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The Improvement of Junction Box Within Photovoltaic Power System

Ki-Ju Sun
Department of Electrical and Electronic Engineering, Graduate School, Dongshin University, Naju 58245, Korea

Min-Woo Cheon†
Department of Health Administration, Dongshin University, Naju 58245, Korea

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In the PV (Photovoltaic) power system, a junction box collects the DC voltage generated from the PV module and transfers it to the PCS (power conditioning system). The junction box prevents damage caused by the voltage difference between the serially connected PV modules and provides convenience while repairing or inspecting the PV array. In addition, the junction box uses the diode to protect modules from the inverse current when the PV power system and electric power system are connected for use. However, by using the reverse blocking diode, heat is generated within the junction box while generating electric power, which decreases the generating efficiency, and causes short circuit and electric leakage. In this research, based on the purpose of improving the performance of the PV module by decreasing the heat generation within the junction box, a junction box with a built-in bypass circuit was designed/manufactured so that a certain capacity of current generated from the PV module does not run through the reverse blocking diode. The manufactured junction box was used to compare the electric power and heating power generated when the circuit was in the bypass/non-bypass modes. It was confirmed that the electric power loss and heat generation indicated a decrease when the circuit was in the bypass mode.

Keywords: Junction box, Diode, PV, Solar cell

1. INTRODUCTION

The PV (photovoltaic) power system uses a number of PV modules to develop an array according to the power generation and uses the surrounding devices for the control or electric power adjustment to generate electric power [1,2]. Such a PV power system can be divided into stand-alone type and grid-connected type [3]. The stand-along type system is a method for using the locally generated electric power. It stores the electric power generated from the solar cells which it converts into a form suitable for use [4,5]. The grid-connected type system is a method for converting the DC power generated from the solar cells into AC power to be supplied to the electric power equipment. Its strength is that the firm electric power can be used when the generation is insufficient [6]. Accordingly, the grid-connected type is normally used when the generation is above a kW level [7].

Such grid-connected PV power system consists of diverse systems constructed for enhancing the generating efficiency and performing a stable operation. However, it normally consists of a PV module which controls the generation of electric power, a junction box which controls the collection of electric power generated from the PV module, an inverter which converts the DC power generated from the junction box/PV module into AC power, and a PCS (power conditioning system) consisting of diverse electric power control systems [8].

Such a junction box is sometimes used to confirm the generation between the modules, but it is mostly used to prevent damage to the modules due to the inverse current created during

† Author to whom all correspondence should be addressed:
E-mail: mwcheon@dsu.ac.kr

the grid connection as well as to secure the safety of the serially connected modules [9]. For such purposes, the use of a reverse blocking diode is essential and such use may create some unnecessary heat during the generation. In addition, the generation environment rapidly increases the internal temperature. Such increase in temperature can cause problems such as insulation and softening of elements due to energy loss and heat accumulation during the kW or more levels generation; such problems can lead to fire accidents [9]. In this research, in order to minimize the heat generation within the junction box, a bypass junction box capable of directly transferring the electric power generated from the PCS without using the diode used for preventing the inverse voltage was designed and manufactured. In addition, the proposed junction box was used to examine the increase in energy efficiency and the increase in internal temperature of the junction box during the PV generation processed at 100 kW level.

2. EXPERIMENTS

The junction box allows the PV modules to generate power without influencing the other modules when more than 2 parallel modules are serially connected, even when the output voltage of the respective serial groups varies.

In this research, in order to construct a 100 kW-level PV power system that features diverse types of serial/parallel combination, a six 4 channel-based junction box was used to construct a junction box that features 24 parallel connections.

