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Hybrid Technology With Battery Balancing

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***Abstract*— In this paper, hybrid (solar and wind power) technology with battery balancing function is proposed. All the inverters are connected to the battery bank individually. Number of batteries are connected to make the battery bank and it can be controlled according to battery voltages to implement the battery-balancing function, the design equation is derived. Experimental set of the battery-balancing discharge function is achieved practically. Finally, a prototype is designed and implemented to verify the feasibility and excellent performance.**

Index Terms

A multilevel inverter, batterybalancing. MPPT, HarmonicReduction.

I. INTRODUCTION

IN RECENT years, environmental concerns and the contin-uous depletion of fossil fuel reserves have spurred significant interest in renewable energy sources. However, renewable energy sources such as wind turbines and photo-voltaics are intermittent in nature and produce fluctuating active power. The multi level inverter was first introduced in 1975. The three level converters was the first multi level inverter introduced. A multilevel converter is a power electronic system that synthesizes a desired output voltage from several levels of dc voltages as inputs. With an increasing number of dc voltage sources, the converter output voltage waveform approaches a nearly sinusoidal waveform while using a fundamental frequency-switching scheme. The primary advantage of multi level inverter is their small output voltage, results in higher output quality, lower harmonic component, better electro magnetic computability, and lower switching losses.

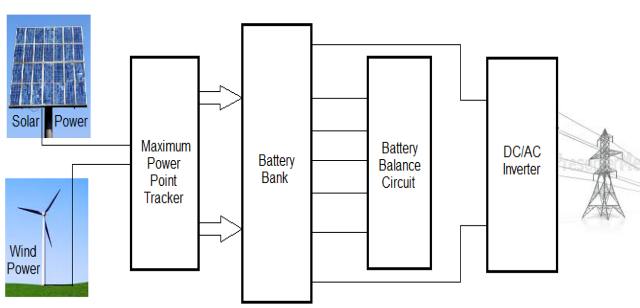


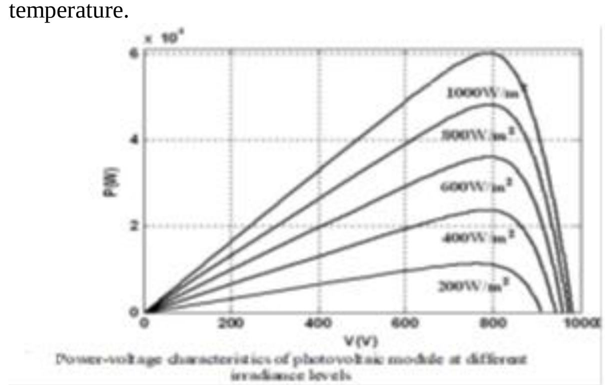
Fig. 1.Renewable Energy System

Interconnecting these intermittent sources to the utility grid on a large scale could affect the voltage/frequency control of the grid An energy storage system which contains a large capacity of the battery bank is indispensable for countering uneven compensation In order to reduce energy loss in transmission lines and increase the overall battery capacity, the battery bank is series connected for a high-voltage dc power supply Because of the manufacturing capacity, The internal impedance and the self-discharge rate are different in each battery Therefore, the power conversion system requires a battery-balancing circuit.

To adjust each battery voltage to be equal. There have been some battery-balancing circuits made to control the battery capacity, and these can be classified as dissipative battery-balancing circuits non-dissipative battery-balancing circuits.

The simplest dissi-pative battery-balancing circuit is made by shunting a resistor across each cell in the string to make the cell maximum voltage equal to prevent voltage unbalance. This dissipative circuit is not good for energy preservation. The nondissipative battery-balancing circuits approach is based on dc/dc converters, such as the flyback converter [3],[5],[7] the buck–boost converter .the switch-capacitor converter , etc The principle is to transfer energy from the higher voltage cell to the lower voltage cell less power loss; it is more energy efficient. However, an additional battery-balancing circuit not only in-creases circuit's complexity and cost but also reduces efficiency hybrid technology with battery balancing is proposed. Additionally, the switch angle is controlled to contain the ac output voltage with minimal total harmonic distortion (THD).

