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Implementation of Installation Two-way DC-DC Converter with IoT Control and Monitoring

Darjat[1], Aris Triwiyatno[2], Hanif Fadhlurrahman[3]

[123]Diponegoro University, Department of Electrical Egineering,
Jl. Prof. Sudarto, Tembalang, Semarang, Indonesia

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Abstract

Renewable energy generation, such as solar energy, produces electrical energy with fluctuating voltages. Light intensity is one of the causes of this fluctuating voltage. The resulting voltage is directly proportional to the intensity of the light. It is necessary to implement a converter system to increase efficiency in the solar panel system. The converter with an insert buck-boost topology is designed to regulate the direction of power in and out of the battery. Setting the direction of the flow of power is considered important in order to increase the efficiency of the solar panel system. This research focuses on the design and implementation of the Online Insertion Two-Way DC-DC Converter. The converter functions to connect the storage media and the DC Bus and smoothes the output current with a phase shift of the PWM signal by 180°. The phase shift feature is set using the ATMEGA328P minimum system. In addition to functioning as a buck (charging) and boost (discharging) battery, there is also an online monitoring function. The online monitoring feature is designed to display the DC Bus voltage value and battery voltage, while the online controlling feature allows users to manually change the converter mode from buck to boost or vice versa. The test results show that the Insertion Bidirectional DC-DC Converter can produce a stable voltage according to the given duty cycle. The average efficiency is 88% for buck mode and 92% for boost mode. In the blynk application, it can display the DC Bus voltage and battery voltage and the user can change the converter mode manually.

Keywords: Converter, charging, discharging, online, phase shift

1. Introduction

1.1 Introduce the Problem

The human need for electrical energy continues to increase every year. Starting in 2013 the electricity demand per capita was 0.84 GWH (Giga Watt Hour) and continued to increase until in 2019 it was 1.08 GWH (Giga Watt Hour) per capita (Ketenagalistrikan, 2019). This is directly proportional to the rate of population growth in Indonesia, according to the population census in Indonesia, which increased by 32.57 million people from 2010 to 2020 (Suhariyanto, 2020). Therefore, it is necessary to develop a renewable energy sector as planned by the Government with a 23% renewable energy utilization program (RI, 2020). One of the renewable energy sources is solar energy. Solar energy is an alternative energy to produce electrical energy through the photovoltaic effect on solar cells (Ramadhan, Diniardi and Mukti, 2016). However, in its application, the solar cell itself produces a voltage that fluctuates according to the changing temperature and irradiation.

Therefore, we need a two-way converter that is able to regulate the load requirements. When the power from the solar panel is sufficient to meet the load requirements, the converter is in buck mode and will drain the excess power to be stored in the battery, otherwise if the power from the panel is still insufficient to meet the load requirements, the converter will drain power from the battery (Raharja *et al.*, 2019). There are various converter topologies, one of which is the insert converter topology. This topology is capable of producing DC electricity which tends to have smaller ripples than conventional topologies. This is able to extend the life of the hybrid home electrical equipment because the DC electricity generated is more stable. Pulse Width Modulation (PWM) is used as a trigger for the Insertion Bidirectional DC-DC Converter with a phase shift of 180 (Yang *et al.*, 2018).

Based on the description above, in this study a Insertion Bidirectional DC-DC Converter has been designed using a minimum system ATMEGA328P as a PWM generator and ESP32 as a control and monitoring converter. This online insertion two-way DC-DC converter is expected to produce smoother output current ripple and make it easier for users to monitor the converter in real time.

1.2 Literature review

Two-way DC-DC converter is a direct current converter that functions as a regulator of the direction of power flow both in and out of the battery. This research designs a converter with an insert converter topology. This topology combines two converters in parallel. Combining these two converters will reduce fluctuations in the output current and voltage. The current from the source will be divided into two parallel circuits and one of the circuits experiences a phase shift of 180º (Inverter *et al.*, 2019). The circuit of the Insertion Bidirectional DC-DC Converter is shown in Figure 1.

