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The First International Conference in Engineering and Technology Development




Universitas Bandar Lampung
20 - 21, June 2012
Lampung, Indonesia

PREFACE

The activities of the International Conference is in line and very appropriate with the vision and mission of the UBL to promote training and education as well as research in these areas.

On behave of the First International Conference of Engineering and Technology Development (ICETD 2012) organizing committee; we are very pleased with the very good responses especially from the keynote speakers and from the participants. It is noteworthy to point out that about 45 technical papers were received for this conference

The participants of conference come from many well known universities, among others: Universitas Bandar Lampung, International Islamic University Malaysia, University Malaysia Trengganu, Nanyang Technological University, Curtin University of Technology Australia, University Putra Malaysia, Jamal Mohamed College India, ITB, Mercu Buana University, National University Malaysia, Surya Institute Jakarta, Diponogoro University, Unila, Universitas Malahayati, University Pelita Harapan, STIMIK Kristen Newmann, BPPT Lampung, Nurtanio University Bandung, STIMIK Tarakanita, University Sultan Ageng Tirtayasa, and Pelita Bangsa.

I would like to express my deepest gratitude to the International Advisory Board members, sponsors and also welcome to all keynote speakers and all participants. I am also grateful to all organizing committee and all of the reviewers which contribute to the high standard of the conference. Also I would like to express my deepest gratitude to the Rector which give us endless support to these activities, such that the conference can be administrated on time.

Bandar Lampung, 20 Juni 2012

Mustofa Usman, Ph.D
ICETD Chairman

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Design an Inverter for Residential Wind Generator

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Abstract— **As one of alternative source of renewable energy, wind energy has an excellence prospect in Indonesia, particularly in coastal and hilly areas that has potential wind to generate electricity for residential use. There is urgent need to locally develop the low cost inverter of wind generator system for residential use. Recent developments of power electronic converters and embedded computing allow improvement of power electronic converter devices that enable integration of microcontrollers in its design. In this project, an inverter circuit with suitable control scheme design was developed. The circuit was to be used with a selected topology of Wind Energy Conversion System (WECS) to convert electricity generated by 500W direct-drive permanent magnet type wind generator which is typical for residential use. From single phase AC output of the generator, rectifier circuit is designed to convert AC to DC voltage. Then DC-DC boost converter was used to step up the voltage to a nominal DC voltage suitable for domestic use. The proposed inverter then will convert the DC voltage to sinusoidal AC. The duty cycle of sinusoidal Pulse-Width Modulated (SPWM) signal controlling switches in the inverter was generated by a microcontroller. The lab-scale experimental rig involves simulation wind of wind generator by running geared DC motor coupled with 500W wind generator where the prototype circuit was connected at generator output. Experimental circuit produced output voltage single phase 240V sinusoidal AC voltage with frequency of 50Hz. Measured total harmonics distortion (THD) of the voltage across load was 4.0% which is within limit of 5% as recommended by IEEE Standard 519-1992.**

Keywords— **Wind Energy, inverter, converter, microcontroller, generator, residential.**

I. INTRODUCTION

Wind energy is a type of renewable energy that is clean is the world's fastest growing renewable energy source. The average annual growth rate of wind turbine installation is around 30% during last 10 years [1,2]. It is clear that the global market for the electrical power produced by wind turbine generators has been increasing steadily, which directly pushes the wind technology into a more competitive area.

Wind turbine is the device that converts wind energy to electricity [3-6]. The system is also generally known as Wind Energy Conversion System (WECS). Generally there are two types of wind turbine: horizontal-axis wind turbine (HAWT) and vertical-axis wind turbine (VAWT). The design of horizontal-axis wind turbine (HAWT) as shown in Fig. 1, consisted of three components namely are: 1) rotor component including blades for converting directional wind speed to rotational speed which constitutes 20% of cost, 2) generator component which is approximately 34% of cost, including electrical generator, gearbox (some design use direct drive), and the control electronics, and finally 3) structural support component which is approximately 15% of the cost including the tower and rotor yaw mechanism [7]. Several types of generator were used in wind turbine particularly the HAWT types and the common ones were Permanent Magnet Synchronous Generator (PMSG), Doubly Fed Induction Generator (DFIG), Induction Generator (IG) and Synchronous Generator (SG) [8-9].