Power Point Tracking (MPPT) techniques are needed to maintain the PV array's operating point at its MPP. The P&O, incremental conductance (INC) method are the most known methods to track the MPP by updating repeatedly the operating voltage of the PV array varying the duty cycle of the power converter with a fixed step size. However, by incorporating maximum power point tracking (MPPT) algorithms, the photovoltaic system's power transfer efficiency can be improved significantly as it can continuously maintain the operating point of the solar panel at the MPP pertaining to that irradiation and temperature.



This paper presents a PV system array connected to Cascaded H-Bridge type multi-level inverter to achieve sinusoidal voltage waveform and output sinusoidal current to the load with a simple power electronic solution. The topologies of multilevel inverters are classified in to three types the Flying capacitor inverter, the Diode clamped inverter and the Cascaded bridge inverter. The cascaded multicarrier multilevel inverter strategy reduced total harmonic. Now requirement of filter size also becomes less. Voltage and harmonics are plotted and compared with normal PWM inverter to capitalise the required result.

Popular Pic 16f877a

This powerful (200 nanosecond instruction execution) yet easy-to-program (only 35 single word instructions) CMOS FLASH-based 8-bit microcontroller PIC16F877A packs Microchip's powerful PIC® architecture into an 40- or 44-pin package and is upwards compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices. The PIC16F877A features 256 bytes of EEPROM data memory, self programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make the PIC16F877A ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

The present chapter introduces the operation of power supply circuits built using filters, rectifiers, and then voltage regulators. Starting with an ac voltage, a steady dc voltage is obtained by rectifying the ac voltage, then filtering to a dc level, and finally, regulating to obtain a desired fixed dc voltage. The regulation is usually obtained from an IC voltage regulator unit, which takes a dc voltage and provides a somewhat lower dc voltage, which remains the same even if the input dc voltage varies, or the output load connected to the dc voltage changes.

As you can see the PIC16F877A is rich in peripherals so you can use it for many different projects.The basic building block of PIC 16F877 is based on Harvard architecture. This microcontroller also has many advanced features as mentioned in the previous post. Here you can see the basic internal architecture and memory organisation of PIC16F877.

The ac voltage, typically 120 V rms, is connected to a transformer, which steps that ac voltage down to the level for the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation. A regulator circuit can use this dc input to provide a dc voltage that not only has much less ripple voltage but also remains the same dc value even if the input dc voltage varies somewhat, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of a number of popular voltage regulator IC units..

II. SYSTEM DESCRIPTIONS

Among topologies of multilevel inverters, the cascaded mul-tilevel inverter with separate dc sources is superior to the other multilevel structures in terms of its structure which is simple and modular. the conventional $2N + 1$-level multilevel inverter composed of N individual full-bridge inverters and N batterie

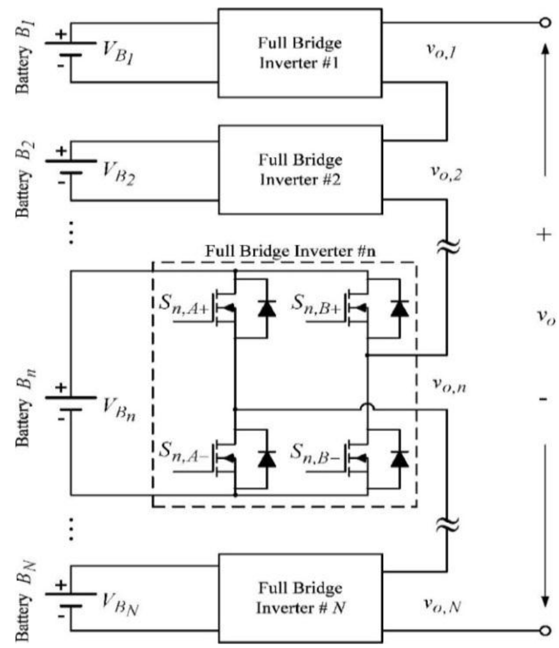


Fig.3. 2N + 1-level inverter with battery balancing.

$$B = \{B_1, B_2, \ldots, B_n, \ldots, B_N\}. \quad (1)$$

TABLE 1

Relationships Of The Output Voltages Of Individual Full-Bridge Inverters And Their Switch States.