Figure 1 shows a diagram of the 4 channel-based junction box circuit. Normally, the junction box consists of a MCCB (mold case current breaker) for prevention of damages caused by short circuit or overload and a diode for the prevention of inverse current. However, in this research, a junction box capable of minimizing heat generation through the use of a bypass circuit is designed and manufactured so that the generation can be executed without running through the diode when the electric current

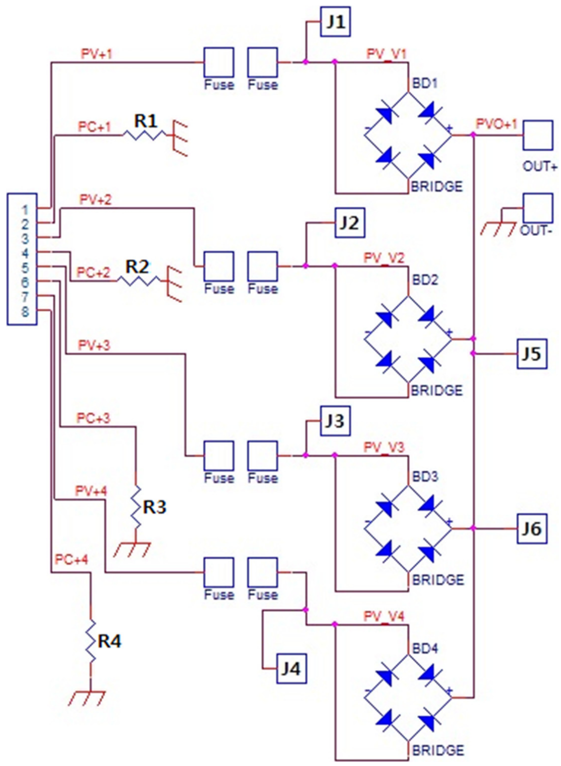

Fig. 1. 4 Channel-based junction box circuit diagram.

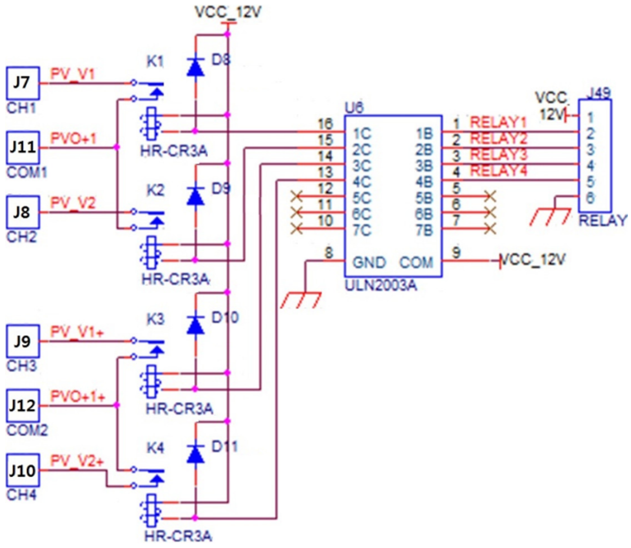

Fig. 2. Relay bypass circuit.

above a certain level is created from the PV module.

To achieve this, a total of 6 terminals ranging from J1 to J6 were constructed to create a separate bypass in respective channels. The manufactured 4 channel-based junction box is designed to activate the relay through the respective terminals when a current above 1A is detected, so that such current does not run through the diode. A MCU (micro controller unit) was used to control the relay during the occurrence of high current, and the 4 channel-based junction box is designed so that the internal junction box temperature, radiator panel temperature, and generation can be confirmed. MG82FGB16 (MEGAWIN Technology Co., LTD., Taiwan) was used as the MCU in this research. MG82FGB16 is a 8051 series microcontroller and its operation requires voltages ranging from 1.8 V to 5.5 V. It consists of a programmable 16 Byte flash ROM and an 8 10-Bit ADC (analog to digital converter). ADC was used to measure the temperature and confirm the current capacity applied to each channel.