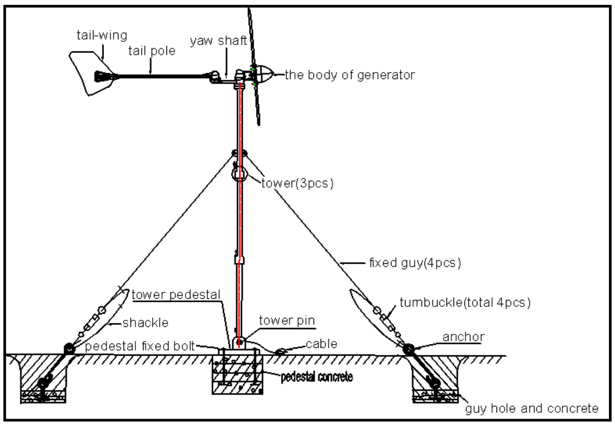

Fig.1 Installation diagram for HAWT

Small wind turbines of generally less than 3kW are suitable to be residential type. Small types normally were installed at house lawn area such as the one shown in Fig. 1 and some were even small enough to be mounted on the rooftops. The type of generator favoured for this segment was Permanent Magnet Synchronous Generator over other types since finding where most urban areas in Indonesia have wind supply of less than 5m/s. Within these speeds, voltage generated at a particular 500W wind generator permanent magnet type is around 18V to 22V (Anhui Hummer, 2007). A power converter system will then convert the generated electricity to the standard level for user consumption. One particular example of savings by consumer when using WECS: If a small wind energy system of 500W can operate for 8 hours minimum, the particular household can save about 40% from the usual electricity bills. Lately, there is an increasing trend to enable the WECS to supply excess generated energy back to the electricity grid. The public demand for this capability is high on residential type market segment particularly after introduction of net-metering policy in some countries like United States and Canada, where consumers were allowed to sold back to the utility companies to offset their consumption [10].

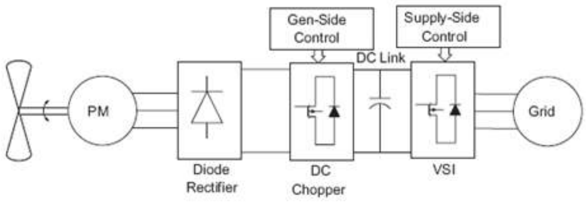

Fig.2 Wind energy conversion system (WECS) with diode rectifier converter options [Baroudi et. al., 2007]

Inverter is actually another type of SMPS device that transforms voltage from direct current (DC) to alternating current (AC). As shown in Figure 2, it is used together with boost DC-DC converter and rectifier circuit in power converter topology to increase the low AC voltage generated at wind generator terminal to nominal AC load and grid voltage. For a typical full bridge, single phase, voltage source inverter (VSI), the circuit consist of H-Bridge circuit containing power switches and inverter control circuit that generates triggering signal to switch the power switches in the H-Bridge circuit [11].

II. Inverter Control Circuit

The objective of this research is to develop and implement inverter control circuit for residential type wind generator. The project was expected to turn output voltage generated by residential wind generator at 18V to 22V to household and consequently grid compatible of single phase sinusoidal AC voltage of 240V ±5% with frequency of 50Hz. The total harmonics distortion (THD) of final output voltage must not exceed 5% as stated in requirement. The proposed design should be able to meet the above requirements with much lesser components and lower cost.

This research was based on experimental approach. From the past research, selected relevant topology and basic circuit, the control algorithm was designed and model simulated under software MATLAB SIMULINK. As the simulation results confirm with the theoretical model, the values of circuit component were selected and the programming was verified. Then, the circuit was built on the prototype board. The circuit was designed under EAGLE software and built on prototype printed circuit board (PCB). Experimental data and result were collected from selected test points on the prototype board using oscilloscopes. The wind generator operation was simulated through a design rig. In the rig, the wind generator was rotated by a DC motor at various speeds from 118 rpm to 400 rpm to simulate its respond to different wind speed.