Output Voltage $v_{o,n}$	Switches State
$+V_{B_n}$	ON: $S_{n,B+}$, $S_{n,A-}$ & OFF: $S_{n,A+}$, $S_{n,B-}$
0	ON: $S_{n,A+}$, $S_{n,B+}$ & OFF: $S_{n,A-}$, $S_{n,B-}$ or ON: $S_{n,A-}$, $S_{n,B-}$ & OFF: $S_{n,A+}$, $S_{n,B+}$
$-V_{B_n}$	ON: $S_{n,A+}$, $S_{n,B-}$ & OFF: $S_{n,B+}$, $S_{n,A-}$

Each individual full-bridge inverter has a separate battery source B_n. Thus, the individual full-bridge inverter can provide three different voltage outputs $+V_{Bn}$, 0, and $-V_{Bn}$ by different combinations of the four switches $S_{n,A+}$, $S_{n,A-}$, $S_{n,B+}$, and $S_{n,B-}$ as shown in Table I.

The output voltage v_O of the multilevel inverter is equal to the sum of the voltages of the individual full-bridge inverters, shown as

$$v_O = \sum_{n=1}^{N} v_{Bn} \quad (2)$$

where V_{bn} is the voltage of battery B_n. The set of the batteries providing the output voltage in the multilevel inverter can be defined as

$$B_{sel} = \{B_1, B_2, \ldots, B_n, \ldots, B_M\}, \quad M \leq N. \qquad (3)$$

$$B_{sort} = \{B_1^*, B_2^*, \ldots, B_n^*, \ldots, B_N^*\} \qquad (4)$$

in which the relation of battery voltages is $V_{B_n^*} \leq V_{B_{n-1}^*}$ $n = 1, n = 2N$. This means that the battery with the highest voltage is denoted as B_1^*, the battery with the second highest voltage is denoted as B_2^*, and the battery with the lowest voltage is denoted as B_N^*. Using the Fourier series analysis, the root-mean-square (rms) voltage and the hth harmonic $H(h)$ of the quasi-sinusoidal wave can be expressed as [34]–[36]

$$V_{h,rms}\left(\alpha_{B_1^*}, \alpha_{B_2^*}, \ldots, \alpha_{B_N^*}\right) = \frac{4}{\sqrt{2}h\pi}\left(V_{B_1^*}\cosh\alpha_1 + V_{B_1^*}\cosh\alpha_2 + \cdots + V_{B_1^*}\cosh\alpha_N\right), \quad h = 1, 3, 5, 7. \qquad (5)$$

According to (5), the switching angles $\alpha_1, \alpha_2, \ldots, \alpha_N$ can be found such that the THD is minimized and the rms of the fundamental frequency is close to the reference voltage v_{1,rms_ref}. After that, M batteries for output voltage are decided according to the switching angles $\alpha_1, \alpha_2, \ldots, \alpha_N$. Finally, these M batteries with higher voltage are chosen and shown as

$$B_M = \{B_1^*, B_2^*, \ldots, B_M^*\}. \qquad (6)$$

The output voltage of the multilevel inverter can be expressed as

$$v_o = \sum_{i=1}^{M} V_{B_i^*} = V_{B_1^*} + V_{B_2^*} + \cdots + V_{B_M^*}. \qquad (7)$$

As shown in Fig. 3, a quasi-sinusoidal wave can be generated. Assume that the load current I_L is constant during a half-cycle of a sinusoidal wave; the discharge capacities Q_{Bn} of battery B_n can be expressed as

$$\cdot (\pi - 2\alpha_n) \qquad (8)$$

where α_n is the nth switch angle and $\alpha_n \leq \alpha_{n+1}$. Clearly, the discharging capacity of a battery with higher voltage is greater than that of a battery with lower voltage. Thus, the battery-balancing function is achieved.

The output voltage v_o of the multilevel inverter is equal to the sum of the voltages of the individual full-bridge inverters.

Each individual full-bridge inverter has a separate battery source B_n. Thus, the individual full-bridge inverter can provide three different voltage outputs $+V_{Bn}$, 0, and $-V_{Bn}$ by different combinations of the four switches $S_{n,A+}$, $S_{n,A-}$, $S_{n,B+}$, and $S_{n,B-}$ as shown in Table I.

