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Research Article

Small Wind Electric Energy Charging System Simulation and Application based on MPPT Algorithm and SEPIC Circuits

[1]Suxiang Qian, [1]Yuansheng Xiong and [2]Lilong Huang
[1]School of Electromechanical Engineering, Jiaxing University, Jiaxing 314001, China
[2]School of Electromechanical Engineering, Jiangxi University of Science and Technology, Ganzhou 341000, China

Abstract: In this study, designed the work principle for the wind power system based on the PMSG and the framework for the system, induced the PMSG mathematic model and put up the control strategy for the whole system, including the output voltage control of the PMSG, the realization of the Maximum Power Point Tracing (MPPT) method, the control strategy for the SEPIC converter. Then, the dissertation built the simulation model for the wind power system based on the PMSG using the MATLAB software. The use of this control strategy is described. To realize the power of the independent regulator and battery charging load design in detail. The control strategies mentioned in the above are simulated and simulation results are obtained, respectively in the condition of different wind speed. The laboratory results show the schemes are reasonable and practical.

Keywords: Maximum Power Point Tracking (MPPT), Permanent Magnet Synchronous Generator (PMSG), Single Ended Primary Inductor Converter (SEPIC), Small Wind Electric System (SWES)

INTRODUCTION

As fickle wind, Leading wind turbine tip speed ratio change, Makes the deviation from the best working conditions of wind turbine, Affect the energy conversion efficiency of wind turbine. Maximum Power Point Tracking (MPPT) can improve the energy conversion efficiency of wind turbine Effective under Variable wind conditions.

The methods Maximum power point tracking used in the past are Measure or estimate the wind speed (Wang and Chang, 2004), neural network control (Li *et al*., 2005), fuzzy control (Simoes *et al*., 1997), etc. However, these three methods Need to know in advance than the Wind turbine tip Relationship between the characteristics of power factor; Generator parts: Including the induction, Permanent magnet synchronous, Double fed induction machine and so on. Doubly fed induction generator for general application in high-power, Induction is used in middle-power, Not suitable for small wind turbine low power features; Control circuit: Boost, Buck, Cuk (Yaoqin *et al*., 2002), but the three circuit only a single realization functions of boost or buck., Can not meet Wind turbine power generation system with the characteristics of a wide range of Output voltage fluctuation.

For the above, this selection of hill-climb search method without knowledge of Wind turbine characteristic curves; Small Mechanical inertia Permanent Magnet Generator and A SEPIC converter with the continuous input and output current. Characteristics of Generator output voltage and its speed is almost a linear relationship (Sato *et al*., 1994). For Small Wind Power System (SWES) maximum power point tracking and related control strategy simulation and experiment.

PRINCIPLE OF MAXIMUM POWER POINT TRACKING

The performance of MPPT in reducing energy loss and improve efficiency is more important in Low-power stand-alone system, Maximum power point comes down to the perturbation observation method and the incremental conductance method. The system uses the slope of power and voltage to adjust the direction of movement of the operating voltage to the maximum power point tracking. While $dP/dV>0$ Voltage V will be increased, in contradiction $dP/dV<$ Voltage V will reduce. The MPPT controller was simulated by MATLAB Engineer software. In order to avoid the slope of the voltage and current harmonics will generate an error calculation, using the moving average of 4 order filtering methods.

From the SWES characteristics we can see that for this maximum power point tracking, last commonly used method is to measure or estimate the wind speed. Then by Wind speed data to make sure $\lambda = \lambda_{opt}$.

Corresponding Author: Suxiang Qian, School of Electromechanical Engineering, Jiaxing University, Jiaxing 314001, China, Tel.: 13867366355

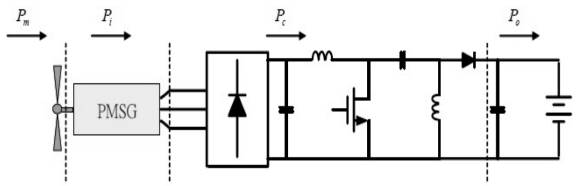

Fig. 1: Permanent magnet synchronous generators and driver circuit

This method requires information on wind and generator velocity, also the cost is more expensive.

