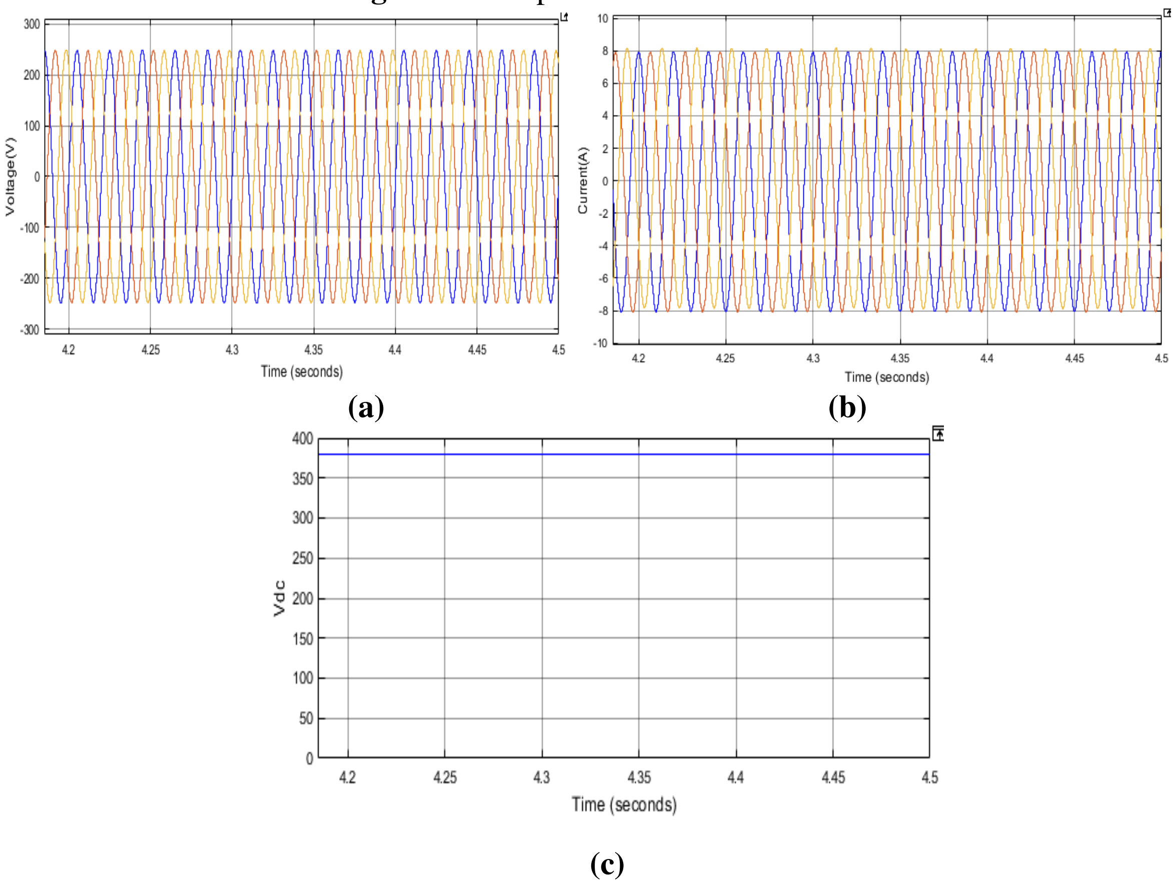


Figure 12: Output response for proposed 5A, (a) Vg; (b) Ig; (c) Vdc

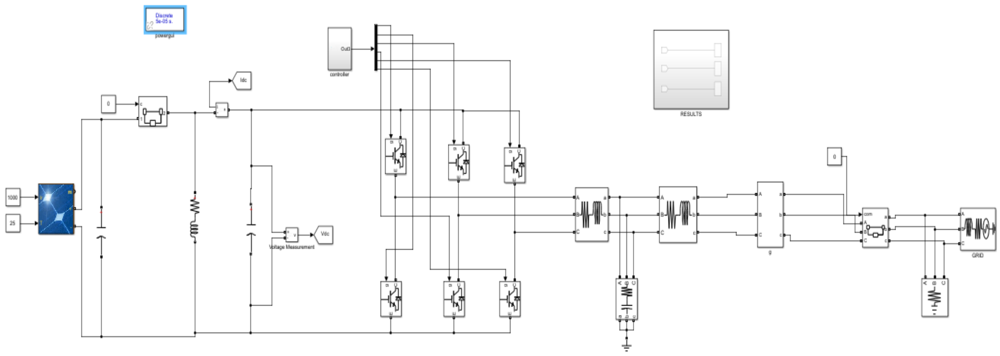
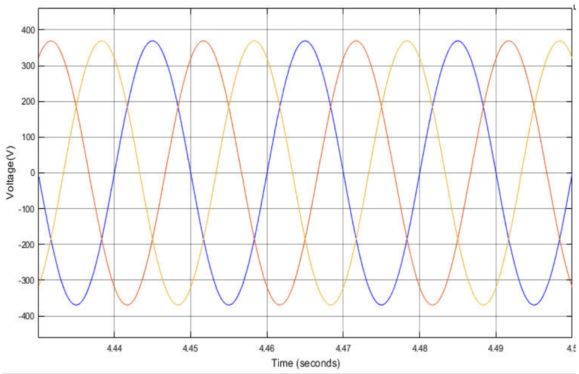
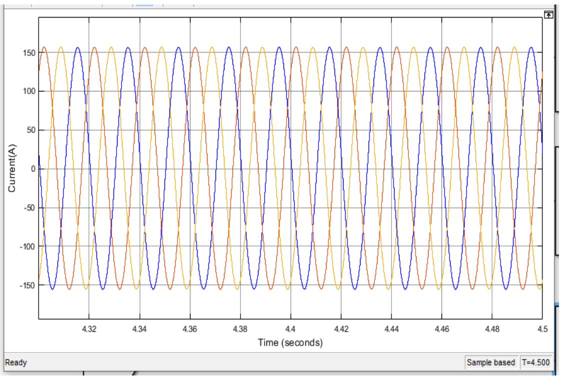
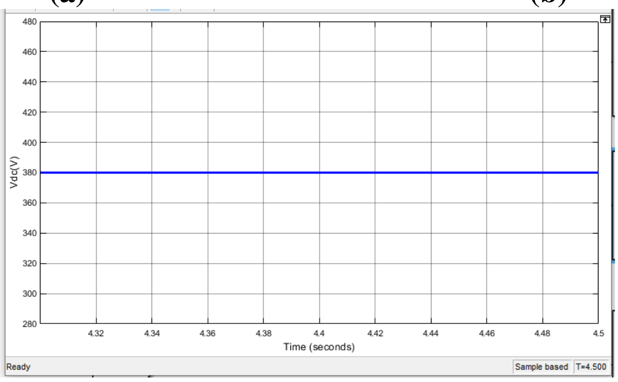


