International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-12, October 2019

Design and Construction of Model Battery Charging Control for Stand-alone self-Excited Induction generator

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***Abstract:** In this paper, design and construction of model battery charging control for stand-alone wind driven self-excited induction generator SEIG) is present. Apart from an energy transfer function from wind turbine (WT) with stand-alone SEIG, the proposed model battery charging control can also be an active power in linear loads with stand-alone for a three-phase four wire system. Initially, mathematical modeling of the wind turbine with stand-alone SEIG is given. The simulation based on mathematical equations obtained from the model provides electrical characteristics of the wind turbine source that which will be use as the battery charging control input of the inverter. Secondly, the main system has been virtually create in order to actualize the conversion from DC to AC and the main power circuit employs insulated gate bipolar transistors (IGBTs) formed in a three-phase full bridge. Thirdly, the control circuit is discuss and has been design and the control method used is voltage control with microcontroller for stand-alone linear loads that is simple. Finally, the obtained results are discusses in order to verify the correct operation as the system is designed.*

***Keywords :** Battery Charging Control, Self-excited Induction Generator (SEIG), Wind Turbine (WT).*

I. INTRODUCTION

The production of electricity from wind power systems of Thailand has become less costly and more efficient in recent years. This leads to a huge market for off-grid wind power systems for rural [1]. A small wind turbine generator (WTG) are still relate to the supply of power to remote areas or rural electrification in developing countries. This system has successfully implemented in many countries of Europe and America [2]-[4]. The demand is increasing renewable energy sources for electrical energy across on Asia [5]-[8]. Technological advancements of inverter control for conversion are consider important of the alternatives for power generation systems [9]-[10].

Revised Manuscript Received on October 30, 2019.
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WTG is highly dependent on the wind regime, and expected to increase in developing countries. Such as in Thailand of Southeast Asia. The system adjustment of voltage and frequency of WTG is first there must be a direct conversion to alternating current by AC to DC convertor before it is the fed DC bus. However, the more efficient of energy and more economical is needed the energy storage and voltage constant with battery is therefore developed and proposed because of its low cost of energy, long service period, low cost of operation and maintenance and high power efficiency [11]-[13]. Whence, a unique and simple battery charging control needs to control voltage and frequency of stand-alone operated SEIG. The aim of the work suggested and implemented a microcontroller based on IGBTs and space vector pulse width modulation - voltage source inverter (SVPWM-VSI) to regulate the terminal voltage of SEIG [14]. The technique SVPWM-VSI presented by Chakrapong Charumit and Vijit Kinnares [15] modified and used in the proposed controller. This wind energy conversion schemes can connect to the system electrical grid, which it can be to strengthen the system rich power source of both reactive and active power, which contains the number of distributed generation (DG) [16]. Nevertheless, stand-alone systems considered for wind turbine that converts kinetic energy into mechanical energy can be drives the power energy SEIG. However, when the energy from the wind produced is not continuous both voltage and frequency different wind velocities and uses it partly to supply the required load demand (reactive power) and partly to charge the battery bank and convert to linear load [17]-[18].

The major contribution of this paper deals with modeling and simulation of battery charging control for stand-alone wind driven SEIG with an active power functionality by microcontroller. Apart from energy transfer from the wind turbine, this system investigation is to develop a simple yet accurate IGBTs and SVPWM-VSI assigned to compensate the harmonic current for the linear loads. Section-II provides the modeling algorithm WTG when operating as a stand-alone power supply. Section –III the proposed algorithm and model control design. In section –IV, results, discussion and verified experimentally and section-V conclusion of this work presented.

II. MODELLING OF WIND TURBINE GENERATOR

The modelling of wind turbine generator this section presents for the reliability and control are study when operating as a stand-alone power supply with other conventional generator.

The proposed model of the wind turbines uses a controller design system.

A. Modeling Wind Turbine Configuration and System

For electricity generation from wind turbine generators and one digital signal processor (DSP) microcontroller controls the system. The wind turbine model was change from per unit system to the actual value system and original model represents a variable pitch model, the model was change to represent a fixed pitch turbine and fixed capacitors bank (C1). Consider the value of the pitch angle to start at zero. [19]. the proposed system show by Fig. 1 overall for testing and Fig. 2, is composed of a 220/380V, 50 Hz, induction generator driven actual for that the system is suitable for each type of load. With a three-phase capacitor connected in conjunction with the terminals of the induction generator.