Small power wind power generation system, the use of Permanent Magnet Synchronous Generator (PMSG), the drive circuit (SEPIC) is shown in Fig. 1.

That is rectified by the three-phase and the DC capacitor filter, then through the DC-DC converter control the generator output power.

Detecting direct current side power of Rectifier Bridge and by controlling the voltage in order to achieve the purpose of MPPT control, the principle is that the rectified DC voltage always proportional to the generator output voltage. With the notion Almost linear relationship between Generator terminal voltage and velocity voltage Control the DC voltage that can control the velocity.

By adjust of the DC voltage power changes for loop until it reaches the maximum power point. This method is called climbing search, it can omit any parameters about the generator and do not need to know the characteristics of information in advance.

SWES developed in this thesis is a small system, the inertia of the windmill is very small and so we can make use the method of climbing search, which has several advantages:

- MPPT control without generator speed sensor
- Characteristics with the adaptive control

MPPT can be adjusted taking into account the speed and accuracy.

Charging diagram of the proposed wind power as shown in Fig. 2.

AS control mode Double-loop control are adopted, Inner loop for the current mode control, Outer loop consists of two control circuit, One is SWES voltage control loop which voltage commands generated from (Maximum Power Point Tracking, MPPT) controller; another is Battery charge control loop.

When the SWES Power issued is insufficient of the load power supply, Current command generated by SWES voltage control loop.

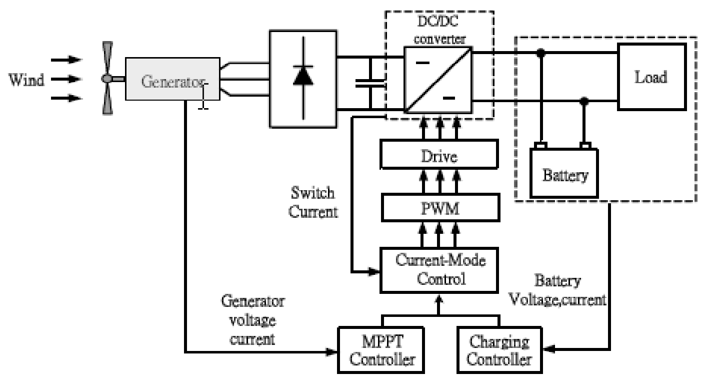

Fig. 2: Charging diagram of SWES

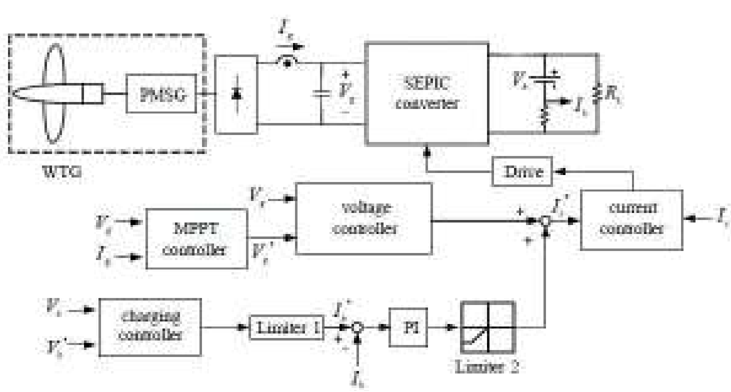

Fig. 3: Wind power control framework

Electric power generated by SWES determined by the MPPT controller. In this case SWES unit will reduce the charge rate or Battery power release to the load. Instead SWES enough to provide load power, the current command is from the charge control circuit. In this case SWES unit will be forced to give up the MPPT and charging for electricity demand and load balancing as Fig. 3.