Figure 13: Proposed Simulink of islanded mode



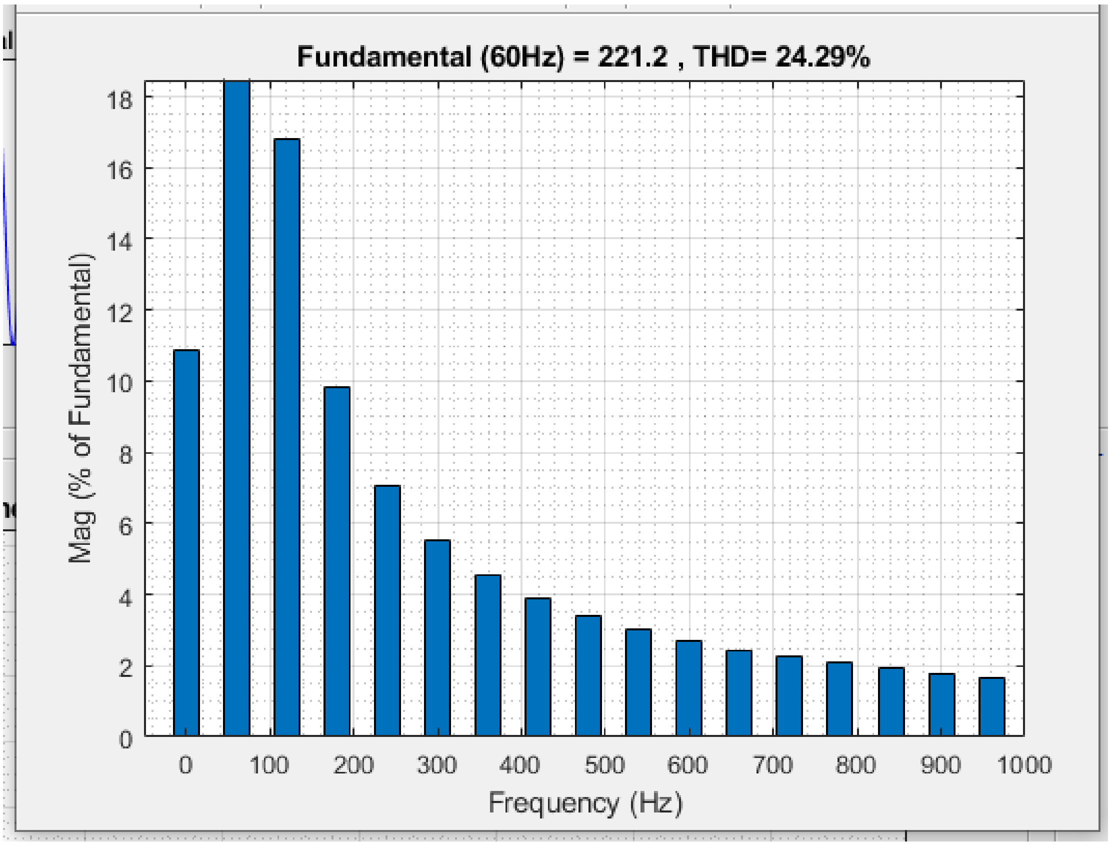