Figure 3 shows the block diagram of the flow of the experiment according to the selected topology. To simulate the problem statement, residential type wind turbine was to be used with condition of low wind power, with wind speed around 3m/s to 5m/s. Based from topology selected, the residential wind generator to be used is permanent magnet synchronous generator (PMSG), direct drive type (which does not utilize gear transmission to increase the turbine rotational speed). For this purpose, a 500W wind turbine system was purchased. Voltage generated at the generator terminal is single phase AC type and very low amplitude. The output voltage is then connected to rectifier circuit to transform the voltage to DC type. Next, boost converter was used to step up the voltage to nominal grid voltage of around 240V. After that, inverter circuit was used to invert the DC voltage to AC voltage. Necessary performance parameter of the output voltage such as amplitude, frequency and total harmonics distortion (THD) was measured and analyzed to ensure generated output compatible to be supplied to the grid. Voltage data from wind generator performance datasheet was used as basis during simulation stage where circuit at each stage was designed and simulated for output.

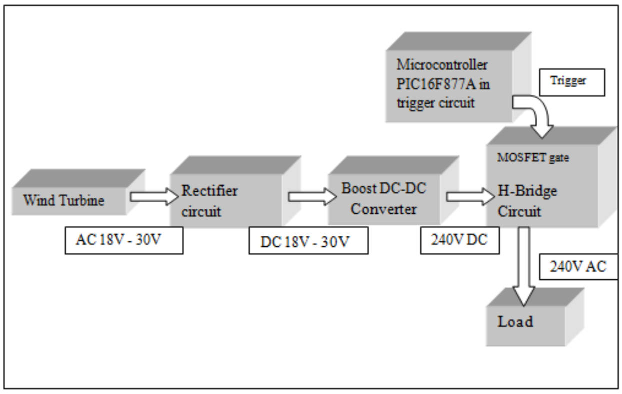

Fig.3 Block diagram of the experimental flow

Fig. 4 shows the experimental rig for the wind generator simulator. In this rig, wind generator was connected to a geared DC motor through a flexible coupling. The output of

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the rig was connected to a resistive load. It has been indicated by Vendor of this 500W Wind Turbine that rated Wind Generator output for this model is 500W at wind speed of 7m/s where the rotational speed was at 600 rpm while the start-up speed for the Wind Generator to operate was at wind speed of 3m/s. Variable Output Power Supply was used to generate various input supply voltage to DC motor which, in turn rotated wind generator at different speed between 118 rpm to 400 rpm.

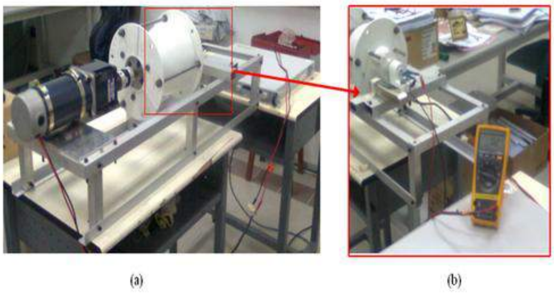

Fig.4 (a) Experimental rig for wind generator simulator; (b) Turbine rotational speed and generator terminal output measurement

Inverter circuit main job function is to invert the stepped up voltage of 240V from DC to AC. The output voltage must be ideal sine wave with frequency at 50Hz and low total harmonic distortion. The circuit consists of H-bridge circuit and control trigger circuit. Fig. 5, shows the H-bridge prototype circuit schematic diagram. The H-bridge circuit consists of four MOSFET transistors Q2, Q3, Q4 and Q5 arranged in H-bridge formation. The input to the H-bridge circuit is the stepped-up DC voltage while the bridge output of the circuit is taken across points between source of Q2 and drain of Q4 and between source of Q3 and drain of Q5.