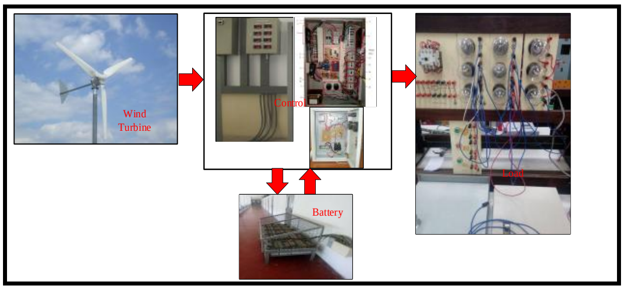

Fig. 1: Overall for Testing Systems

When there is a strong wind, the blades (S) of the wind turbine due to the wind velocity (V_w) and the air density (ρ). The torque generated by the blades of the wind turbine transmitted power (P_{WT}) and the rotating turbine torque (T_{WT}) because wind power obtained is the ratio of the out power to the shaft speed[20].

$$P_{WT} = Cp(\lambda)\rho S V_w^{\,3} \tag{1}$$

$$T_{WT} = \frac{Cp(\lambda)}{\lambda} r \rho S V_w^{\,2} \tag{2}$$

Where $Cp(\lambda)$ is the power factor by wind turbine, $\lambda = \omega r/V_w$ is the tip speed ratio, ω is the turbine angular velocity, and r is the radius of wind turbine. For each wind speed has a maximum of characteristic $Cp(\lambda)$ in the point CPmax at λopt. Based on the maximum power point (MPP) take place a directly proportional dependence $\omega opt = (\lambda opt/r)\, V_w$.

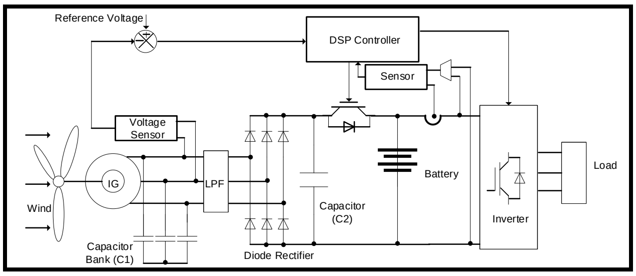

Fig. 2: Diagram of SEIG and Control

In Fig. 2 it consists of model and control, WT-driven variable speed SEIG, LC low-pass filter, capacitors, three-phase uncontrolled diode rectifier with a chopper in series battery and sensor, DSP controller, interfacing dc–ac power inverter and loads. To avoid the charging issues, all IGBTs are connect to the DC bus. Three control strategies are develops to ensure stable and affective operation of DSP controller under sever conditions.

B. Dynamic State Modeling of SEIG for Control

The principles of electricity generation from wind turbines models and basic equations of the SEIG and controller typical parameters are express by Equation (3), (4). When assumptions load resistance (R= 20Ω) and inductance (L= 80 mH) calculated by considering the rate value of current and voltage of induction machine (IM) for finding the solution of C_{min} and all parameters can be evaluated from $X_m = X_{smax}$ show in Figure 3.

$$IZ = 0 \tag{3}$$

$$Z = \left[\left(\frac{R_r}{(F-v)} + jX_{lr}\right) \| X_m\right] + \frac{R_s}{F} + jX_{ls} + \left[-\frac{jX_c}{F^2} \middle\| \frac{R}{F} + jX\right] \tag{4}$$

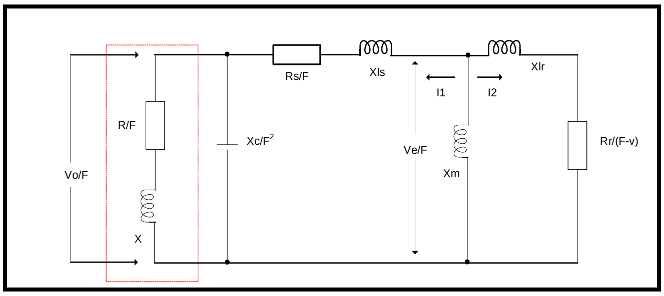

Fig. 3: The value per unit per phase as an equivalent circuit. SEIG with calculated RL load

