ISOLATED BIDIRECTIONAL MICROINVERTER WITH PROPORTIONAL RESONANT CONTROLLER FOR RENEWABLE ENERGY SYSTEM

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Abstract

An isolated bidirectional microinverter with single-stage, single-phase, proportional resonant (PR) control is created in this work. From zero to infinite, resonant converter voltage conversion ratio may be modulated by the use of PR-PWM, which can be used in single-stage isolated inverters with a wide voltage range. It's for these two reasons: Power transmission is not an issue when it comes to determining voltage conversion ratios. A bidirectional DC/AC conversion is possible because the converter's value and flow direction may be easily altered. When calculating the voltage conversion ratio, one uses the equivalent duty cycle, which does not change regardless of how much power is sent in either direction. A bidirectional DC/AC conversion is possible because the converter's value and flow direction may be altered with ease. This means that an inverter and rectifier may both use the same basic unified current controller. In addition, the suggested system may provide gentle switching for the majority of the grid time and high efficiency. The suggested microinverter's functioning principles, features, design concerns, and control method are explained.

Keywords. Renewable Energy, Microinverter, Resonant controller

1. INTRODUCTION

The need to use renewable energy for satisfying our residential consumption of power is a burning question now. Day by day, the total electrical system gets worse to worsen for fulfilling the incremental demands of industries, household users, irrigation machineries and nevertheless the backup sources of UPS (Uninterrupted Power Supply), IPS (Interrupted Power Supply), battery vehicles etc. The number of power plants have been increased in the last few years but, the total cost and fuel management is under question for choosing the best futuristic steps taken in our country. We can use this as a source of electricity for our residential users. Now, where a localized grid can be developed in some economically advanced area for saving that amount of energy, then those can be provided to other region instead of making load shed there. The concept is well judged and approved and we are going to give a better insight to these in the preceding sections, where micro-inverter with MPPT algorithm is elaborately described and a new one is designed for adopting in the natural situation to form a micro grid.

There are inverters available in sizes ranging from 50 watts to 50,000 watts, however they are rarely employed in residential or other PV systems. An inverter connected to an ac grid directly or through a battery is what we're interested in in this research for photovoltaic systems that provide DC current for charging. While solar cells are capable of generating direct current, a load must be placed between their outputs to do so. At the PV unit's output, there is usually an inverter to generate ac voltage, which drives the home's 98 percent demand. Due to their ability to optimize the power generated by each individual solar panel, micro-inverters may produce 5-25 percent more electricity than conventional solar panels (utilizing MPPT). Because of this, the string inverter will only produce power at the rate of the string's worst-performing solar panels. This is due to the fact that each panel has a slight variance in it. Between the highest and least efficient panels of a string, these changes can account for 5 percent of the variation in performance. Micro inverter generates optimum power output from that panel, regardless of its age or condition. As a result, the array's panels are all operating at their maximum capacity. This means that even a single panel that is covered in dirt or leaves might have a negative impact to the whole string inverter's output.

2. LITERATURE SURVEY

L. Zhang et al an inverter system with series-connected module integrated inverters for grid-connected photovoltaic (PV) generation (SC-MIIs). For maximal solar energy harvesting, the grid-tied SC-MII system uses individual MPPT-enabled MIIs with each PV panel. For the utility grid to meet its voltage requirements, the outputs of MIIs are linked in series.

A. Pal et an innovative single-stage soft switched high frequency link 3-phase DC-AC converter architecture is presented by al. Grid-integration of solar sources, a fuel cell, etc., are among the applications for which this topology is suited. High frequency magnetic isolation reduces system space, weight and cost. In the DC side converter, a sine-wave pulse width modulation is used. DC side converters are soft-switched for the most of the line cycle, despite being high frequency switched.

Y. S. Jeong et al proposes a control system for a highly efficient bidirectional grid-tied converter that utilizes a single power conversion to provide high quality grid current. Bidirectional flyback DC-DC converter and an unfolding bridge circuit are the components of the proposed converter. – Bi-directional power conversion between the grid and energy storage device may be achieved by altering the flyback's PWM signal. All three controllers in the system include an allow pass filter to prevent the system from overshooting its limits.

J. R. Kan, S et al CSR-HFL inverter was shown to be a new combination of synchronous rectifiers and high frequency links. The performance of three different types of conventional HFL inverters is examined and reported. According to cyclo-converter-type HFL inverter (CHFL) inverter, the combined rectifiers structure may be determined from. In the redesigned architecture, two more switches are employed to prevent the short circuit.