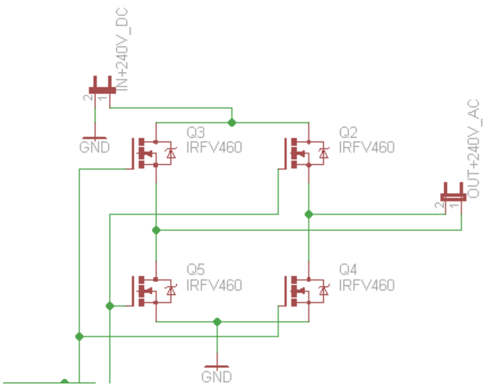

Fig.5 Schematic diagram of H-Bridge inverter circuit (shown without LC-filter components and load)

III. Results and Analysis

A. Results of Wind Generator Simulator rig

Test run results of the wind generator simulator rig was shown in Fig. 6, in the rig, wind generator was rotated by DC motor at various speed as the output was connected to a resistive load. The data for simulator rig starts at lower speed due to constraints of DC motor as prime mover to the rig. The results from the graph agrees with the manufacturer performance datasheet where as the rotational speed increase due to increasing wind speed, the voltage output increase. From the graph, the generated voltage at wind speed ranging from 3m/s to 5m/s was around 13V to 20V. The generated voltage at the terminal was single phase AC type with a variable frequency that also increases as the speed increase. From the simulation rig, power generated across the load was slightly above 40W. Hence rating for components at rectifier circuit was selected to be within 50V for voltage and 50W for power.

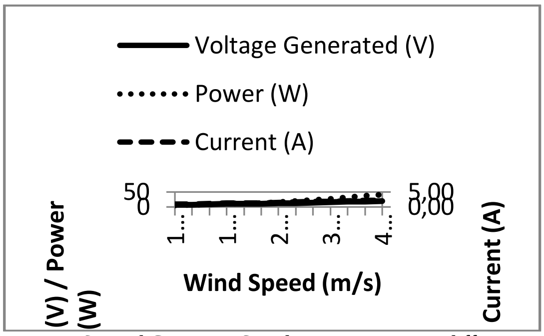

Fig. 6 Wind Generator Simulator Rig output at different generator rotational speed

B. Simulation Results of Inverter

A simulation results of the inverter system shown in Fig. 6. . The control algorithm for the generation of trigger control signal method using unipolar switching SPWM has been used [8-9]. Amplitude modulation ratio, was selected to be at 0.8 because ratio of less than 1 has linear effect on amplitude of fundamental frequency component while ratio exceeding 1 will have noticeable increase in output distortion. Frequency modulation ratio, was selected to be at 40 to be sufficiently high to enable better control of amplitude, wave shape and frequency of the inverter output. Reference sinusoidal frequency was selected at 50Hz while carrier sawtooth frequency was selected at 2kHz. These parameters were also comparable with works by [12], that selected and values to be 0.8 and 150 respectively.

Figure 6 a. shows output voltage after the MOSFET H-bridge circuit. The input to the H-bridge circuit was 240V DC voltage. The output was deployed as PWM pulses with amplitude 240V along the positive and negative sides. The output obtained is not sinusoidal because the LC filter was not included in the design. Figure 6.b. shows the output voltage after implementing the LC filtering components in the circuit. From the graph the output voltage has sinusoidal shape with amplitude 240V and frequency 50Hz which has met criteria set by objective. THD measurement of the output voltage after LC filtering was 2.3% as shown in Fig. 6.c.