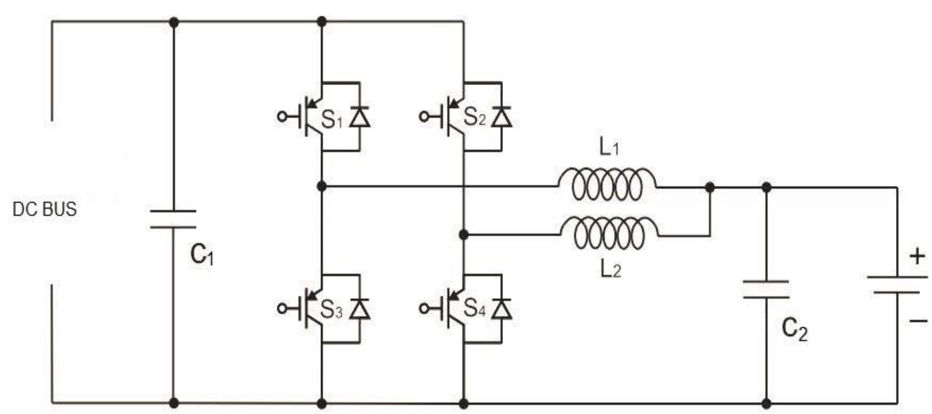

Figure 1. Insertion Bidirectional DC-DC Converter (Lai, Lin and Lee, 2015)

The Bidirectional Insertion DC-DC converter has two different modes, namely buck mode and boost mode. Buck mode or charging mode is a condition where the converter supplies power from the DC Bus to the battery. MOSFET on S1 and S2 gets a PWM signal and will be active with a phase angle difference of 180º, while S3 and S4 act as diodes (Lai, Lin and Lee, 2015).

Boost mode or discharging mode is a condition where the converter supplies power from the battery to the DC Bus. MOSFET on S3 and S4 gets a pwm signal with a phase angle difference of 180º, while S1 and S2 act as diodes (Lai, Lin and Lee, 2015).

MOSFET (Metal Oxide Semiconductor Field Effect Transistor) adalah sebuah perangkat semikonduktor yang biasanya digunakan untuk switching dengan kecepatan tinggi. Ada dua tipe MOSFET, tipe yang pertama adalah tipe N channel dan P channel (Wardani and Manan, 2016).

PWM (Pulse Width Modulation) is a modulation technique by changing the pulse width (duty cycle) with a fixed amplitude and frequency. One pulse cycle is a high condition then is in the transition zone to a low condition. The PWM pulse width is directly proportional to the amplitude of the original unmodulated signal. Duty cycle is a representation of a logical high condition in a signal period and is expressed in the form (%) with a range of 0% to 100%. PWM technique that can be used as input to a two-way converter to control the output (Anjana Thakur, 2016) is single pulse width modulation.

1.3 Research design steps

Two-way Insertion DC-DC Converter designed in this final project aims to control the direction of energy from the DC Bus to and from the battery. The design of the Inserted Bidirectional DC-DC Converter in this final project consists of several parts, namely the TLP250 driver supply section, the power circuit section which is a Bidirectional Inserted DC-DC Converter, the control circuit section consisting of a PWM generator microcontroller, a microcontroller monitoring converter online, and power storage blocks. The hardware block diagram designed in this final project is shown in Figure 2.

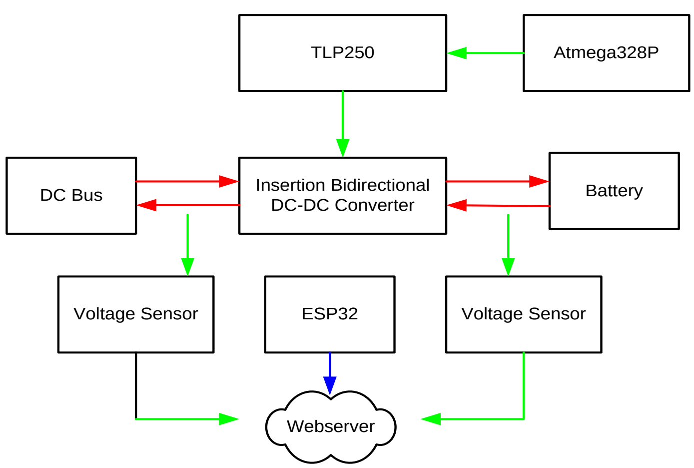

Figure 2. Hardware design block diagram

2. Method

2.1 Driver MOSFET Design

TLP250 is an Integrated Circuit (IC) that functions as an optical circuit separator and as a signal amplifier. The TLP250 output voltage range is 10-35 volts and the maximum output current is 1.5 amperes and can be seen in the TLP250 specification (Inverter *et al*., 2019).

The PWM signal output from the microcontroller is only 5 VDC, so it is necessary to use TLP250 to amplify the PWM signal and separate the power circuit and the PWM generator circuit.

2.2 PWM Switch Circuit Design

The PWM switch circuit functions as a PWM signal input switch in the MOSFET driver circuit and the components used are 2N3904 transistors (Data, 1996). This transistor will activate or deactivate the incoming signal to the TLP250, so that the TLP250 in buck mode and boost mode will be set and lit alternately according to the command given. This PWM switch circuit is depicted in Figure 3.

