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РАЗРАБОТКА НА КОНТРОЛЕР ЗА МАЛКИ ВЕТРОГЕНЕРАТОРИ С МОБИЛНА НАСТРОЙКА

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DEVELOPMENT OF A CONTROLLER FOR SMALL WIND TURBINES WITH A MOBILE SETUP

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Abstract

Controllers for wind generators can be PWM or MPPT. MPPT controllers provide maximum battery charging current while protecting the turbine from damage. Due to the differences of wind turbines, in order for the controller to cope with this task, it is necessary to know the electrical and mechanical characteristics of the wind turbine.

This paper proposes a method to automatically capture turbine characteristics at different wind speeds and different loads. The data is sent to a mobile device where the calculations are performed, then the characteristics are sent back to the controller. This is necessary due to the calculation of a large number of linear equations that the controller cannot handle.

Keywords: DC-DC, wind turbine, Wi-Fi

INTRODUCTION

The use of small wind generators up to 1000W is becoming an increasingly preferred way to add power to photovoltaic and hybrid systems for places without central power. Wind turbine controllers are used to regulate the charging current to the batteries and to regulate the rotation speed of the wind turbine. [7,8,9] Although both solar and wind charge controllers protect the battery from overcharging, they are very different. A wind turbine charge controller must release its excess load, while a solar charge controller does not.

Wind turbines use the kinetic energy of the wind and convert it into electricity. The process of creating electricity with wind turbines is mechanical compared to what happens in solar panels. Due to this mechanical process, it cannot be allowed to rotate freely without any load. When a wind turbine is not powering a device or charging a battery, the process by which it creates electricity does not stop. The power it accumulates has nowhere to go but back into the turbine itself. The system heats up and the engine can then burn out, potentially destroying the entire turbine. [10,11,12,13] To prevent this, the wind turbine must continue to operate under load. When not charging a battery, the wind turbine needs another load where the electricity it creates can be sent. The main function of a charge controller, whether it is a solar or wind charge controller, is to protect the battery from overcharging or undercharging by cutting off the current from the battery when it is full and turn back. It should also prevent battery charge from flowing back into the system after it is fully charged. A wind turbine charge controller must protect the battery, but it must also protect the turbine. The way this is done is that the controller measures the voltage of the battery and once the battery is full, the electricity is diverted instead of just being turned off like in a solar panel. This protects the battery and maintains the load on the turbine, preventing it from spinning out of control.

EXHIBITION

Fig. 1. *System block diagram*

Fig. 1 shows a block diagram of the system connection. The controller measures the turbine rotation speed, charging current and battery voltage. After starting the wind turbine characterization procedure, the controller connects to a router via Wi-Fi. The controller starts sending information about the measured values to the mobile device. All data remains saved in the memory of the mobile device. After transferring enough information, the mobile device calculates the mechanical and electrical parameters of the turbine and returns their values back to the controller.

The turbine charge controller is a step-up DC-DC converter that is controlled by PWM and duty cycle regulation. Depending on the rotation speed of the wind turbine, the battery voltage and the duty cycle of the PWM, the charging current to the battery is measured.

$\mathrm{V}_{\mathrm{wind}}[rpm]$ - The rotation speed of the wind turbine

$\mathrm{I}_{\mathrm{wind}}[A]$ – Current generated by the wind turbine

$V_{\mathrm{wind}}[V]$ - Voltage generated by the wind turbine

$I_{\mathrm{bat}}[A]$ – Battery charge current

$V_{\mathrm{bat}}[V]$ – Battery voltage

D - PWM duty factor

Determining the transmission characteristic of a wind turbine boils down to solving a system of linear equations with two unknowns. The general form of the required function has the form:

$$\mathrm{D} = a_0.P_{wind}^{n} + a_1 P_{wind}^{n-1} + \ldots + a_{n-1} P_{wind} + a_n + \ldots$$

$$\ldots + \mathrm{b}_0 V_{wind}^{n} + b_1 V_{wind}^{n-1} + \ldots + b_{n-1} V_{wind} + b_n \text{ ,(1)}$$

To determine the unknown coefficients $a_0 \ldots a_n, b_0 \ldots b_n$ solving a system of linear equations is required.

The number of equations depends on the degree of the polynomial n. Since the function is a polynomial with two unknowns, the number of all equations will be equal to $2.(n+1)$. Determining the coefficients of the polynomial determines what the fill factor should be at different wind speeds and wind turbine power.

The developed controller in Fig.2 is built on the basis of an ESP32 microcontroller with a built-in Wi-Fi function.