The shunt resistor installed on R1~R4 shown in Fig. 2 was used to measure the current capacity applied to the respective terminals. The small voltage signal measured in the shunt resistor is amplified and transferred to the ADC terminal of the MCU that controls the junction box. Based on the transferred ADC signal, MCU analyzes the current capacity by calculating the current value resulting from the potential difference between both ends and then activates the relay so that the generation can be executed without running through the diode for preventing the inverse current when a current above 1.5 A flows in respective terminals.

Figure 2 shows a relay bypass circuit constructed with 4 channels.

The terminals ranging from J7 to J12 are constructed in order to avoid using the reverse blocking diode and are connected to the terminals ranging from J1 to J6 as shown in Fig. 2. The small signal output from MCU is amplified through the transistor to activate the relay. Since the 4 channel-based junction box circuit requires 4 transistors to active the bypass terminal, ULN2003A (STMicroelectronics, Switzerland), consisting of 7 transistors, is used to simplify the circuit.

3. RESULTS AND DISCUSSION

In this research, a bypass junction box capable of executing

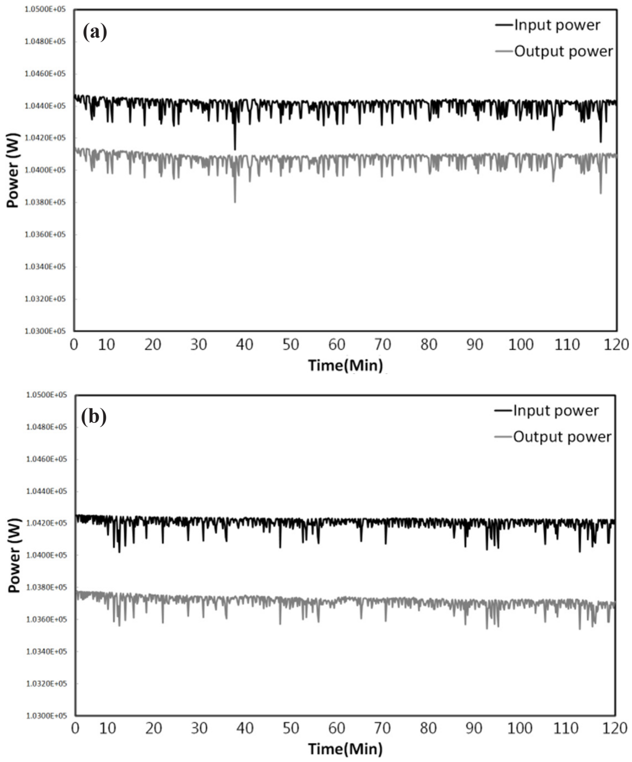

Fig. 3. Integrated energy curve for input/output. (a) Bypass mode and (b) non-bypass mode.

a generation without using the reverse blocking diode, a factor generating heat within the junction box when high current flows during the PV generation, was designed and manufactured. In addition, the characteristics of the junction box input/output as well as the changes in heat generation were confirmed when the bypass/non-bypass modes were used.

High Power Modular DC Power Supplies (AMETEK / SG series / 400 kW) capable of digesting an input of large current power sources such as a PV module was used to analyze the efficiency of the junction box. It was connected to the 24 channels of the constructed junction box to supply approximately 100 kW of DC voltage to the junction box. Considering the high current generated from the actual solar cell, the current per channel was set to 8.2 A. In addition, Precision Power Analysis (WT3000, YOKOGAWA, Japan) was used to compare the electric energy input to and output from the junction box. To compare the output changes depending on the use of the reverse-blacking diode during the PV generation, an identical junction box was used to measure the integrated energy curve of input/output in the bypass/non-bypass modes, as shown in Fig. 3.

The electric energy inputs to and output from the junction box were measured for 120 minutes. During the time measured, the electric power input to and output from the junction box showed identical patterns. The ideal output from the junction box was indicated when the input and output were identical. However, a loss occurs in the circuit/wiring within the junction box and a smaller gap between the input and output signifies higher efficiency.

