ROBUST THREE PHASE DYNAMIC TRI-LEVEL H-INVERTER SCHEME

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Abstract: ***This paper presents a robust three phase multi-level inverter topology controlled by a programmed micro-controller switching circuit. The inverter consists of three H-type bridges, each bridge comprises four (4) solid state switches. The inverter feeds from a DC battery source or a PV-Fuel Cell-Battery or combination hybrid source. The on/off switching pattern is regulated by the micro-triggering circuit controller. The proposed multilevel inverter improves waveform output quality, lower total harmonics distortion (THD) than the two level one and less electromagnetic interference (EMI). The results show that the inverter output is near to sinusoidal waveform and give the same frequency of the network also the designed inverter improves the power quality and decrease the produced harmonics than the traditional one.***

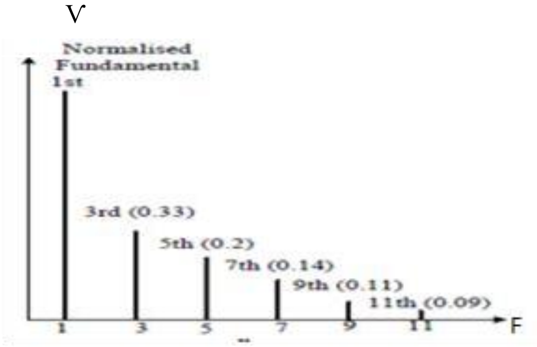
Keywords: Multilevel Inverter, microcontroller, Harmonic reduction.

I. INTRODUCTION

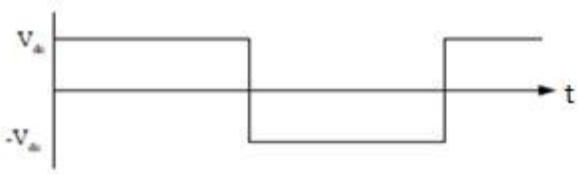
An inverter is an important device in Micro grid as it is a link between distributed generators and the grid [1]. Most of the natural resources of Micro-grids are photovoltaic cells and wind power generation systems etc. an important role of inverter is to connecting photovoltaic (PV) modules to a micro grid in order to generate power to a certain local area. Traditional inverter has a number of problems such as high levels of harmonics and distorted waveforms whereas a multi-level inverter [2] overcomes these problems, obtaining nearly pure sinusoidal output voltage and reduce the total harmonic distortion, also a lower switching loss than those of conventional two-level inverters, a filter size is smaller than the old one. The multi- level inverter is lighter, cheaper, and more precise [3-4].

Traditional H-Bridge inverter output is square wave causing distorted waveforms rich in harmonics and ripple content. This cause power quality problems as well as severe total Harmonic Distortion of Voltage and Current at the AC bus interface. Harmonic content requires addition of expensive bulky AC side Filters including Tuned Arm and C-Type fixed or Active Type Filters [5-6].

As traditional inverters encounter some problems such as high level of harmonics and if they used in driving motors, they cause surge voltages which lead to stator winding failures. In Fig. 1, traditional inverter produces high levels of odd harmonics which increase the THD so a number of filters are used to reduce the distortion. In [7] a PWM inverter is used with a smaller number of filters. Multilevel inverter topology can be used to address power quality issues as well as large power ratings for LV and MV power electronic interfacing of DC to AC smart grids [8-9].



(a)



(b)

Fig.1 a) Frequency spectrum for traditional inverter.
b) Traditional inverter output voltage.

The multilevel Inverter Schemes use limited number of switches at low-switching frequency [10]. Several models of multilevel inverters have been mentioned in [11-13]. Some ones are diode-clamped, flying capacitor or multi-cascaded H-bridge, and modulated H-bridge multilevel. In [14] a thirteen- level H-cascaded stages for Micro-grid connected Photovoltaic (PV) array system with a pulse width-modulated (PWM) control method is designed.

In [15] the author analyzed the inverter failure and studied the effect of this failure on the photovoltaic system performance. Fig. 2 shows [16] the voltage waveform as an output of an eleven -level cascade inverter with five separated dc supplies. For multi-level inverter it is found that the THD will be decreased by increasing the number of H-bridge cells, and the output voltage waveform will be near to sine wave. In [17] the author introduce multilevel inverter suits the medium and high voltage applications which give this type of inverter a wide variety of operations.