When under steady-state excitation at $I \neq 0$, that Z = 0 in follow from (3) and simplifying (4), the obtained equation is given by

$$-a_1F^3 - a_2F^2 + (a_3x_c + a_4)F - a_5x_c = 0 \tag{5}$$

$$-b_1F^4 - b_2F^3 + (b_3x_c + b_4)F^2 - (b_5x_c + b_6)F - b_7x_c = 0 \tag{6}$$

Where, I = 0,1,2,… 4 are positive constants solving that $X_m = X_{smax}$ giving two real roots, the obtained C_{min} = 65 μ F and C_{max} = 134 μ F can be rearranged as

$$a_4F^4 - a_3F^3 + a_2F^2 - a_1F^1 + a_0 = 0 \tag{7}$$

or

$$a_4F^4 + a_2F^2 + a_0 = a_3F^3 + a_1F^1 \tag{8}$$

The technique presented by M. Sathyakala and M. Arutchelvi (5)-(8) [21] modified and used in the proposed for two polynomials by using Matlab/Simulink for determined and simulation result for minimum capacitance value are taken for SEIG is show in Fig. 4. It is for C_{min} to C_{max} and we used average value.

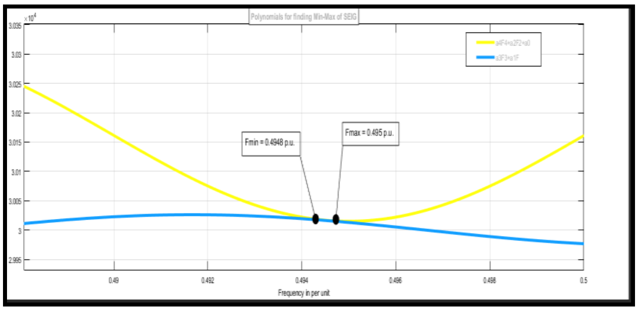

Fig. 4: Two polynomials for frequency in per unit

The turbine power of SEIG equation and simulation of energy conversion of wind turbines (1) and (2) are simulation of the output power of the change of wind speed and rotor speed are present in Fig. 5 and Fig.6. Which is going to have the same power along with the speed characteristics for the between λ_{min} and λ_{max} wind velocity. It will produce an appropriate value for the wind turbine based on this feature and able to be used appropriately with the load.

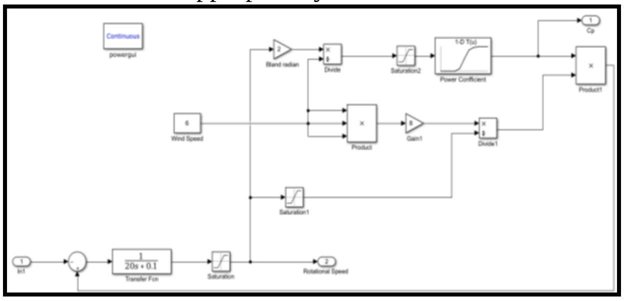

Fig. 5: Simulation of SEIG by Matlab/Simulink

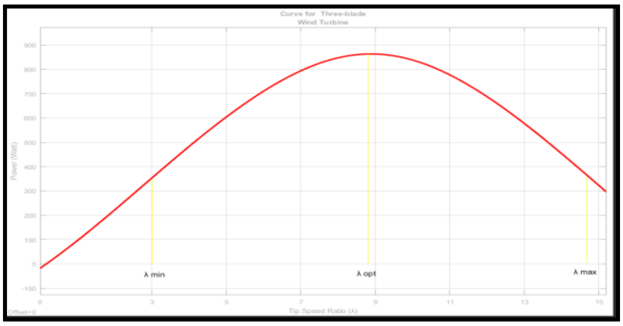

Fig. 6: Typical power and versus λ curve.