The use of Maximum Power Point Tracking (MPPT) controller can generate the maximum power of the rectified generator output voltage command. Then the voltage controller to adjust the rectifier voltage is set by the voltage command, Sum of this current and the current from Charge control circuit, a sub tractor and limiting current together to determine the final converter current command ultimately converter switching signal obtained by current controller and PWM.

The controller can be achieved by the arrangement of wind power generation systems distribution status:

- When the electricity issued SWES less than required load power.
- When the electricity issued SWES more than required load power, but the extra power is still not enough to charge the battery in Maximum charge current. Two conditions above PI controller charge control circuit for the forward saturation. After the limit of zero through positive limiter (Limiter 2), Charge control circuit on the current command without any contribution to Battery Therefore, the current command determined entirely by the MPPT, SWES are operating at maximum power point.
- SWES maximum power point balance between load and charging, SWES need to deviate from the maximum power point in order to reduce electricity generation. Charging control loop PI controller will enter the negative the work area thus impact to the current command produced from MPPT. So that the final current command are determined Charge control loop.

When the battery voltage is below the set voltage, (Limiter1) to set the maximum charge current; when the battery voltage is close to the set voltage, the controller began to enter the linear region to reduce the charge current command. Eventually, the battery voltage will be maintained at the set and Charge current only to provide the loss of the battery itself. This charging method can be achieved given current charging, constant voltage charging and float charging the purpose of the three stages to extend battery life.

MODELING AND SIMULATION OF CHARGING SYSTEM

Combination of options of the circuit, topology determination, MPPT and charging control program

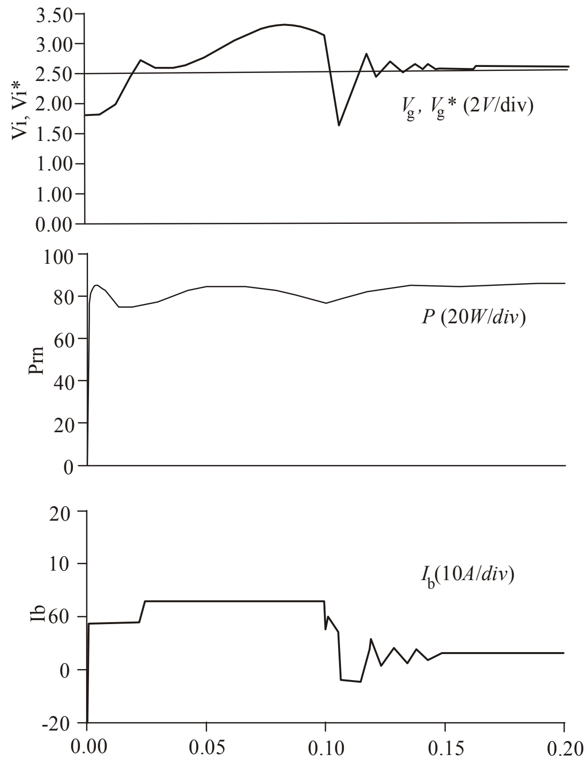

Fig. 4: Voltage power current output

selection System controller design based on the above specifications, MATLAB simulation software to be validated. MATLAB simulation with the SEPIC circuit set the parameters and specifications are as follows:

Wind turbine parts: R = 1.1m, ρ = 1.1 kg/m^3, θ = 3^0, In the 12 m/s can produce P_m up to approximately 1KW, Generator parts : 12 poles, K_ω = 30V/1100 rpm, L_s = 8.5 mH, R_s = 0.4Ω. Transmission and converter section: Generator output to the transmission between the converter R_l = 0.3Ω, Three-phase rectifier diode drop V_{df} = 0.7V, Converter efficiency η_c = 0.85, Converter input voltage is adjustable: $V_d = V_s/\sqrt{3}$.

After control of transfer of power to Wind turbine mechanical system equivalent circuit, Wind turbine output torque obtained. This torque driven generator and becomes SEPIC's input voltage through rectifier bridge. When the wind speed so high that the SEPIC's input voltage is too high, short-circuit the input voltage, which is equivalent to short-circuit the generator output, to protect the fan and generator.