R. K. Surapaneni, et al experiments with high frequency ac to line-frequency ac conversion using a new half-bridge half-cycloconverter design on the load side, where devices operate at line frequency. Full-bridge, half-bridge, or push-pull microinverter topologies for solar photovoltaic AC modules are also compared and evaluated in this work. The advantages of double-ended converters include no transformer saturation, smaller transformer and filter sizes, and the ability to use a single power supply.

S. Zhong, J et al the suggested SSA includes an HFL-SSI with bipolar phase shift modulation (BPSM) and a half bridge active clamp (HBAC). Using a cycloconverter switch to clamp voltages, HBAC may then use the energy stored in the filter inductor and leakage inductance in other circuits. Implementation of cycloconverter switches may be done using a ZVS active clamp circuit Switches with primary-side magnetizing current can perform ZVS.

T. Chen, et al DAB and GaN HEMTs are employed in this AC/DC converter's single-stage architecture. A wide range of input voltages and loads may be employed to create ZVS through the use of dual-phase-shift (DPS) modulation and variable-frequency (VF) control. PFC-enabled AC-DC converters may accomplish Zero Voltage Switching (ZVS) throughout the whole range of AC mains voltages, according to F. Jauch et al. To accomplish a single-step power conversion, this DAB employs an isolation transformer with a half-bridge and a full-bridge.

H. Wu et al for regulating power flow and achieving the following desirable outcomes in a suggested converter.

3. PROPOSED SYSTEM

PR controller system-enabled bidirectional resonance converters are suggested as a feasible solution. Single-stage microinverter based on the idea of PR-PWM driven resonant converters is provided in this research (RC). The following are some of the benefits of using an approach like this: Isolated single-stage DC/AC converters based on LLC converters are one approach to solving the zero-crossing issue. Voltage gain is unaffected by the amount of power given. Changes in power transmission may be made with ease. It is far more difficult to design DC/AC single-stage systems based on bidirectional resonant converters than unified current controllers are shown in figure 3.1.