This paper presents a prototype design and Laboratory practical implementation of a three phase multi-level inverter with a controlled three (3) H-bridges. The circuit components are arranged as controlling part which represents the electronic circuit and the inverter circuit which represents the power circuit, the whole circuit is tested and results are introduced then followed by conclusion and references.

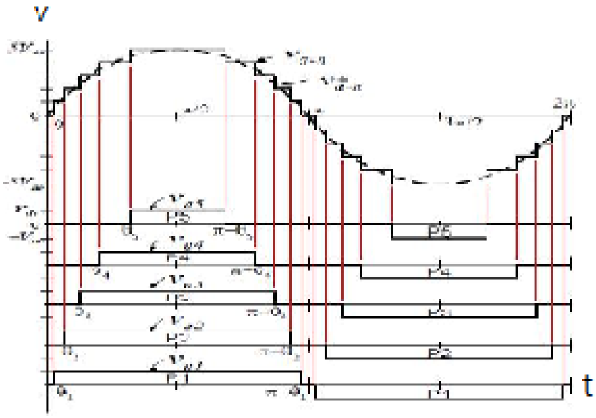


Fig. 2. Voltage waveform output of an eleven -level cascade inverter with five separated dc supplies.

II. IMPLEMENTATION OF THREE LEVEL – THREE PHASE MULTI-LEVEL INVERTER

The multi-level inverter circuit consists of three H bridges, every bridge consists of 4 switches (MOSFET transistor), these transistors are feeding from separate batteries These switches could be controlled by making them on or off by receiving controlling signals from microcontroller circuit. The control signals which micro controller send are so week and not able to switch the MOSFETs, an optcoupler which represents a drive circuit is used to receive signal from microcontroller circuit at the same time to change the switch status. Fig. 3 illustrates a block diagram of the multi-level inverter circuit.

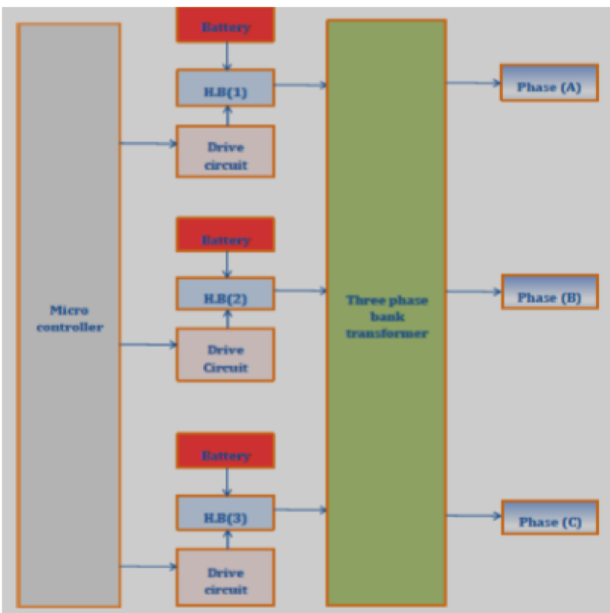


Fig. 3. Block diagram of multi-level inverter

a. H Bridge.

It consists of 4 N-Channel enhancement mode silicon gate power field effect transistors which is a power MOSFET. They are tested, and secured to bear a high level of energy in the breakdown avalanche mode operation. These power MOSFETs are designed for switching applications, regulators, switching convertors, motor drivers, relay drivers, and drivers for high power bipolar switching transistors requiring high speed and low gate drive power. These types can be operated directly from integrated circuits. Every MOSFET gate is connected to optcoupler which transfers electrical signals between the two isolated circuits by using light and prevent high voltages from affecting receiving end. Optpcoupler is consists of a diode emitting light and phototransistor. MOSFET gate is connected to photo transistor emitter which act when optocoupler diode emit light. The MOSFET drain and source are connected to fast recovery diode. Each H bridge feeds from a single-phase bridge and each bridge feeds from a battery of 12 V. The H bridge terminals are connected to step up transformer with turns ratio 12/220 to give 220V to an external circuit. Fig.4 shows H bridge connection.