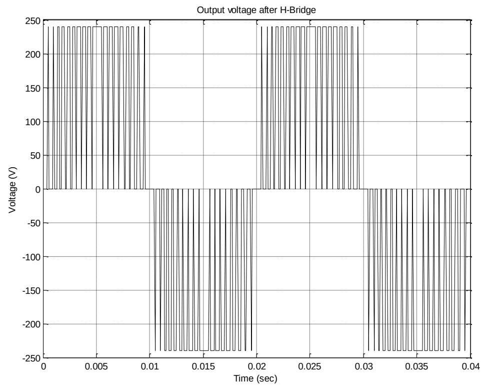

Fig. 6.a. Output voltage after the H-bridge circuit before LC filtering

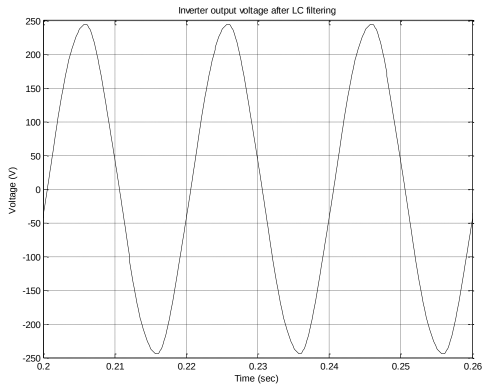

Fig. 6.b. Output voltage after LC filtering

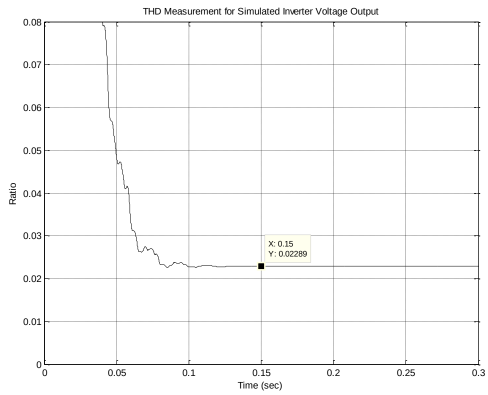

Fig. 6.c. THD Measurement of simulated output voltage after LC filtering

C. Experiment Results of Inverter

The rig was run at 300 rpm (which is equivalent to wind speed of 3.5m/s) to generate around 20V of energy at terminal. A resistive load with resistance 480 ohm and power rating 120W was connected at inverter output. Figure 7.a. shows the output of the voltage after the MOSFET H-bridge circuit before LC filter. The output was deployed as PWM pulses with amplitude 240V along the positive and negative sides. Figure 7.b. shows the output voltage after implementing the LC filtering components in the circuit. From the graph the output voltage has sinusoidal shape with amplitude 240V and frequency 50Hz which has met criteria set by objective. The sinusoidal output voltage signal was then sampled as data where the Fourier Transform was calculated for each sample points.

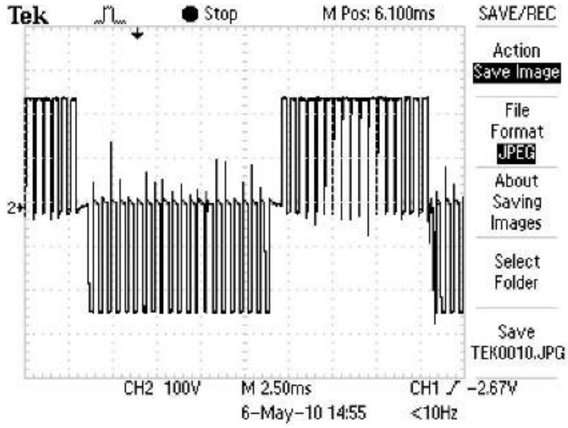

Fig. 7.a. Output voltage after H-bridge circuit on prototype board

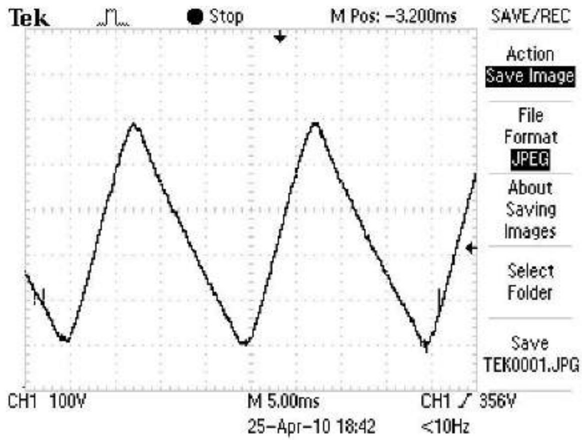

Fig. 7.b. Inverter output voltage after LC filtering on prototype board

IV. Conclusions

In this paper simulation and experimental results were included together with explanation and analysis. Final simulation result complied with the project objective that the output of inverter voltage should be sinusoidal with peak voltage 240V, frequency 50Hz and THD below 5%. Finally when the rig was run with all hardware connected according to topology, the measured output voltage complies with the project objective which voltage should be sinusoidal AC with peak voltage 240V, frequency 50Hz and THD below 5%..

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