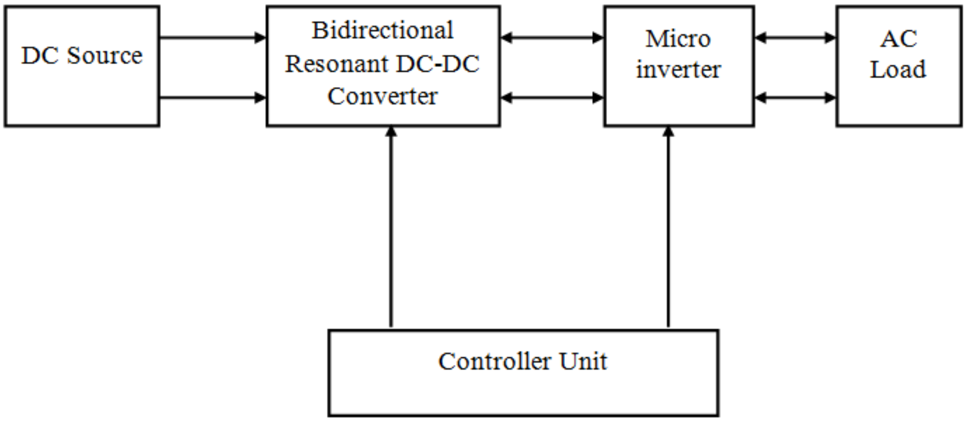

Figure 3.1- Proposed System Block

4. PROPOSED BIDIRECTIONAL MICROINVERTER

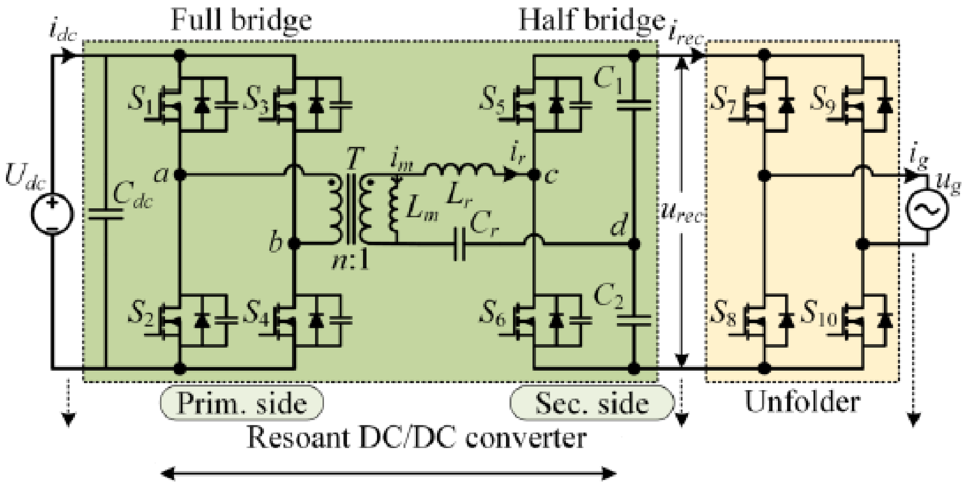

Figure 3.2-The proposed bidirectional microinverter

FIG. 3.2 depicts a single-stage, single-output isolated bidirectional converter. The device's heart is a resonant DC/DC converter and a line-frequency inverter. – (unfolder). To link the half bridges that make up the resonant converter, high-frequency transformer T, resonance inductor Lr and resonance capacitor Cr are used. Using a half bridge to minimize the turn-to-ratio of the high frequency transformer in a bidirectional DC/AC converter is necessary because of the low DC voltage. This device's primary function is in maintaining and improving the output current and power factor (PFC). To convert the pseudo-DC link current to sinusoidal alternating current, the unfolder is used. Using a converter or an unfolder, you can move power in both directions.

At resonant frequencies, LLC converters' voltage conversion ratio is not dependent on the load. Resonant frequency is stated as a frequency at which the suggested converter is constantly operating (1).

$$f_r = \frac{1}{2\pi\sqrt{L_r C_r}} \qquad (1)$$

Using the resonant current and voltage as inputs, we can derive the following state function for the capacitor: (2).

$$\begin{cases} L_r \frac{di_r}{dt} = u_{ab} - u_{cd} - u_{Cr} \\ \quad C_r \frac{du_{Cr}}{dt} = i_r \end{cases} \qquad (2)$$

Uab and ucd represent the midway voltages of the primary and secondary sides, respectively. State function (2) may be reduced in complexity by using the essential components of ir and uCr: (3).

$$U_{ab1} - U_{cd1} = j\omega_s L_r L_{r1} + \frac{I_{r1}}{j\omega_s C_r} \qquad (3)$$

What is the switching frequency's angular frequency?

These two components, Uab1 and Ucd1, form the core of their respective systems.

The fundamental impedance of the resonant tank is zero when the converter is operating at its resonant frequency. To put it another way, the amplitude and phase of Uab1 and Ucd1 are identical in this scenario. As a result, the main side and secondary side midpoint voltages uab and ucd have the same phase as one another, too.

4.1. Proportional resonant controller

The one of the most common transfer functions used to regulate closed-loop systems with sinusoidal behavior is the proportional resonant controller, abbreviated as PR. Having both a proportional and resonant term, they may be tuned in any way you see fit. The proportional resonant controller is shown in figure 3.3

Because of its high performance and ease of implementation, proportional resonant controllers (PR) for single-phase AC current/voltage regulation have become a hot topic in the field of power electronics.

Because the integral control action provides an essentially infinite DC gain in PI controllers in DC applications, the controllers have a very low steady-state error. Since PI controllers have finite gains that can't prevent steady-state error in AC applications, their tracking response is always delayed.

As a well-known solution to this problem, synchronous reference frame implementation is used. A rotating reference frame (dq) synced to the AC frequency is used to construct the PI controllers (if any are used at all) (e.g., of the grid or the electric motor). DC gain can be relocated to a chosen frequency, in this case 50/60Hz (or the motor rotating speed).

As an alternative, proportional resonant controller can be used. There are no coordinate transformations needed since they work in a stationary reference frame. Resonant terms give a limited, but extremely high gain at the AC frequency, which enables tracking and perturbation rejection capabilities comparable to dq-control.

Park transformations are not required in single-phase systems since the formulation of the direct and quadrature axes is not evident.

4.2. Operating principles of proportional resonant control

It is common for proportional resonant (PR) control systems to have a transfer function similar to the one seen in this figure

GC(s)=Kp+2Kiss2+ω02 (4)

The target reference current frequency is 0. The denominator term s2+02 produces an infinite control gain at 0 in this equation.