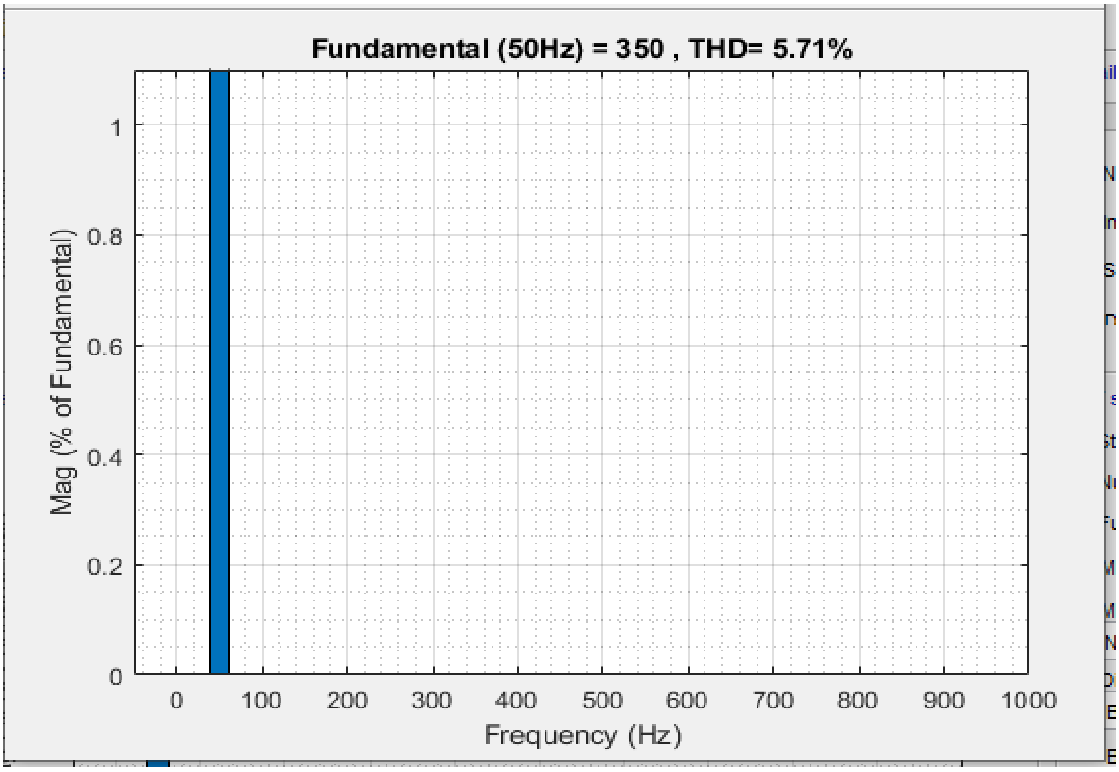
(a) **(b)**



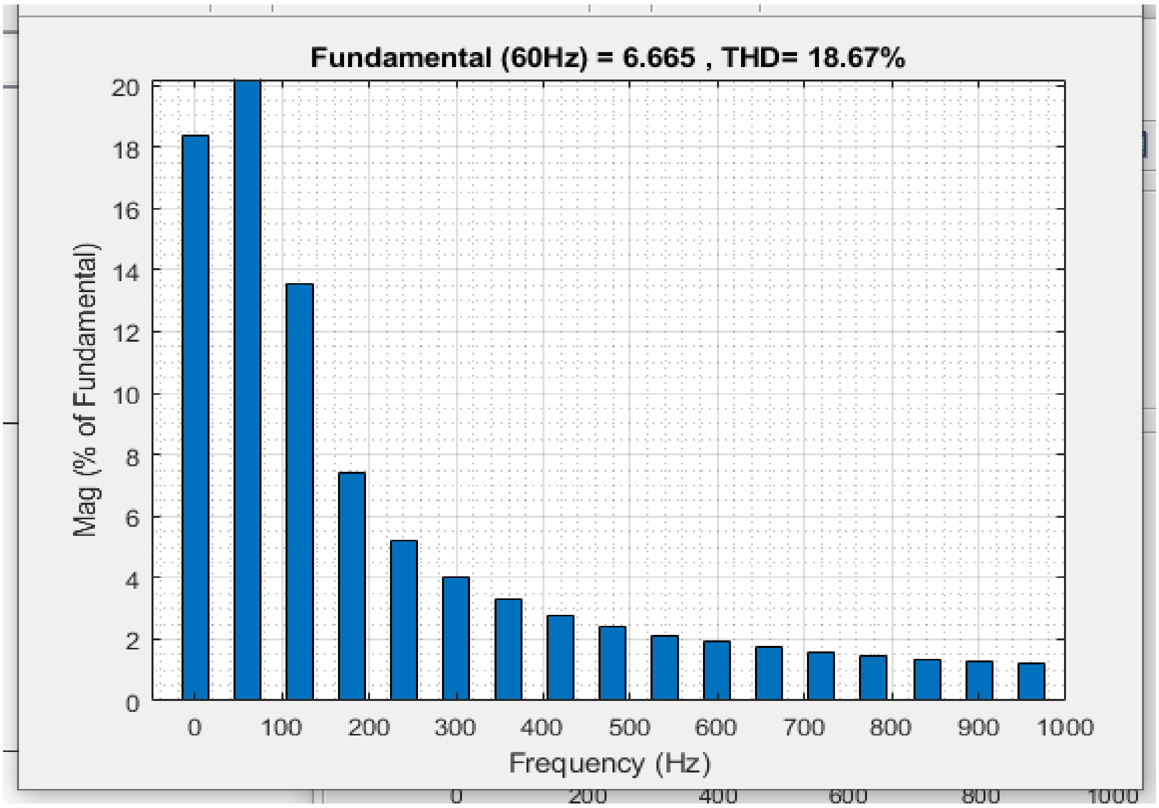
(c)