The output voltage v_o of the multilevel inverter is equal to the sum of the voltages of the individual full-bridge inverters.

EXISTING SYSTEM

Renewable energy sources such as wind turbines and photovoltaics are intermittent in nature and produce fluctuating active power. Interconnecting these intermittent sources to the utility grid on a large scale could affect the voltage/frequency control of the grid and lead to severe power quality issues. An energy storage system which contains a large capacity of the battery bank is indispensable for countering uneven compensation.

PROPOSED SYSTEM

Better battery storage performances, many battery charging strategies have been presented.
In order to reduce energy loss in transmission lines and increase the overall battery capacity, the battery bank is series connected for a high-voltage dc power supply.

III. DESIGN EXAMPLE

In order to verify the performance of the proposed single-phase multilevel inverter with battery balancing, a seven-level inverter for providing a 110-V ac source is designed and imple-mented. The circuit specifications are listed in Table II. Fig shows the block diagram of the realized seven-level inverter that comprises three individual full-bridge inverters and a controller. By using the Newton–Raphson method, we can find a set of switching angles $\alpha 1$, $\alpha 2$, and $\alpha 3$ to meet (9)–(11). If the switching angles $\alpha 1$, $\alpha 2$, and $\alpha 3$ cannot meet all of (9)–(11), then (9) will be the priority. Since finding a set of switching angles $\alpha 1$, $\alpha 2$, and $\alpha 3$ by using the Newton–Raphson method requires complex computing, the real-time decision and control are difficult to be realized. In this paper, a lookup table is built for the controller to solve this problem.

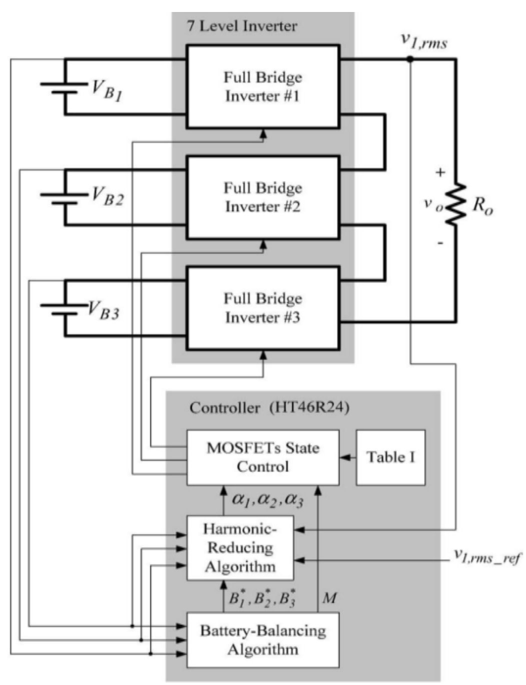


Fig.4.System block diagram of the realized prototype

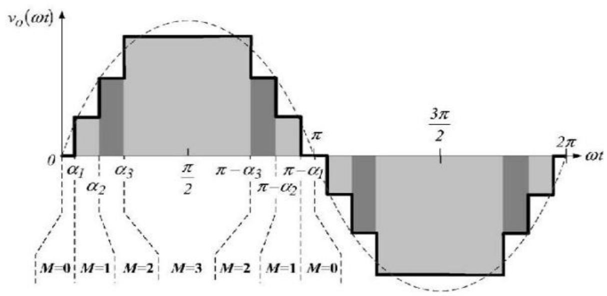


Fig.5.Output voltage waveform of the proposed seven-level inverter.

The controller is mean t to achieve battery balancing and selective harmonic elimination the suitable switching angles $\alpha1$, $\alpha2$, and $\alpha3$.

IV. THE CONTROLLER INCLUDES AS

1. Battery-balancing algorithm
2. Harmonic-reducing algorithm
3. MOSFET state control algorithm.

In this prototype, a microprocessor HT46R24 is adopted as the controller.

Battery-balancing algorithm

Different algorithms of cell balancing are often discussed when multiple serial cells are used in a battery pack for particular device. The means used to perform cell balancing typically include bypassing some of the cells during charge (and sometimes during discharge) by connecting external loads parallel to the cells through controlling corresponding FETs. The typical by-pass current ranges from a few milliamps to amperes.