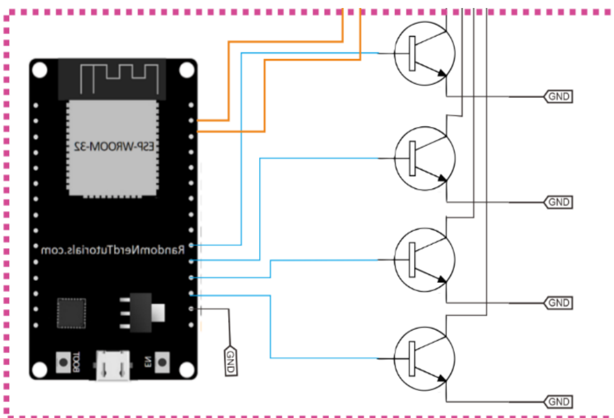

Figure 3. PWM switch circuit

2.3 Power Circuit Design

Insertion bidirectional DC-DC converter designed in this study aims to control the direction of energy from the DC Bus to and from the battery. The design of the Inserted Two-Way DC-DC Converter in this study consists of several parts, namely the TLP250 driver supply section, the power circuit section which is the Insertion Two-Way DC-DC Converter, the control circuit section consisting of a PWM generator microcontroller, an online converter monitoring microcontroller. and power storage blocks.

There are 4 components that make up the converter circuit, namely inductors, capacitors, diode MUR1560 (Intersil, 2000), Metal Oxide Semiconductor Field Effect Transistor (MOSFET) K3878 (TOSHIBA, 2013).

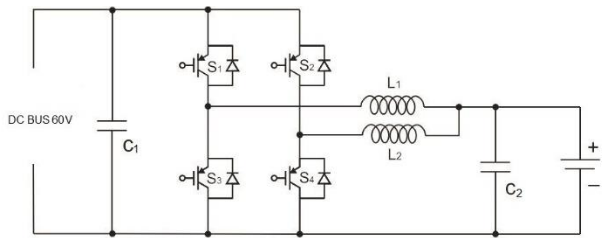

Figure 4. Insert converter circuit

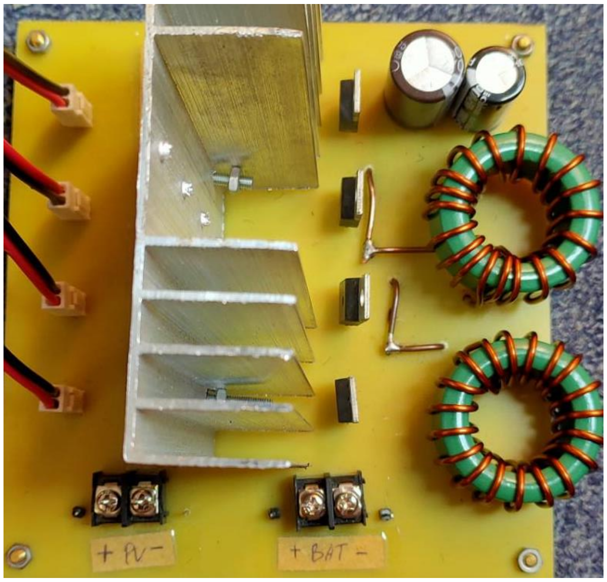

Figure 5. Converter circuit realization

2.4 Control Circuit Design

The design of the control circuit in this study is divided into 2 parts, namely, the design of the PWM generator circuit that uses the ATMMEGA328P minimum system and the online converter control and monitoring circuit. The following is an explanation of each part of the control circuit design in this study.

2.4.1 Minimum System ATMEGA328P

The PWM signal generation in this research design uses the Port Register to generate a PWM signal which seems to have a phase shift of 180°. The port used on the ATMEGA328P is PORTB and leads to pins D8 to D13. For boost mode, the pins used are pins 10 and 11 while for buck mode, the pins used are pins 8 and 9.

2.4.2 Online Control and Monitoring

Online control and monitoring of the converter using the ESP32 microcontroller. This feature aims to display the voltage sensor readings on the DC Bus and the battery in the blynk application. In addition to these features, there is a control feature that allows the user to change the converter mode.

There are two converter modes, namely auto mode and manual mode. Buck mode and boost mode in auto mode are set automatically by the ESP32 based on the DC bus voltage. When the DC bus is more than 60 V then the PWM switch in buck mode will be active and the PWM switch in boost mode will be deactivated, otherwise when the DC bus is less than 60 volts the PWM switch in buck mode will be disabled and the PWM switch in boost mode will be active. For manual mode, the user can adjust the condition of the converter from buck to boost mode or from boost to buck mode. The flow chart of the online control and monitoring circuit is shown in Figure 6.