Simulated test conditions of 12 m/s in the Wind turbine's maximum output power of 80W,Load resistance is 10 ohms. The output of the SWES exceed the demand of load and charging (charging power in 40W); t = 0.1 the load will change to 100W, SWES will be out of MPPT.

The simulation results shown in Fig. 4, at beginning SEPIC input voltage V is raised to 35V, so

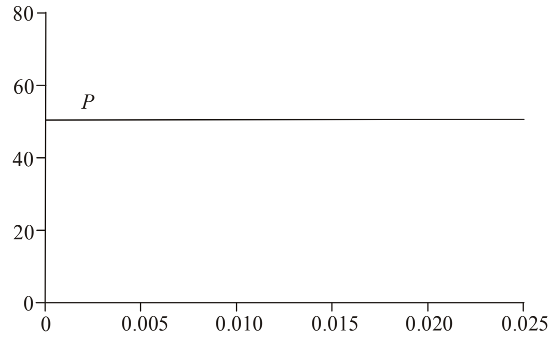

Fig. 5: Output power

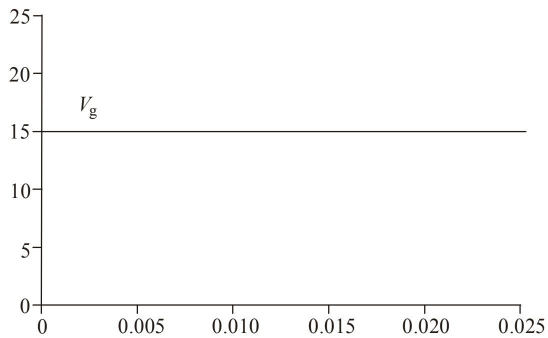

Fig. 6: Output voltage

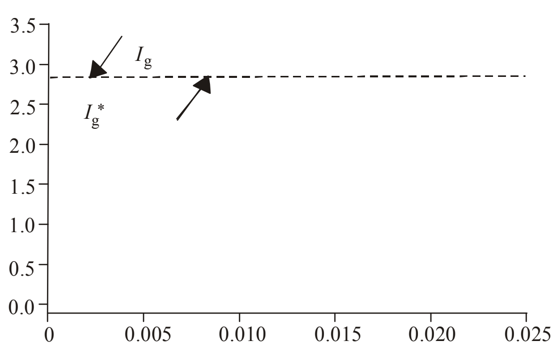

Fig. 7: Output current overlap

that P_m = 60 W, at this point the charge current is set in the constant current charging mode; t = 0.1 ms, after a period of adjustment after MPPT and voltage control in V_g = 25 V to P_m = 80 W, reached to the maximum power point indeed. Battery discharge current is less than the load demand. These have confirmed the system can really involved to achieve the functionality and performance.

SWES Connection Diagram in the MATLAB Real-time control and MPPT controller. SWES boot process to the stable process to verify that the appropriate MPPT tracking; Fig. 5 and 6 is obtained corresponding to the above MATLAB simulation of the corresponding waveform, this data confirms the effectiveness of the proposed control circuit mentioned above, Fig. 7 SWES