In this research, the efficiency was calculated based on the input/output electric power. For the normal junction box, the 2-hour average input electric power was 104,205 W and the output electric power was 103,713 W. The rate of output in comparison to the rate of input was 99.52%. For the junction box in which the bypass method is applied, the average input electric power was 104,407 W and the output electric power was 104,073 W. The rate of output in comparison to the rate of input was 99.67%. Such results signify that the bypass applied to the junction box decreases the loss of electric power.

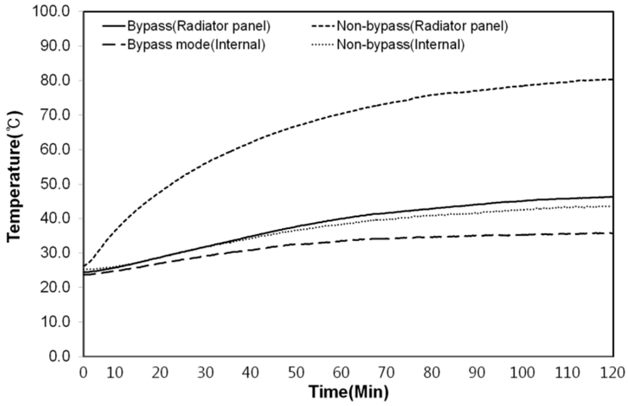

Fig. 4. Temperature changes in radiator panel/junction box.

A K-type thermometer (GP10, YOKOGQWA, Japan) having the resolving power of 0.2℃ was used to analyze the characteristics of heat generation. The internal junction box temperature and the radiator panel temperature were measured to confirm temperature changes.

Figure 4 shows temperature changes in the radiator panel and junction box for 120 minutes.

The temperature of the radiator panel was measured at room temperatures ranging from 24℃ to 26℃. When the bypass mode was used, the temperature of the radiator panel indicated a rapid increase for approximately the first 80 minutes and subsequently indicated a slow increase. When the non-bypass mode was used, the temperature indicated a comparatively steady increase until completion of the measuring. As a result of comparing the highest temperatures indicated in the radiator panel throughout the measuring, the highest temperature when the bypass mode was used was 46.2℃ and the highest temperature when the non-bypass mode was used was 80.3℃

The internal junction box temperature indicated an increase when the radiator panel temperature increased. For the junction box in which the bypass mode was used, the temperature indicated a slight increase from 33℃ to 36℃ after the first 60 minutes. When the non-bypass mode was used, the temperature indicated a continuous increase throughout the measuring and the temperature was approximately 47.7℃ upon completion of the measuring. It is determined that the significantly decreased heat generation within the diode contributed to such results.

4. CONCLUSIONS

In this work, a junction box capable of minimizing the heat being generated within the junction box used in the PV power system was designed and manufactured. By constructing the manufactured junction box so that the six 4 channel-based junction box was connected to allow a parallel connection of the 24 serially connected PV modules, a PV power system could be constructed with the generating capacity of above 100 kW.

For the manufactured junction box, a bypass circuit was constructed to activate the relay when a high current above 1.5 A is generated, so that the DC voltage generated from the solar cell can be directly transferred to the PCS without running through the diode. An identical junction box was used to confirm the characteristics of input/output. Also, the changes in heat generation were confirmed when the bypass-non-bypass modes were used.

As a result of analyzing the characteristics of input/output, the gap between input electric energy and output electric energy was greater when the bypass mode was used in comparison to when the non-bypass mode was used. In addition, as a result of analyzing the rate of output in comparison to the rate of input based on the average electric power measured for 120 minutes, the output electric energy was greater when the non-bypass mode was used in comparison to when the bypass mode was used. For the heat generation within the junction box, a lower heat generation was indicated when the bypass mode was used. Based on these results, it is determined that a junction box using the bypass mode can be used to increase the output efficiency by decreasing the thermal loss occurring in the terminal while high current is being generated.

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