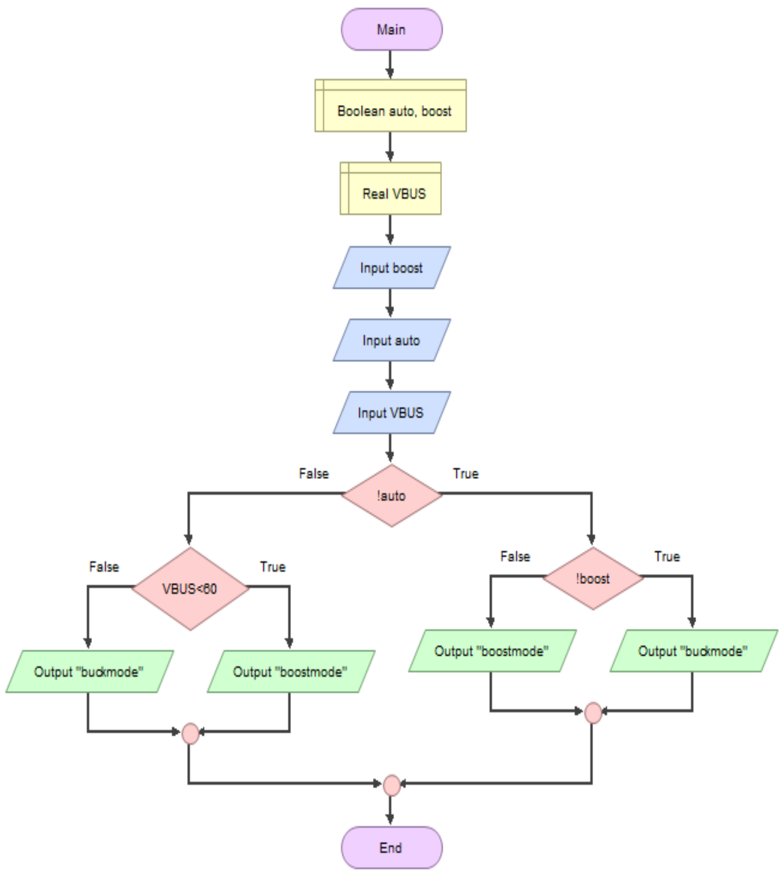

Figure 6. Flowchart of online controlling and monitoring

3. Results

Circuit testing aims to ensure that the designed converter is working. The test is carried out by measuring the value of the input voltage, input current, output voltage, and output current.

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3.1 Buck mode testing

In testing the buck mode plays a role in providing a PWM signal with a 180° phase shift. In the buck mode test, it is done with a voltage source from the DC Bus. The test uses a variation of resistors, namely 47, 56, and 100 Ω and a duty cycle variation of 10%-70%. Optimal test results are 40% duty cycle. The following is a test result of a two-way insertion DC-DC converter circuit.

Table 3.1. Test results of 47, 56, and 100 Ω load buck modes with a duty cycle of 40%.

Load (Ω)	*Duty cycle* (%)	Vin (V)	Iin (A)	Vout (V)	Iout (A)	Efficiency (%)
47	**40**	**60,3**	**0,19**	**23,65**	**0,5**	**94,54**
56	40	60,3	0,18	25,2	0,45	93,45
100	40	60,3	0,13	27,72	0,27	90,32

3.2 Boost Mode Test

The boost mode test plays a role in providing a PWM signal with a 180° phase shift and is carried out with a DC source. Data retrieval using a resistor variation of 400, and 470, as well as a 10%-70% duty cycle variation. The optimal result is a solid 60% duty cycle. The following are the results of testing the Insertion Bidirectional DC-DC Converter circuit.

Table 3.2. Test results for load boost modes of 400, 470, and 570 Ω with a duty cycle of 60%.

Load (Ω)	Duty cycle (%)	Vin (V)	Iin (A)	Vout (V)	Iout (A)	Efficiency (%)
400	**60**	**12.5**	**0.19**	**29.4**	**0.07**	**90.87**
470	60	12.5	0.16	29.55	0.06	87.45
570	60	12.5	0.14	30.90	0.04	70.06

3.3 Overall Circuit Test

This test aims to find out the circuit made runs according to the given algorithm. In this test, the voltage source used is from the battery and from the solar panel output. The data from the serial monitor is shown in the following table.