III. PROPOSED ALGORITHM AND MODEL CONTROL DESIGN

A. Diode Bride Rectifier Circuit

Diode bride rectifier multi-level converts the AC output variable magnitude, frequency from SEIG using, and those that do not use controls with rectifiers. By having a chopper circuit that can adjust the DC voltage into with the DC bus. DC voltage of the load (V_R) will be able to show the maximum voltage that the generator can supply.

$$V_R = \left(3\sqrt{2}/\pi\right)V_s \tag{9}$$

Moreover, when the rms. voltage at the polarity of SEIG exceeds 10% of the rated voltage. Makes it possible to determine the transient voltage due to the rms. value. The input AC maximum voltage can be calculated as follows.

$$V_{peak} = \sqrt{2}(10\% \text{ of rated voltage}) \tag{10}$$

In addition, the value of the dc-link capacitance based on the ripple factor (RF). In addition, when the ripple factor is greater than 5% it can be considered as, three-phase bridal rectifier circuit that detects capacitors and ripple factor values on DC bus values given by,

$$C_2 = (1/12\, fR_{RL})(1+1/\sqrt{2}RF) \tag{11}$$

Where, R_{RL} is assumptions load calculated by considering the rate value of current and voltage of IM.

B. Battery Bank

In this section, the design of the model is probably the most well known and most frequently used battery model for analysis. [22] This model describes the direct electrical behavior of the battery in terms of voltage and current of the DC bus is high voltage.

$$V_{batt} = (V_o - R_i)(I - K_i)(1/(1-f)) \tag{12}$$

When,

$V_{batt.}$ = battery terminal voltage (volts)
V_o = open circuit voltage battery (voltage)
$R_{i.}$ = internal resistance of battery (ohms)
I = instantaneous current (amps)
$K_{i.}$ = polarization resistance (ohms)
f = integral of [I(dt$_{time}$/Q)]
(Accumulated ampere-hours divided By full battery capacity)
Q = battery capacitance (ampere-hour)

C. SVPWM-VSI Inverter

The DC energy contained in the battery output is constant and converted into AC power using SVPWM-VSI inverter by DSP controller simulate the system by using double edges modulation. The switching loss regulation is normally achieve by IGBTs with multi-level. It can select eliminate overvoltage stress and reduce the switching frequency by increasing the voltage levels of the inverter. SVPWM using a three-lag VSI is illustrated in Fig. 7. Va, Vb and Vc is an equivalent vector space reference for each phase of the leg, which is not sinus contaminated with strange harmonic components. In connecting the switchgear in parallel connection, it will lead to higher current levels. The alternating waveforms for each leg are obtained by comparing the general triangular carrier wave and each space vector reference. To achieve the three-phase reference required for three legs VSI for creating SVPWM formats, Multi-level converter topology is based on this principle and therefore the voltage applied to the device sensor for DSP controller can be controlled and limited.

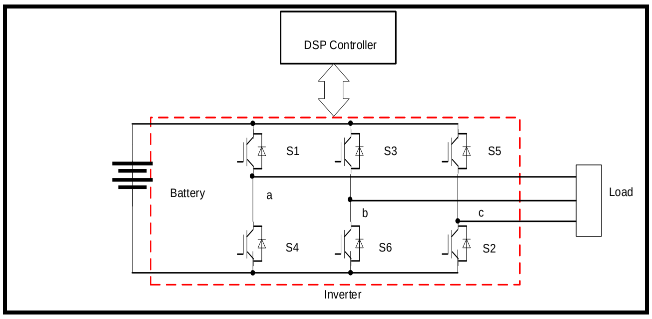

Fig. 7: Three-leg VSI supplying inductive loads.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The wind-driven three-phase SEIG are sensitive to wind speed changes. If the speed drops below the threshold between λ_{min} - λ_{max} of self-motivation, the turbine speed is assumed to vary in wide range with purpose to predict the charges in the turbine power, the voltage at the destination machine will be lost. The simulation results of this situation vary according to wind speed from 3m/s to 14.8m/s of three-phase wind driven SEIG for bride rectifier fed to the series battery with assumptions calculated R-L load for excitation capacitance is illustrate in Fig.4 and Fig.5. To verify the SVPWM-VSI method presented, the designed modulator has been implemented and tested with the main power circuits as shown in Fig. 7. The three-leg. IGBTs inverters are used with a 5 kHz switching frequency and The DC link voltage is 565V by the DSP controller. The RL load values are 120 Ω and 550 mH. for resistors and inductors respectively for each phase.