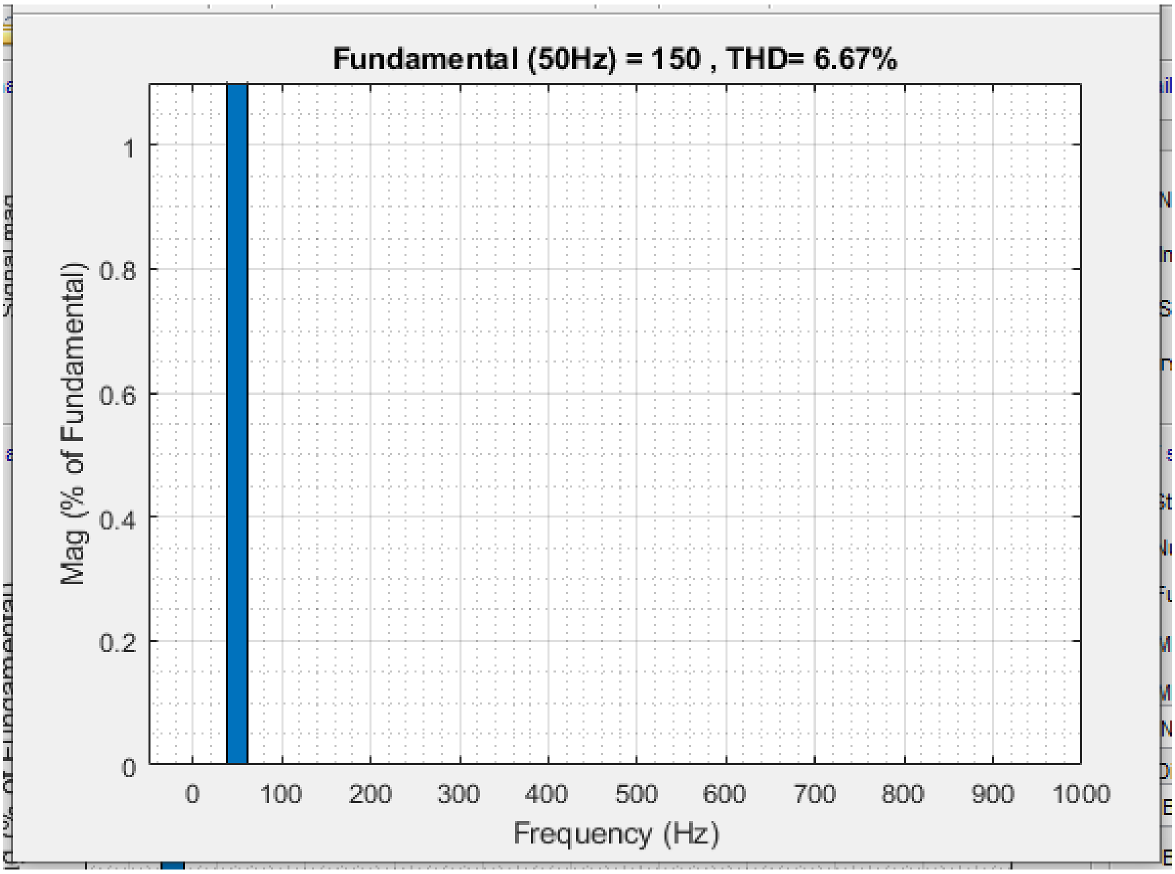
Figure 14: Output response for proposed 5A, (a) Vg; (b) Ig; (c) Vdc