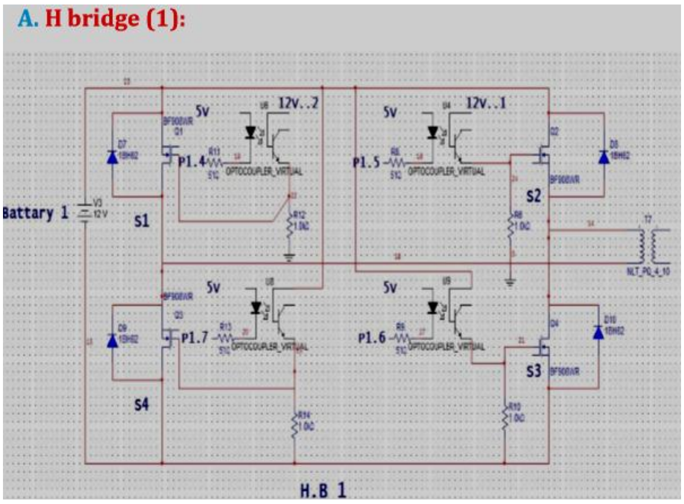


Fig. 4. H bridge connection

b. Control Circuit.

Fig.5 shows the switching control circuit, which consists of **:**

i) AT89C52 micro controller.

The AT89C52 is a, high-performance low-power CMOS (8bits) microcomputer with 8K bytes of Flash Programmable and erasable read only memory (PEROM). It consists of 4 ports. The on-chip Flash allows the Program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. The Microcontroller is programmed with Assembly Language, 0 logic on micro controller output- port means 0 volt to enable opto-coupler to work and makes switch- status (on). 1 logic on microcontroller output port represented by high volt and this signal makes opto-coupler to stop and turns switch status (off). This performance is repeated for all H bridges, a delay time equal the phase shaft between phases is considered.

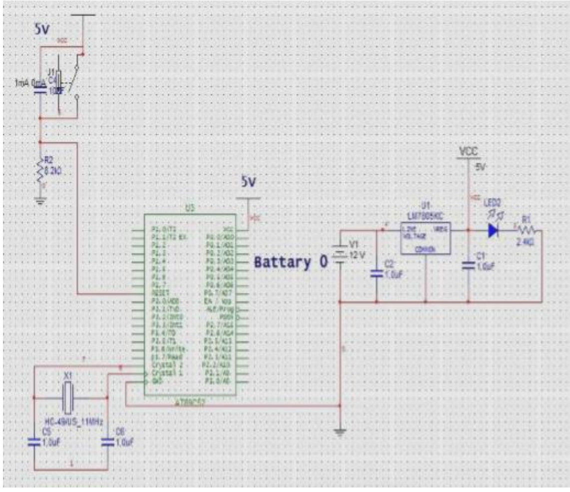


Fig. 5. The control circuit.

ii) External Oscillator.
The external clock (EC) mode uses external oscillator as a clock supply. 20 MHz is the maximum frequency of this clock. It operates in High-Speed modes used for high-frequency quartz crystal with clock frequency of 8 MHz. It is connected to pins 18 and 19 of the microcontroller. Fig. 6 shows oscillator circuit connection.

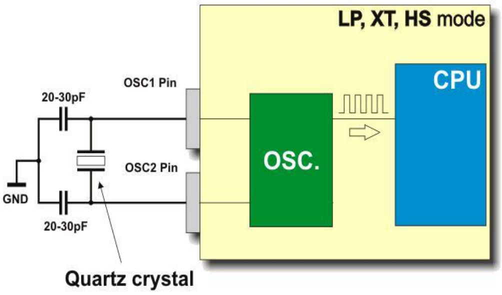


Fig. 6. Clock Oscillator circuit

iii) Auto reset circuit.
This circuit is responsible to operate the control circuit or disconnecting it.

IV) Regulating circuit.
A regulated is connected to 12V battery to produce 5V to suits microcontroller operation.

C. **LM 7805 regulator.**
A regulator is to eliminate noise and control distribution problems and to give an accurate output voltages and currents, also can be used as the power-pass element in precision regulator-A regulator with output 5 V to feed the microcontrol-switching circuit and virtual ground circuit.

d. Batteries.
4 battery are needed, 3 batteries to feed 3 H bridges and the fourth battery is to feed the control circuit and ic4047, every battery has the following configuration: Rated voltage : 12 volt .