Fig. 8 - 14 shows the results of computer simulation of the proposed SVPWM-VSI of rated power 1 kW. This shows that in theory the operation of the variable speed will increase energy. The gain between λ_{min} - λ_{max} and optimize about 8.85 m/s. show in Fig. 8. Its turbine speed (p.u.) can be DC/DC converter is to DC bus output voltage to a variable-load resistance from a fluctuating DC input voltage by rectifying a line voltage that is changing in magnitude.

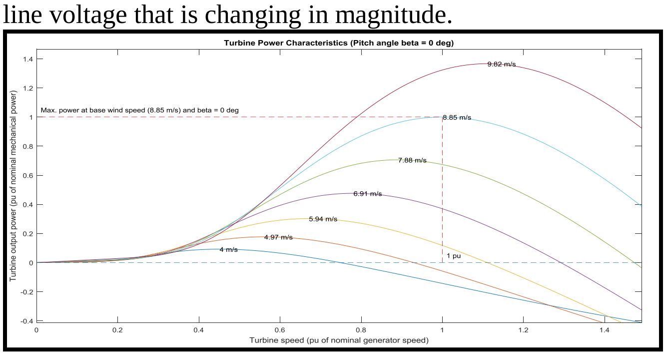

Fig. 8: Turbine Speed (p.u.)

In Fig. 9, this shows the between startup to be charging battery by a SEIG feeding bride rectifier and the variation of voltage, current, speed, and power are controlled by a rectifier as . The real power and reactive power of startup period to charge the series battery, where, the state of charge (SOC in %) the power is utilized by using the battery. Observe that the voltage and currents are quite “smoothing” despite the use of a variable speed show that in Fig.10, at SOC 100% to 96.5% for 0 – 20 sec. makes it possible to analyze the value of stored energy storage in the battery and use the obtained values appropriately. There must be a relationship between actual power, reactive power, voltage at the terminal, current of battery and duration of charging. The output of each stage is shown in Fig. 9 and Fig. 10 of this purpose in the schematic.