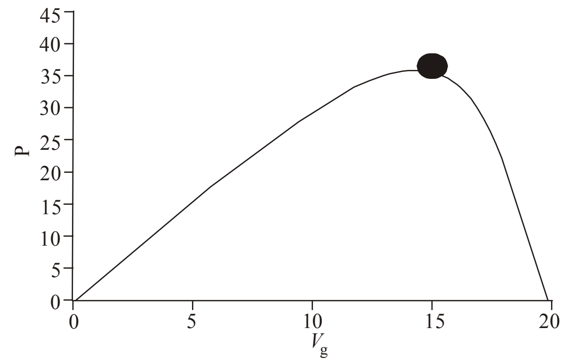

Fig. 8: Maximum power point tracking

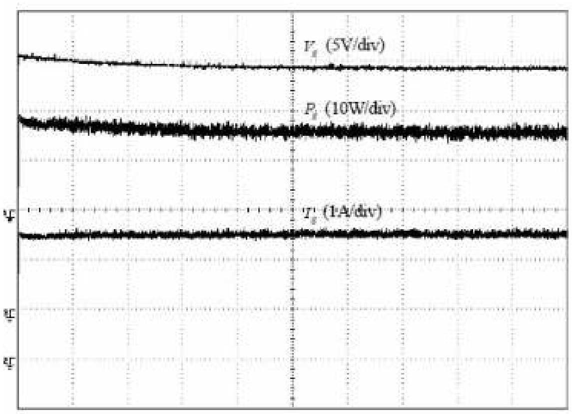

Fig. 9: SWES system starts the process of waveform

corresponding simulator, the simulation of the Wind turbine for maximum power point current state, the input current coincides with the output current.

EXPERIMENT AND DATA

The actual production system, including the DSP28027 master chip, SEPIC converter, half bridge inverter circuit, load, transformers, reactance, oscilloscope, as detailed below.

Half-bridge converter analog Wind turbine driven permanent magnet synchronous generator and the DC output voltage obtained through the rectifier. Adding the actual windmill system and simulation parameters based on experimental platform to build, experiment, the results an be obtained as follows: Fig. 8 to achieve MPPT observation point, easy to draw, voltage 15 V, maximum power output stable at 35 W, run to maximum power point tracking.

Figure 9 is SWES waveform measured during startup process, voltage, power, current, stable output, respectively which verify that the corresponding tracking MPPT. Figure 10 and 11 for the corresponding measured power above the corresponding analog waveform, these data are consistent with the simulation, verify the effectiveness of the proposed control circuit.

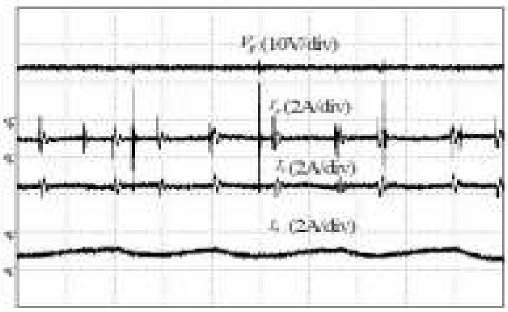

Fig. 10: SWES issued by the demand for electricity is less than the load and the battery discharge operation MPPT

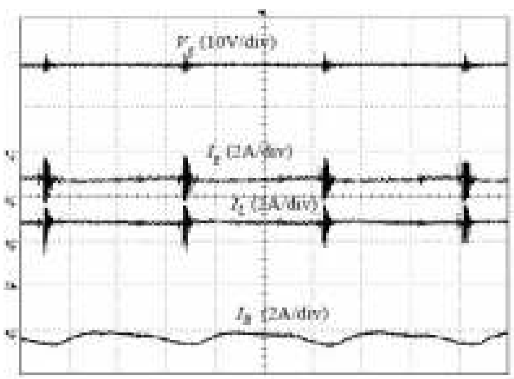

Fig. 11: SWES issued by the demand for electricity is greater than the load from the battery discharge and SWES separate MPPT

Based on Wind turbine performance analysis, select and put to use Simple control, running reliability, Variable speed PMSG wind generation system. Propose Independent power electronic energy converter control scheme of charging process and indirect speed control of the maximum power point tracking method.

Experiments results show that the mode can work stability; can be more accurate simulation of the experimental wind turbine at different wind speeds required range, the operation of state under different speed. And to achieve the maximum wind capture, verify the MPPT algorithm, further research of wind power loop control based MPPT charge independent operational control of the original motivation, research and development to improve the efficiency of wind power generation system.

CONCLUSION

At present, the theory has developed in a domestic company successful application of small wind turbines and through international certification such as CE and ROHS. Widely used in the domestic oil fields, islands, grasslands.

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