Rated current: 7.2A.
Duration: 20 hr.
Initial current: less than 2.16A.
Max discharge current :105A

e. Virtual Grounding Circuit.
It is found that there is grounding problem because it is needed of 12 earthed points for the 12 switches for the as in circuit shown in fig.4. The lower opto-coupler can use the ground of main battery to make the switch on or off. The upper opto-coupler cannot use the ground of the main battery for switching the upper transistors because it will make short circuit on the lower transistor. So 6 separate DC sources are needed with separate ground for all upper drive circuits and that will be costly, so Virtual ground circuit are designed. This circuit consists of 6 transformers connected as shown in Fig. 7.
All primary windings of all transformers are connected together in series with a center connected to transistors. These transistors are connected to IC 4047 which feed from 12 V supply. IC 4047 share ground to each terminal periodically with frequency 50 HZ from which each transformer with primary input as AC source. Each transformer secondary windings are connected to rectifier bridges in order to obtain 6 separated DC sources with separate grounds in order to feed the upper drive circuit.

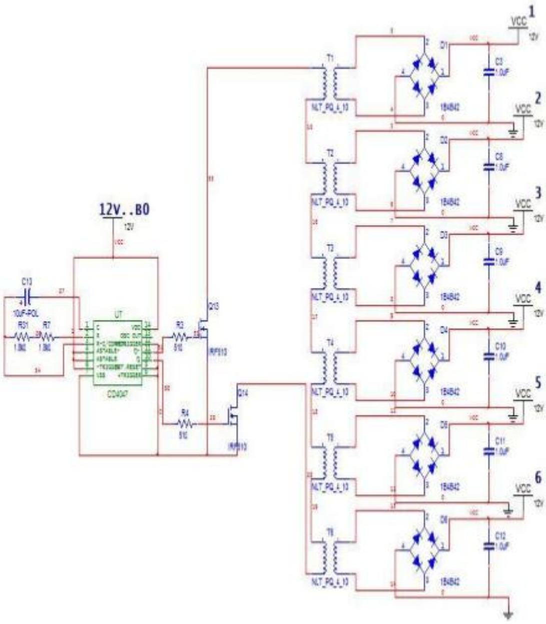


Fig. 7. Virtual ground circuit.

g. Transformers.
The main transformer used in this circuit has a turns ratio of 12/220 as the H bridge output voltage of 12 volt and the desired output phase voltage is 220V. As the output voltage is three phases, we use three identical single phase-transformer bank, every transformer is connected to H Bridge output.

h. Optocoupler (PC817).
It is a component that transfers electrical signals between two isolated circuits by using light and prevent high

voltages from affecting the receiving end. An opto-coupler construction is as shown in Fig. 8.

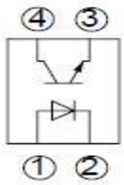


Fig. 8. An Opto-coupler chip

III. MULTI LEVEL INVERTER CIRCUIT OPERATION

The required output for this experiment is three phase-three level output. A microcontroller is programmed so that the inverter output frequency is to be 50 Hz, the inverter output cycle is divided into 18 intervals and the microcontroller send signals to switches through drive circuit as shown in table. 1. Three batteries are considered as sources for the three H bridges. Each switch in every bridge is numbered with a micro-controller port and has special statue in each interval as in tables. (2,3,4). Every switch is connected to an opto-coupler.

TABLE. 1
MICROCONTROLLER SWITCHING INTERVALS WITH H BRIDGES.