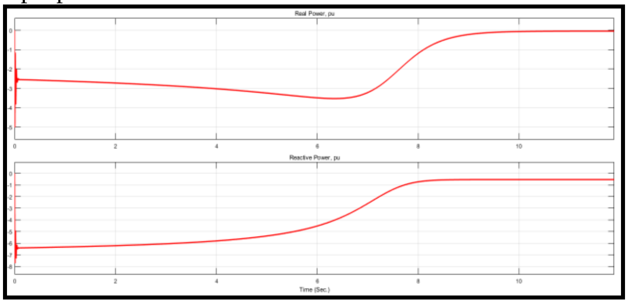

Fig. 9: Real Power and Reactive Power of Startup Period

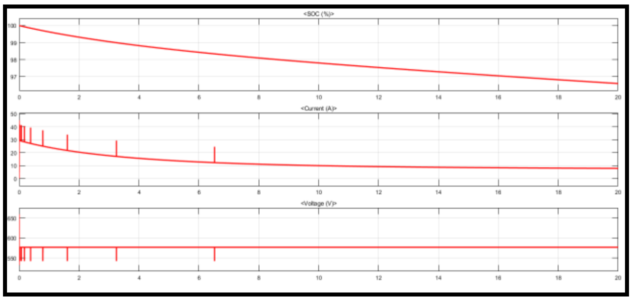

Fig. 10: Terminal Voltage, Current and SOC of Battery

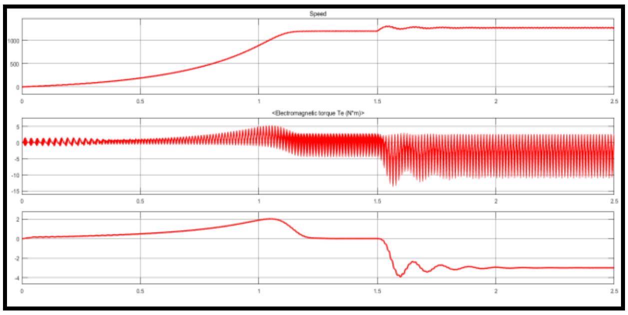

Fig. 11: Speed and Torque of Startup Period of Full Load

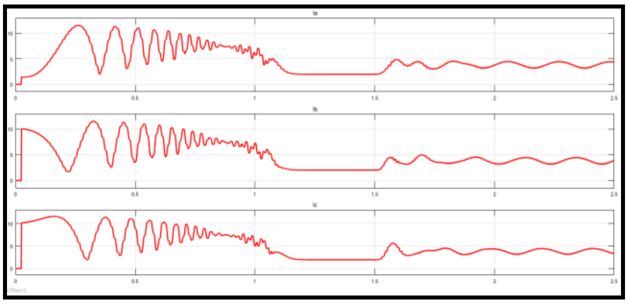

Fig. 12: Current I_a, I_b, I_c of Startup Period of Full Load

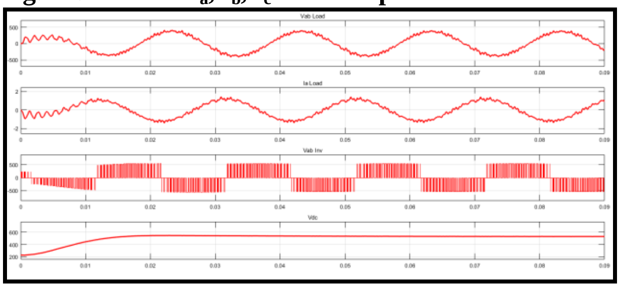

Fig. 13: Voltage and Current Supply Load and Inverter

Retrieval Number: L26521081219/2019©BEIESP
DOI: 10.35940/ijitee.L2652.1081219
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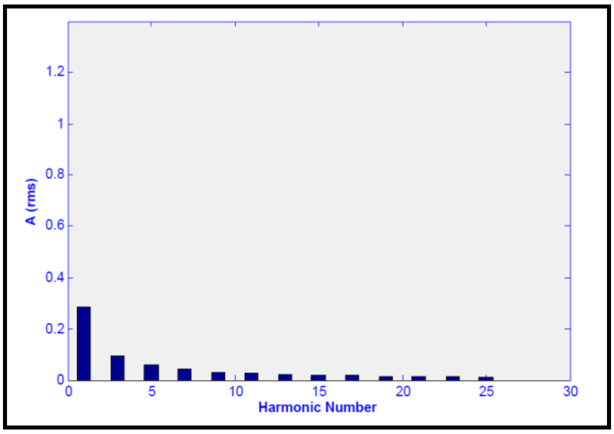

Fig. 14: Signals Current harmonic spectrum (I_{Load})

This power generated is indeed related to the wind speed shows in Fig. 11, speed and torque of startup period at 1460 rpm. and 1.5 N*m. where start phase, and current average 4.8 A. of three-phase show in Fig.12. When supply load R-L are average 400 V, 1.6 A. show in Fig. 13. For the next show, to inverter voltage and Vdc bus in a configuration presented in 565 V. and current harmonic spectrum of load for high values where the optimum power increase quickly show in Fig. 14.

With the maximum expression / minute centering on the power of the load reference defined in the experimental results.