1. Normal status

In the S-8209B Series, both of CO and DO pin get the VDD level; the voltage between VDD and VSS (VDS) is morethan the overdischarge detection voltage (VDL), and is less than the overcharge detection voltage (VCU) andrespectively, the CTLC pin input voltage (VCTLC) > the CTLC pin voltage "L" (VCTLCL), the CTLD pin input voltage(VCTLD) > the CTLD pin voltage "L" (VCTLDL). This is the normal status.

2. Overcharge status

In the S-8209B Series, the CO pin is in high impedance; when VDS gets VCU or more, or VCTLC gets VCTLCL or less.This is the overcharge status.If VDS gets the overcharge release voltage (VCL) or less, and VCTLC gets the CTLC pin voltage "H" (VCTLCH) or more,the S-8209B Series releases the overcharge status to return to the normal status.

3. Over-discharge status

In the S-8209B Series, the DO pin is in high impedance; when VDS gets VDL or less, or VCTLD gets VCTLDL or less. This is the overdischarge status. If VDS gets the overdischarge release voltage (VDU) or more, and VCTLD gets the CTLD pin voltage "H" (VCTLDH) or more, the S-8209B Series releases the overdischarge status to return to the normal status.

4. Cell-balance function

In the S-8209B Series, the CB pin gets the level of VDD pin; when VDS gets the cell-balance detection voltage (VBU) or more. This is the charge cell-balance function. If VDS gets the cell-balance release voltage (VBL) or less again, the S-8209B Series sets the CB pin the level of VSS pin. In addition, the CB pin gets the level of VDD pin; when VDS is more than VDL, and VCTLD is VCTLDL or less. This is the discharge cell-balance function. If VCTLD gets VCTLDH or more, or VDS is VDL or less again, the S-8209B Series sets the CB pin the level of VSS pin.

Harmonic Reduction:

To eliminate 5th, 7th, and 9th order harmonics, the firing angles for each level is found by solving the following equations.

$$Cos\ 5a1 + Cos\ 5a2 + Cos\ 5a3 + Cos\ 5a4 = 0$$
$$Cos\ 7a1 + Cos\ 7a2 + Cos\ 7a3 + Cos\ 7a4 = 0$$
$$Cos\ 9a1 + Cos\ 9a2 + Cos\ 9a3 + Cos\ 9a4=0$$

The Battery Energy Storage System

An energy storage system is indispensable for compensation of the active-power fluctuations, which is often referred to as "power leveling." For example, if a wind turbine generator produces a larger power than an average power over a period of time, say several seconds to 30 min, the energy storage system stores the excess power from the grid. On the other hand, if the generator produces a smaller power, it releases the shortage of power back to the grid. The energy storage system brings a significant enhancement in power quality, stability, and reliability to the grid. Batteries are dc sources, power conversion is required to interface these batteries to the ac system. The most convenient way of conversion is to have a four-quadrant converter so that a bi-directional energy flow can be achieved. Voltage Source Inverters (VSI) have been traditionally used to modulate the energy flow. The voltage source inverter can be controlled to deliver real power or reactive power simultaneously and independently. Hysteresis current control with its simple design can also be used with its inherent advantages. The front-end converter regulates the real and reactive power demand of the power system under linear and nonlinear loads. The proposed scheme has the following features,

- ✓ Has an integrated battery charging system in the main control function.
- ✓ Provides load leveling feature.
- ✓ Provides active filtering to eliminate the harmonics
- ✓ Ensures unity power factor although the load is inductive
- ✓ Has simple modular control scheme.