Port number	P1.4	P1.5	P1.6	P1.7	P1.0	P1.1	P1.2	P1.3	P3.0	P3.1	P3.2	P3.3	P1 H	P3 H
Interval	HB (1)				HB(2)				HB(3)					
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4		
1	0	0	1	1	1	0	1	0	0	1	0	1	5C	FA
2	0	1	0	1	1	0	1	0	0	1	0	1	5A	FA
3	0	1	0	1	1	0	1	0	1	1	0	0	5A	F3
4	0	1	0	1	1	0	1	0	1	1	0	0	5A	F3
5	0	1	0	1	1	0	1	0	1	0	1	0	5A	F5
6	0	1	0	1	0	0	1	1	1	0	1	0	CA	F5
7	0	1	0	1	0	0	1	1	1	0	1	0	CA	F5
8	0	1	0	1	0	1	0	1	1	0	1	0	AA	F5
9	1	1	0	0	0	1	0	1	1	0	1	0	A3	F5
10	1	1	0	0	0	1	0	1	1	0	1	0	A3	F5
11	1	0	1	0	0	1	0	1	1	0	1	0	A5	F5
12	1	0	1	0	0	1	0	1	0	0	1	1	A5	FC
13	1	0	1	0	0	1	0	1	0	0	1	1	A5	FC
14	1	0	1	0	0	1	0	1	0	1	0	1	A5	FA
15	1	0	1	0	1	1	0	0	0	1	0	1	35	FA
16	1	0	1	0	1	1	0	0	0	1	0	1	35	FA
17	1	0	1	0	1	0	1	0	0	1	0	1	55	FA
18	0	0	1	1	1	0	1	0	0	1	0	1	5C	FA

All upper MOSFET switches are fed from the virtual ground circuit whereas all lower ones are fed from batteries. When microcontroller send a signal 0 to the opto-coupler led, it emits light enough to operate the photo transistor which subsequently gives signal to the MOSFET switch to operate. When logic on micro controller port is 5 volts then optocoupler stops and makes switch status (off). This sequence of switching operation is executed related to microcontroller program steps as in table 1.

Each H bridge output is a single-phase alternating voltage equal to 12 V AC. The output of H bridge (1) is phase (A). The output of H bridge (2) is phase (B). The output of H bridge (3) is phase (C). A transformer bank is used to convert the H bridge output to 220 V AC. During circuit operation oscilloscope read the inverter voltage output and the three-phase induction motor which is connected to inverter output is operating.

TABLE 2
SWITCHES STATUS IN EACH INTERVAL FOR H BRIDGE 1

Interval		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H.B(1)	S1	ON	ON							off		OFF							OFF
	S2	ON	OFF							off		ON							OFF
	S3	OFF	ON							on		OFF							ON
	S4	OFF	OFF							on		ON							ON

TABLE 3
SWITCHES STATUS IN EACH INTERVAL FOR H, B2 AND 3

Interval		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H.B(2)	S1	OFF						ON	ON							OFF		OFF	
	S2	ON						ON	OFF							OFF		ON	
	S3	OFF						OFF	ON							ON		OFF	
	S4	ON						OFF	OFF							ON		ON	

Interval		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H.B(3)	S1	ON		OFF		OFF							ON		ON				
	S2	OFF		OFF		ON							ON		OFF				
	S3	ON		ON		OFF							OFF		ON				
	S4	OFF		ON		ON							OFF		OFF				

IV.RESULTS

The experiment is installed as in Fig. 9. The input voltage is 12 V dc voltage and 7.2 dc current. The output phase voltage is 220V ac voltage and the output current is 0.25 A. The installed circuit gives an output power of 190 W. The inverter output is connected to three phase motor load as seen in Fig. 9. Results show that when the motor feeds from the installed inverter, the motor operates at its normal stat as if it feeds form ac standard supply. Fig. 10 shows the inverter output phase voltage waveform which is 220V, single phase voltage.

Fig. 9. The final shape of the experiment

Fig. 10. The inverter output phase voltage waveform

Fig. 11 shows 220√ 3 V Line to line output voltage waveform at the primary side of main transformer. Fig. 12 shows the line-to-line output voltage 220√ 3 V waveform at the secondary side of main transformer, as seen from the figure that the output waveform voltage is more smother than the waveform at the primary side due to presence of transformer. Fig. 13 shows the inverter output Frequency which equal to 49.2Hz which is nearly equal to the grid frequency.