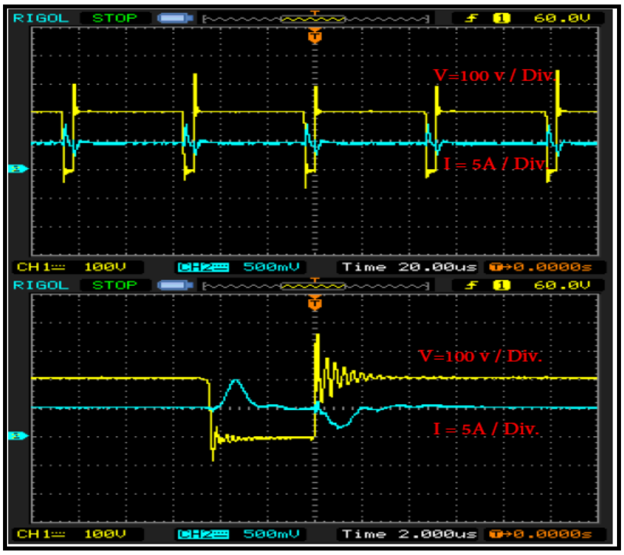

Fig. 15: Signals Voltage and Current at Speed 8.85 m/s

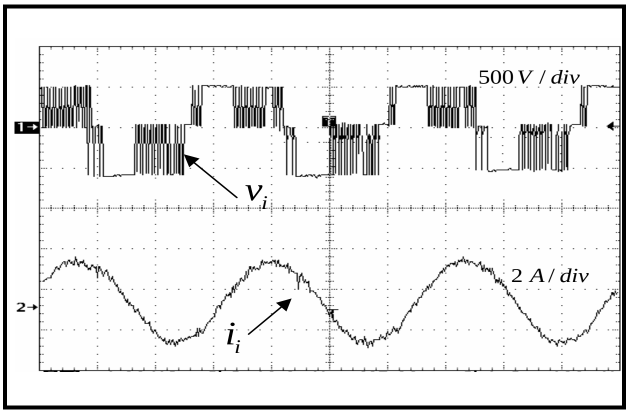

Fig. 16: Signals Voltage and Current at Inverter

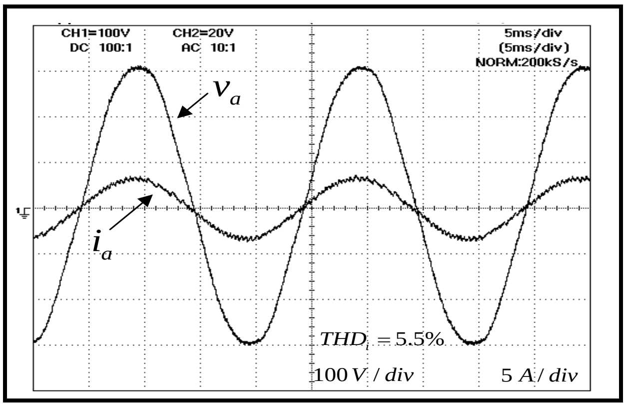

Fig. 17: Signals Voltage and Current at Supply Load

In Fig. 15, this experimental results show signals the voltage and current at maximum wind speed of 8.85 m/s, voltage 100V/Div.(upper), current 5A / Div. (bottom) at time / div. = 20 µs. and 2 µs. respectively.

Fig. 16 show the voltage and current on single switches of SVPWM-VSI operating under DSP microcontroller: voltage 500V/Div.(upper), current 2A / Div. (bottom) at time / div. = 20 µs. and 2 µs. When load voltage becomes stable and

normal, the inverter connects into the inductive load, The load current and phase voltage are pure sine wave forms, at phase A, Less than THD 5.5% and higher efficiency than 90% at voltage 100V/Div.(upper), current 5A / Div. (bottom) at time / div. = 20 µs. and 2 µs. respectively.

Since the dynamic responses in the previous section will reach load voltage values, the developed wind turbine model, mathematical and control SVPWM-VSI model by DSP controller can be directly employed to stability and durability of the load power.

V. CONCLUSION

A new model and control approach for WT and SEIG a high-frequency link inverter that tracks the highest available power and creates a similar power factor of SVPWM-VSI model by DSP controller technique coupled with the six-state of DC/DC power conversion, The proposed inverter system is easier when the load is supplied three-phase balance. Produces more promising result while

comparing with the other existing approaches. With a method that offers balanced control of the output voltage, it is possible for the needs of asymmetrical three-phase induction loads to improve battery performance that developed using the SVPWM-VSI model by DSP controller, which classify the percentage of the possibility of load power more accurately.

APPENDIX

Wind turbines and SEIG coefficients and parameter scores used for simulation and experiments are given below.

Table 1: Parameters of wind turbine and SEIG

Rated power	1 kW.
Type	3 Blade upwind
Rotor diameter	2.7 m.
Start up wind speed	2.5 m/s.

Wind speed cut	3.5 m/s.
Wind speed	14 m/s.
Wind speed cut	None
Furling wind speed	18 m/s.
Design wind speed	50 m/s.
Propeller volume control	None, Fixed pitch
Over speed protection	Auto furl
Gear box	None, Direct drive
Temperature range	-40 to 60 Deg. C
Generator	Induction Generator
Output	220/380 V, 4 pole

ACKNOWLEDGMENT

Key project of the development project of alternative energy learning center, Tak Province, Thailand, and research project has been fund by the research budget from the graduate research project, creative and academic services to the community in 2015 of Rajamangala University of Technology Lanna, Thailand, for its equipment and financial support to carry out this research.

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