As a digital controller, this expression may be difficult to implement; instead, dampening around the resonant frequency may be more practical because it is easier to apply.

GC(s)=GCp(s)+GCr(s)=Kp+2Kiωcss2+2ωcs+ω02 (5)

When written as a fraction, c denotes the cutoff frequency for resonance (i.e. width of the resonant filter). A smaller steady-state error can still be enforced even if the gain at 0 in this second formulation is limited. As a side effect of the broadening of the bandwidth around 0, grid-tied applications may tolerate minor frequency fluctuations more easily.

4.3. Proportional resonant digital control implementation

The bilinear (Tustin) transform makes it simple to construct a workable implementation in practice. Resonant term's discrete transfer function, discretized with a period Ts, yields:

$GCr(z)=Y(z)E(z)=a1(1-z-2)b0+b1z-1+b2z-2$ with $a1=4KiTs\omega cb0=Ts2\omega 02+4Ts\omega c+4b1=2Ts2\omega 02-8b2=Ts2\omega 02-4Ts\omega c+4$ (6)

Using the resonant component as a difference equation, we get:

$y(k)=1b0[a1\cdot e(k)-a1\cdot e(k-2)-b1\cdot y(k-1)-b2\cdot y(k-2)]$ (7)

Generate run-time code with this difference equation. Furthermore, a Simulink implementation is provided in the next section.

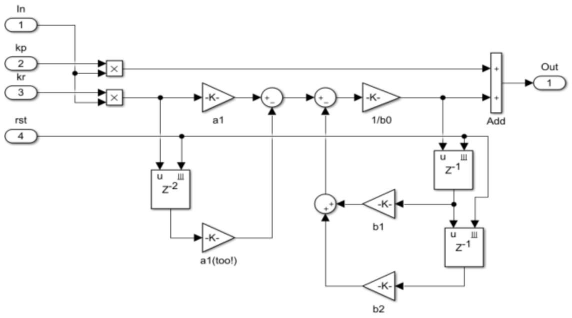

Figure 3.3-Proportional resonant controller implementation example

5. RESULTS & DISCUSSION

Dynamical systems modeling, simulation, and analysis are all possible using Simulink. If you're looking for a system that can handle both linear and nonlinear systems, it's the best option for you. Systems can also be multi-rate, i.e., sampled or updated at various rates by distinct components [2].

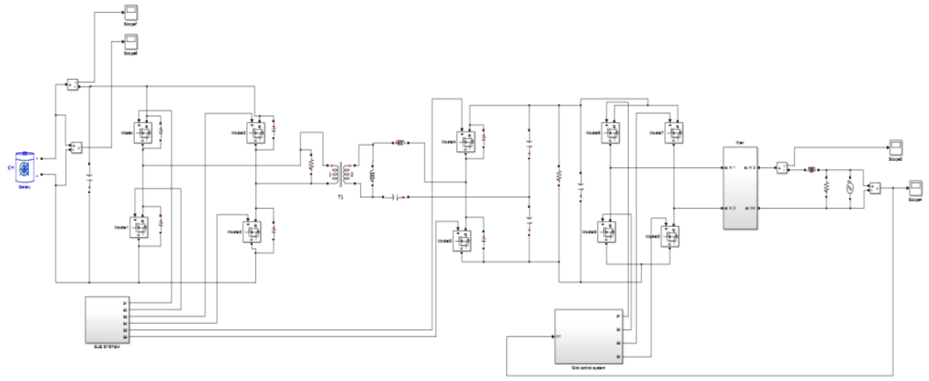

Figure 3.4- Proposed system model

MATLAB 2014a Simulink is used to create the suggested system model. Designing and simulating the circuits was accomplished with the help of the MATLAB Simulink and Sim power system tools. Figure 3.4 depicts the suggested Simulink model. Figures 3.5 shows control system and 3.6 shows PWM control.