Considerations on the battery energy storage system based on a multilevel cascade PWM converter can be categorized as Follows:

a) Active-power control of individual converter cells: Production tolerances, uneven temperature conditions, and differences in ageing characteristics may eventually bring one or more battery units to reduced power-handling capacities. Therefore, an active-power control of individual converter cells is indispensable to enable the multiple battery units operate at different power levels. It is also advantageous when one or more of the battery units are replaced by new ones. This paper discusses the issue in detail.

b) Optimization between the cascade number and the dc voltage: The ncascade number2 affects communication and reliability issues while the dc voltage affects cost and life issues of battery units. Therefore, optimization between them is an important design consideration.

c) Battery cost and life: The cost and life of battery units are the major hurdles in putting large-scale battery energy storage systems into practical use. Comprehensive research and development have to be achieved on cost reduction and life expansion.

d) SOC-balancing of battery units: The SOC of a battery is its available capacity expressed as Percentage of its maximum available capacity. Due to battery-unit tolerances, unequal converter-cell losses, and so on, SOC imbalance may occur among multiple battery units. This may result in reducing the total availability of the battery units and may also cause over charge/over discharge of a particular battery unit

V. INVERTER [MOSFET] (DC-AC)

Inverter:

Converts DC to AC power by switching the DC input voltage (or current)in a pre-determined sequence so as to generate AC voltage (or current) output.

Filtering:

Output of the inverter is "chopped AC voltage with zero DC component".In some applications such as UPS, "high purity" sine wave output is required.An LC section low-pass filter is normally fitted at the inverter output to reduce the high frequency harmonics. In some applications such as AC motor drive, filtering is not required.

A power inverter, or inverter, is an electrical power converter that changes direct current (DC) to alternating current (AC); the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits.

VI. SIMULATION OF HYBRID TECHNOLOGYUSING 7-LEVEL INVERTER

MATLAB, which stands for MATrix LABoratory, is a software package developed by MathWorks, Inc. to facilitate numerical computations as well as some symbolic manipulation. The collection of programs (primarily in FORTRAN) that eventually became MATLAB were Developed in the late 1970s by Cleve Moler, who used them in a numerical analysis course he was teaching at the University of New Mexico. Jack Little and Steve Bangert later reprogrammed these routines in C, and added M-files, toolboxes, and more powerful graphics(original versions created plots by printing asterisks on the screen). Moler, Little, and Bangert founded MathWorks in California in 1984

MATLAB

MATLAB ("MATrix LABoratory") is a tool for numerical computation and visualization The basic data element is a matrix, so if you need a program that manipulates array-based data it is generally fast to write and run in MATLAB (unless you have very large arrays or lots of computations, in which case you're better off using C or Fortran).

Advanced operations.

There's a lot more that you can do with MATLAB than is listed in this handout. Check
out the MATLAB help or one of the "Other Resources" if you want to learn more about
the following more advanced tools:

- ✓ Numerical integration (quad)
- ✓ Discrete Fourier transform (fft, ifft)
- ✓ Statistics (mean, median, std, var)
- ✓ Curve fitting (cftool)
- ✓ Signal processing (sptool)
- ✓ Numerical integration of systems of ODEs (ode45)
- ✓ M-files and functions

This circuit is simulated in MATLAB and the harmonics are obtained using FFT analysis. The output waveform is shown in the Fig.

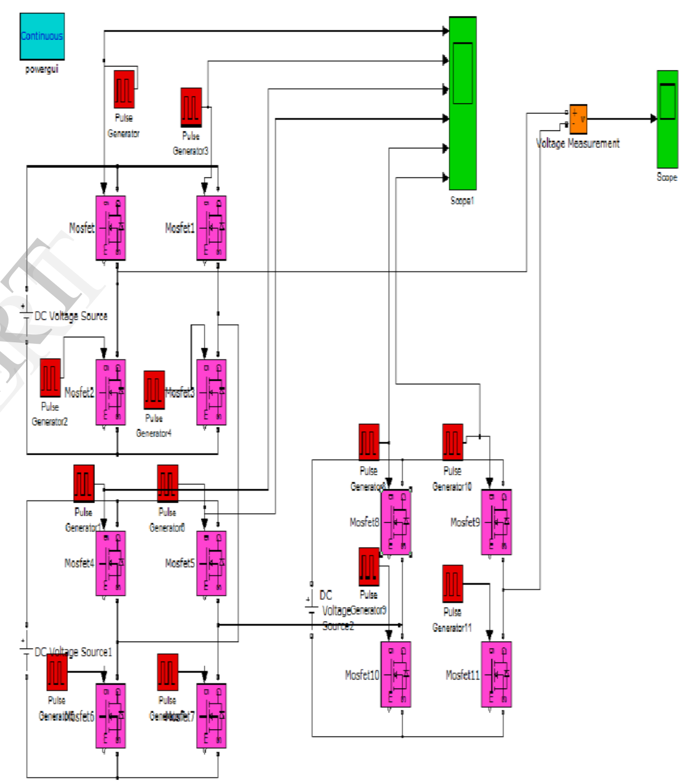


Fig.6.7-Level Inverter Simulink diagram.