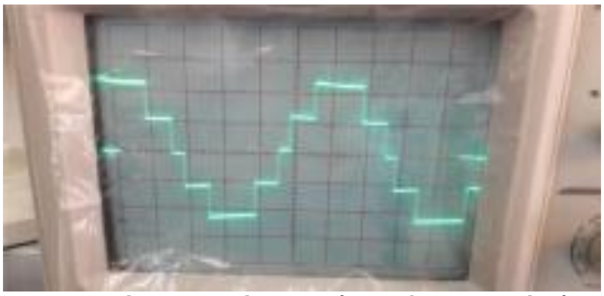


Fig. 11. Line to line output voltage waveform at the primary side of main transformer

Fig.12 Line to line output voltage waveform at the secondary side of main transformer.

Fig.13 The three level H bridge inverter output frequency.

FFT harmonic analyses are done for the three level inverter output and for the two level PWM inverter with Matlab program as shown in Fig. 14 and 15. It is obvious that the third fifth and ninth harmonic amplitude in three level H bridge inverter are less than of these of the two level PWM voltage source inverter, also total harmonic distortion (THD) in three level H bridge inverter is 12.01% whereas in Fig. 15 it is found that (THD) of the two level PWM voltage source inverter (VSI) is 38.7% which indicates that the installed inverter has less THD than the two level PWM one.

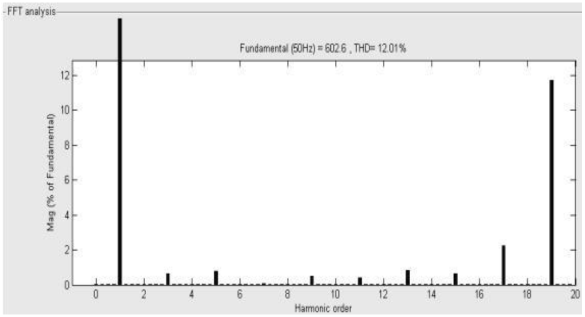


Fig. 14. FFT harmonic analyses for line voltage of three level H bridge inverter.

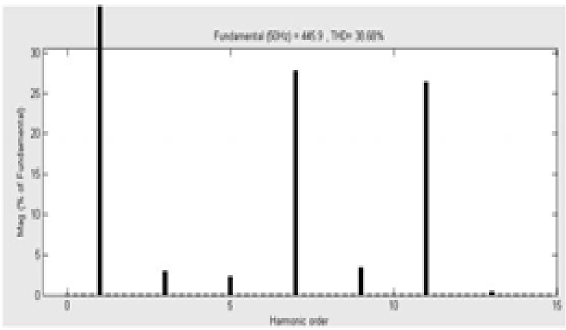


Fig. 15. FFT harmonic analyses for line voltage of two level PWM voltage source inverter.

Fig. 16 shows the inverter output for another operating condition case when replacing the three-phase motor load with a three single phase motors, it is found that three level H bridge inverter output voltages give the same ac output waveform without any distortion.

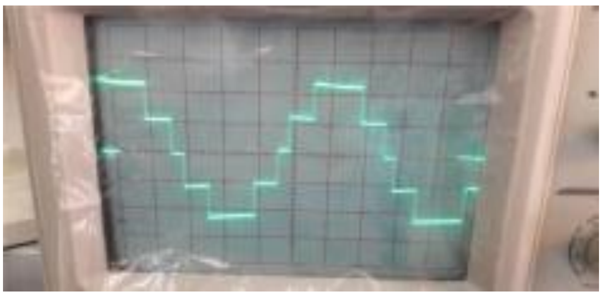


Fig. 16. Line to line output voltage waveform at the primary side of main transformer for the second case operating condition.

V. CONCLUSION

This paper has presented a novel of three stage H bridge inverter prototype scheme to reduce harmonics and improve power quality. A prototype Scheme controlled by micro-control switching circuit which built and validated for robust satisfactory low distortion three phase three level inverter. The test results validated that the proposed multi staged inverter topology produces a wave nearer to a sine wave with frequency suits the grid. The results show that the proposed inverter topology with the proposed tri-level H bridges and control technique give better waveforms and less total harmonic distortion compared to the conventional H-type-voltage source inverter and the prototype test results shows that the output voltage in the three-level inverter has reduced distortion and total ripple content. The proposed VSI-Tri- Level Scheme can be used with larger Induction and BLDC, Permanent Magnet Synchronous Motor drives as well as Smart Grid interfacing of renewable energy PV-Fuel Cell-ESS Energy Battery Storage in Micro-grid DC-AC systems.

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