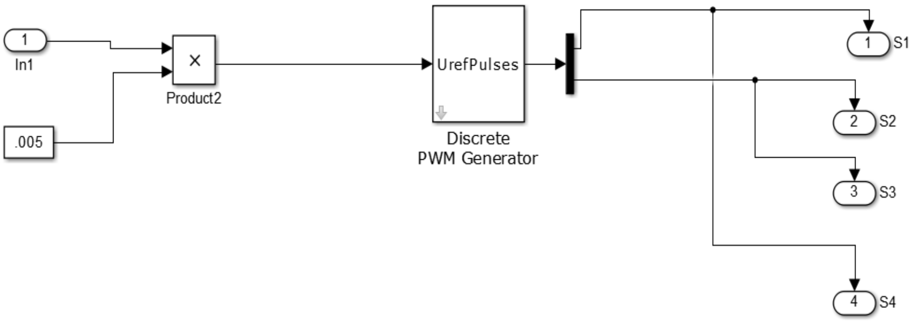

Figure 3.5-Control system

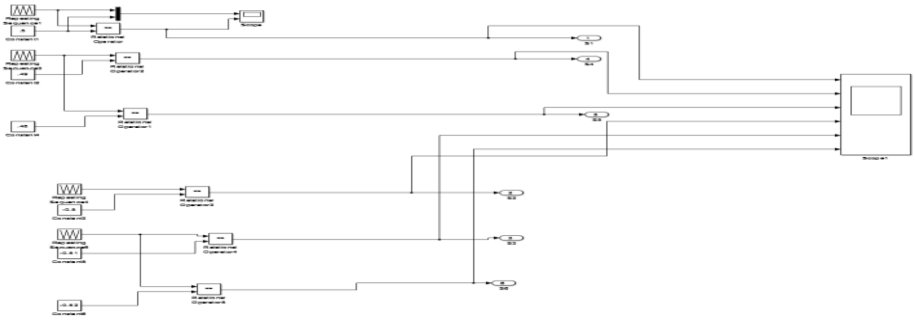

Figure 3.6 PWM Control

The DC voltage and current of the battery is shown in the following figure 3.7 and 3.8. The battery outputs 40 volts of DC electricity.

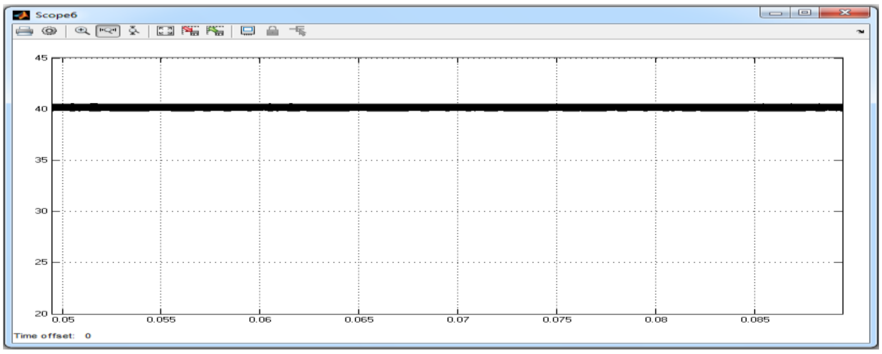

Figure 3.7- Battery voltage

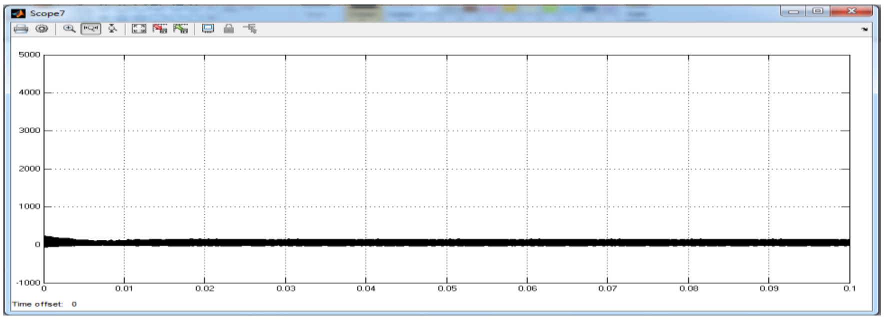

Figure 3.8- Battery current

Figure 3.9 illustrates the PWM gate signal. For the PWM pulse signal, ramp and sine wave are used in conjunction.