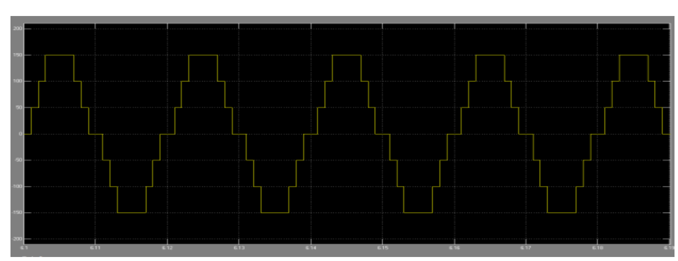


Fig.7.7- Level Inverter Simulink Output

VII.EXPERIMENT RESULTS

The hardware is fabricated and tested in the laboratory. Top view of the proposed 7-level inverter hardware is shown in Fig The control circuit and power circuit of proposed 7-level inverter is shown in Fig and c, respectively. The hardware implement -tation and hardware output voltage of proposed 7-level inverter shown in Fig. the battery discharging voltage and current curves in a fully discharging period. The discharging voltage of the battery pack begins at 52 V and stops at 44 V. The total discharging time is 13 690 s.

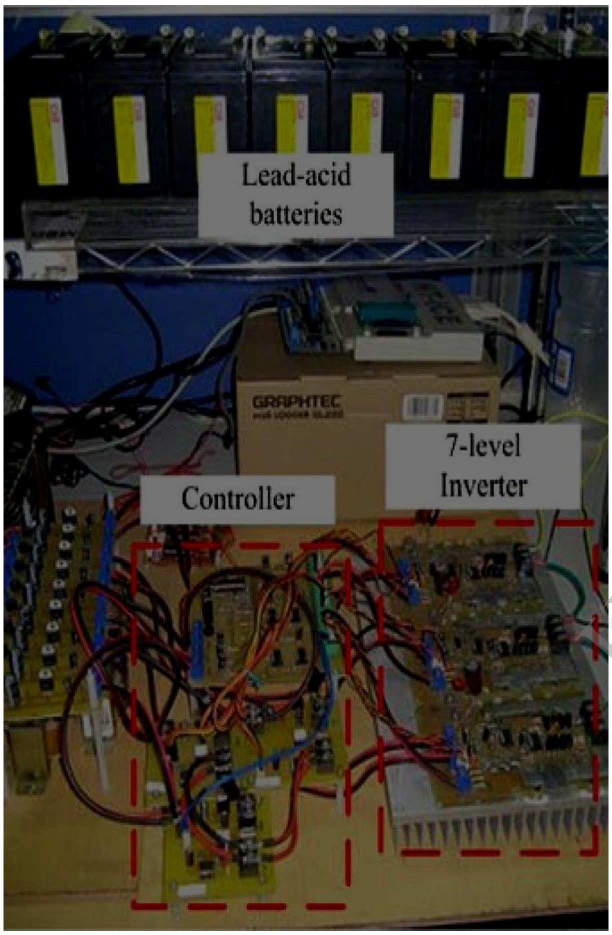


Fig.8.Picture of the 1-kW prototype

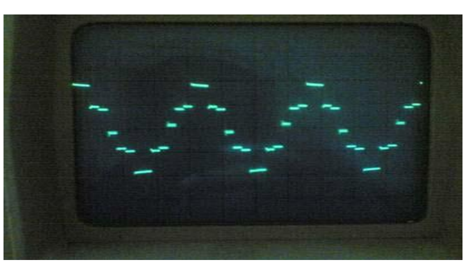


Fig.9.Hardware output of proposed 7-level inverter

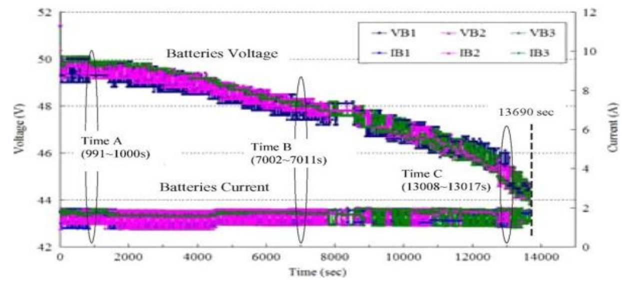


Fig.10.Battery discharging voltages and currents of the realized prototype.

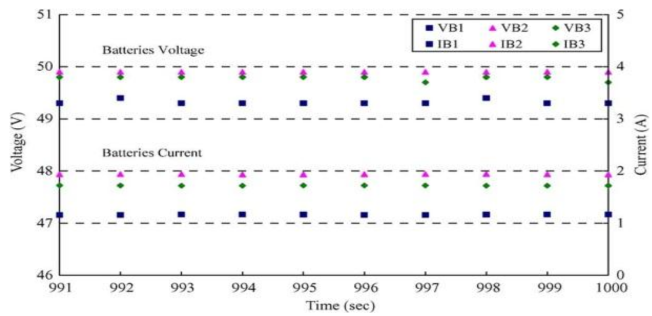


Fig.11.Battery discharging voltages and currents during 991–1000 s.

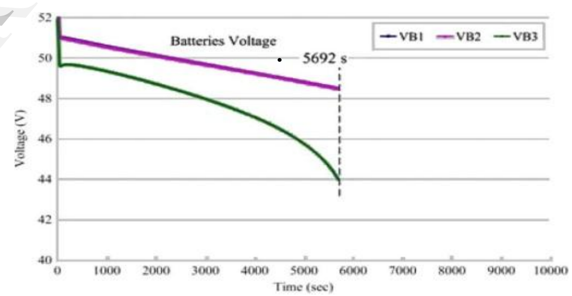


Fig.12.Battery discharging voltage curves of a conventional inverter without battery balancing.

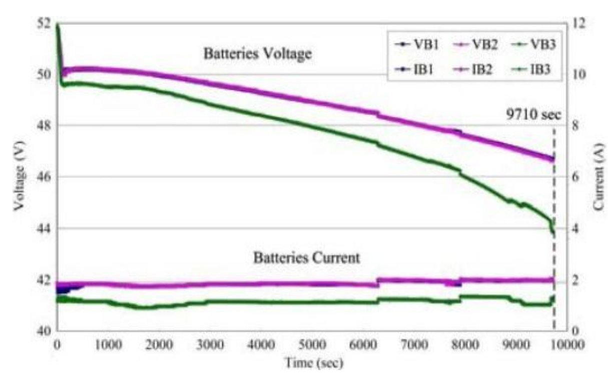


Fig.13. Battery discharging voltage and current curves of the realized prototype.

TABLE 2
Discharging capacities of batteries with and without the battery-balancing function

	B_1	B_2	B_3
With Battery-balancing Function	5.02Ah	5.09Ah	3.09Ah
Without Battery-balancing Function	3.14Ah	3.14Ah	3.14Ah

B_2, and B_3 discharging with battery-balancing function can obtain a greater discharging capacity to proving to load

Precautions

- ✓ The application conditions for the input voltage, output voltage, and load current should not exceed the package power dissipation.
- ✓ Do not apply an electrostatic discharge to this IC that exceeds the performance ratings of the built-in electrostatic protection circuit.
- ✓ SII claims no responsibility for any and all disputes arising out of or in connection with any infringement by products including this IC of patents owned by a third party.

VIII. CONCLUSION

In this paper, hybrid technology with battery balancing has been proposed and proved successful. The input of each individual inverter is directly connected to a battery. The combination of batteries can be controlled according to the batteries' voltages to implement the battery-balancing func-tion. A prototype was designed and implemented to verify the feasibility and excellent performance. Experiments show that the battery-balancing discharge function was achieved as we wanted. Additionally, the switch angle is controlled to contain the ac output voltage with minimal THD.

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