Table 3.3. Full circuit test table

Time Stamp	Boost Voltage	Buck Voltage	Bus Voltage	Mode	Converter Mode
16:50:16.931	57,67	24,68	59,15	AUTO	Boost
16:50:19.120	58,40	24,72	60,08	AUTO	Buck
16:50:21.269	57,70	24,79	59,11	AUTO	Boost
16:50:23.464	58,11	24,57	59,66	AUTO	Boost
16:50:25.611	58,51	24,57	59,96	AUTO	Boost
16:50:27.803	58,42	24,81	60,12	AUTO	Buck
16:50:29.951	57,64	24,92	-	MANUAL	Boost
16:50:36.150	58,66	24,77	-	MANUAL	Boost
16:50:38.253	58,53	24,81	-	MANUAL	Boost

3.4 Converter Monitoring

This test aims to determine the control and monitoring functions of the converter are working properly. The test was carried out using the blynk application on a smartphone. The initial display of the blynk application is shown in Figure 3.1.

Figure 3.1 The initial view of the blynk application

3.5 Converter Control

In the blynk application there are 2 buttons that can be accessed by the user. The first button is the auto and manual buttons. When the auto button is pressed, the ESP32 is in auto converter mode. This mode is a mode that regulates the converter change from buck to boost or vice versa based on the DC bus voltage reading. The second button is a manual boost and manual buck button. This button will change buck mode to boost mode manually.

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Figure 3.2 Display of voltage readings on DC boost and battery

4. Discussion

Based on the results of testing and analysis in the study, it can be concluded that the inserted two-way DC-DC converter that is made can supply two-way power from the battery side to the DC bus and vice versa. In the buck mode power circuit test using 47, 56, and 100 ohm resistors it can produce a high efficiency average of 88% and in boost mode testing using 400, 470, and 570 ohm resistors can produce a high efficiency average of 92 %.

The online control and monitoring circuit is capable of displaying the voltage value on the buck and boost sides, and manual control is able to change the converter mode through the blynk application.

Acknowledgments

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References

Anjana Thakur, D. A. K. S. (2016) ‘An Overview of Different PWM Techniques to Reduce Total Harmonic Distortion of Output in’, *International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)*, 3(2), pp. 65–69.

Data, S. T. (1996) ‘General Purpose Transistors MMBT2907LT1’, pp. 1–7.

Intersil (2000) ‘Mur1540, mur1560, rurp1540, rurp1560’, (2778), pp. 1–3.

Inverter, I. *et al.* (2019) ‘Tlp250’, pp. 1–7.

Ketenagalistrikan, direktorat J. (2019) 'Statistik ketenaga listrikan', *Https://Gatrik.Esdm.Go.Id/Frontend/Download_Index?Kode_Catagory=Statistik.*, 53(9), pp. 1689–1699.

Lai, C. M., Lin, Y. C. and Lee, D. (2015) 'Study and implementation of a two-phase interleaved bidirectional DC/DC converter for vehicle and DC-microgrid systems', *Energies*, 8(9), pp. 9969–9991. doi: 10.3390/en8099969.

Raharja, L. pradigta setiya *et al.* (2019) 'Perancangan Dan Implementasi DC-DC Bidirectional Converter Dengan Sumber Energi Listrik Dari Panel Surya Dan Baterai Untuk Pemenuhan Kebutuhan Daya Listrik Beban', *JTT (Jurnal Teknologi Terpadu)*, 7(2), pp. 111–118. doi: 10.32487/jtt.v7i2.709.

Ramadhan, A. I., Diniardi, E. and Mukti, S. H. (2016) 'Analisis Desain Sistem Pembangkit Listrik Tenaga Surya Kapasitas 50 WP', *Teknik*, 37(2), p. 59. doi: 10.14710/teknik.v37i2.9011.

RI, S. (2020) 'Rencana Pembangunan Jangka Menengah Nasional Tahun 2020-2024 - Lampiran II: Proyek Prioritas Strategis (Major Project)'.

Suhariyanto (2020) 'Catalog : 1101001', *Statistik Indonesia 2020*, 1101001, p. 790.

TOSHIBA (2013) 'K3878 Datasheet', *Source*, pp. 1–6.

Wardani, I. S. and Manan, S. (2016) 'Power Supply Inverter Dc-Dc Sebagai Supply Audio Amplifier', *Gema Teknologi*, 18(4), p. 5. doi: 10.14710/gt.v18i4.21909.

Yang, Y. *et al.* (2018) 'More Symmetric Four-Phase Inverse Coupled Inductor for Low Current Ripples & High-Efficiency Interleaved Bidirectional Buck/Boost Converter', *IEEE Transactions on Power Electronics*, 33(3), pp. 1952–1966. doi: 10.1109/TPEL.2017.2745686.