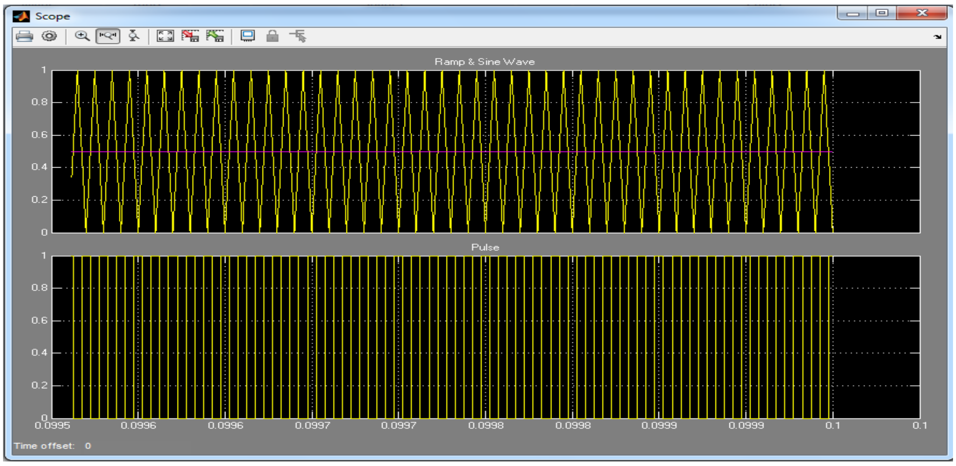

Figure 3.9- Ramp & Sine wave

Grid output AC voltage is shown in the following figure 3.10. To power the resonant converter and inverter, a battery voltage is sent into the system. Generator injects DC power into grid through inverter. A 230V AC output is provided.

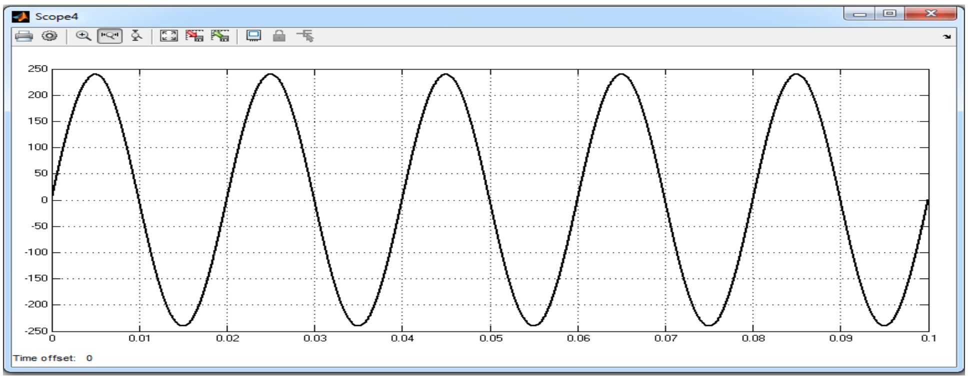

Figure 3.10 Output AC voltage

The following figure 3.11 shown the grid output current. It reached at 6A.

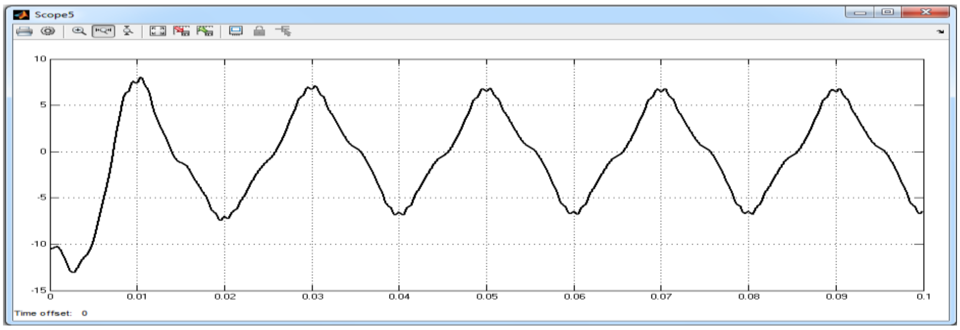

Figure 3.11 Output current

6. CONCLUSION

As part of this study, an embedded-based controlled resonant converter microinverter is suggested and tested for energy storage applications. Resonant converter voltage conversion ratio may be varied over a large range using PR-PWM control, allowing for step-up and step-down voltage conversion to be done. With a simple unified current controller, you may rapidly and easily alter the amount and direction of power being delivered. It has also been possible to perform soft switching during the majority of the grid time MATLAB/Simulink is used to simulate a PR (proportional resonant) controller for an isolated bidirectional microinverter and to observe its performance during a fluctuating load state.

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Biographies

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