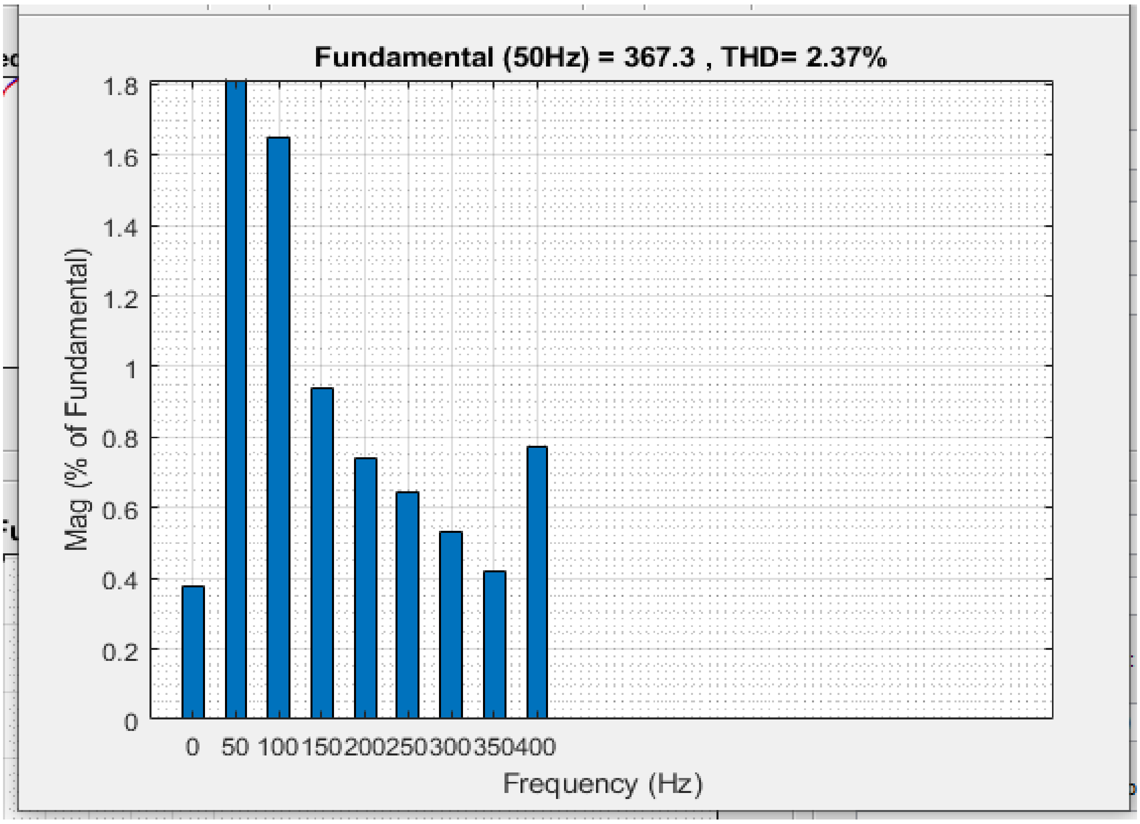


Vg-with PI Controller

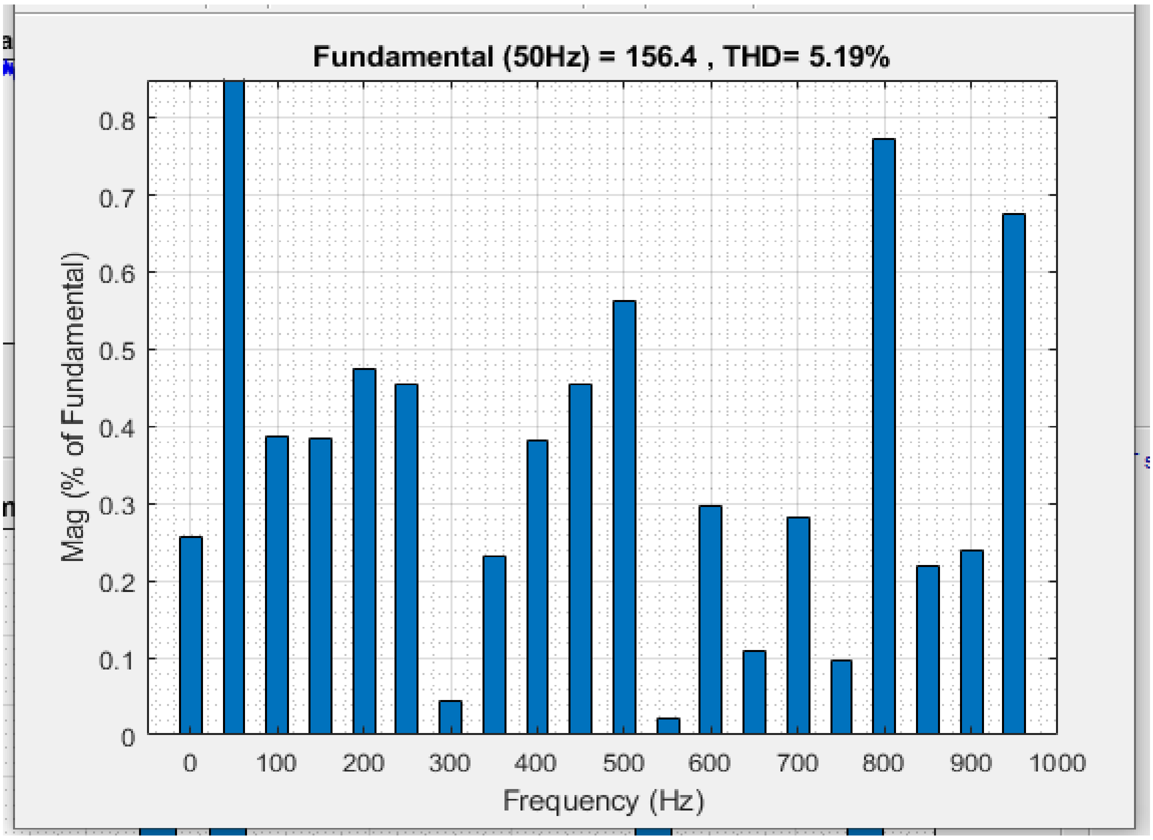




Ig with PI controller



Vg with FLC controller



Ig with FLC controller

Table 1: %of THD Obtained by using PI & FLC Controller

Parameter	%of THD Obtained by using PI Controller	%of THD Obtained by using FLC
Grid Voltage (Vg)	5.71%	2.37%
Grid Current (Ig)	6.67%	5.19%

IV. CONCLUSION

In this paper, we demonstrate the simulation of an active and reactive power control strategy for a bidirectional interlinking converter in a single-phase AC-DC residential hybrid micro grid. Power factor correction at the point of common coupling with the AC power grid is the basis for this work. Because the reactive power can be regulated in any direction (rectifier, inverter, islanding), the power factor can be calculated accurately and in accordance with the standards set by the AC distribution grid. The Hybrid Micro-Grid system described here is proposed for actual use in subsequent works.

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