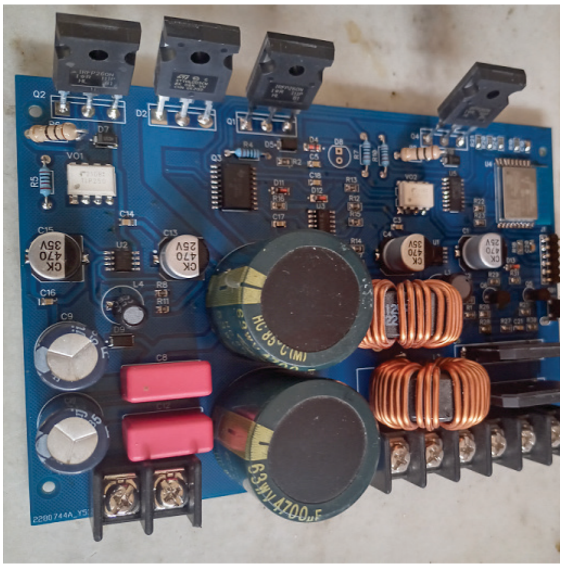

Fig.2 *Wind generator battery charge controller*

The purpose of any wind generator controller is to maintain optimum rotational speed at various wind speeds so that maximum power is generated from the turbine. Since small wind generators cannot change the angle of inclination of the propeller, the speed regulation is done by including a load to the turbine. The developed controller achieves this through a calculated turbine transfer characteristic function. The transfer of information is done via the MODBUS TCP/IP protocol. All data from the microcontroller is recorded in sixteen bit registers which are supported by the specified protocol. Data transfer takes place in a time interval of 50ms.

From (1), the degree of the polynomial is chosen to be equal to 2. Transmission characteristic takes the form:

$$\mathrm{D} = a_0.P_{wind}^2 + a_1 P_{wind} + a_2 + b_0.V_{wind}^2 + b_1 V_{wind} + b_2$$

, (2)

After accepting a sufficient number of measurements, the system of linear equations is solved.

$$\left| \begin{array}{l} a_0.P_1^2 + a_1 P_1 + a_2 + b_0 V_1^2 + b_1 V_1 + b_2 = D_1 \\ a_0.P_2^2 + a_1 P_2 + a_2 + b_0 V_2^2 + b_1 V_2 + b_2 = D_2 \\ a_0.P_3^2 + a_1 P_3 + a_2 + b_0 V_3^2 + b_1 V_3 + b_2 = D_3 \\ a_0.P_4^2 + a_1 P_4 + a_2 + b_0 V_4^2 + b_1 V_4 + b_2 = D_4 \\ a_0.P_5^2 + a_1 P_5 + a_2 + b_0 V_5^2 + b_1 V_5 + b_2 = D_5 \\ a_0.P_6^2 + a_1 P_6 + a_2 + b_0 V_6^2 + b_1 V_6 + b_2 = D_6 \end{array} \right. ,$$

(3)

The unknown parameters are found by Cramer's method:

$$a_0 = \frac{1}{\Delta} \begin{vmatrix} D_1 + P_1 + 1 + V_1^2 + V_1 + 1 \\ D_2 + P_2 + 1 + V_2^2 + V_2 + 1 \\ D_3 + P_3 + 1 + V_3^2 + V_3 + 1 \\ D_4 + P_4 + 1 + V_4^2 + V_4 + 1 \\ D_5 + P_5 + 1 + V_5^2 + V_5 + 1 \\ D_6 + P_6 + 1 + V_6^2 + V_6 + 1 \end{vmatrix} ,(4)$$

, where

$$\Delta = \begin{vmatrix} P_1^2 + P_1 + 1 + V_1^2 + V_1 + 1 \\ P_2^2 + P_2 + 1 + V_2^2 + V_2 + 1 \\ P_3^2 + P_3 + 1 + V_3^2 + V_3 + 1 \\ P_4^2 + P_4 + 1 + V_4^2 + V_4 + 1 \\ P_5^2 + P_5 + 1 + V_5^2 + V_5 + 1 \\ P_6^2 + P_6 + 1 + V_6^2 + V_6 + 1 \end{vmatrix} ,(5)$$

The solution is repeated for all unknown parameters. Since the free terms in the determinant set its value to zero, the solution is reduced to four equations.

Real measurements were taken from a small wind turbine and the following values were reported at different PWM duty factor.

$$\begin{array}{l} \mathrm{D}_1 = 10\%, P_1 = 25, V_1 = 1.4 \\ \mathrm{D}_2 = 20\%, P_2 = 40, V_2 = 2.8 \\ \mathrm{D}_3 = 30\%, P_3 = 62, V_3 = 3.0 \\ \mathrm{D}_4 = 40\%, P_4 = 68, V_4 = 3.2 ,(6) \end{array}$$

The system takes the form:

$$\begin{cases} 10 = a_0 625 + a_1 25 + b_0 1.96 + b_1 1.4 \\ 20 = a_0 1600 + a_1 40 + b_0 7.84 + b_1 2.8 \\ 30 = a_0 3844 + a_1 62 + b_0 9 + b_1 3 \\ 40 = a_0 4624 + a_1 68 + b_0 10.24 + b_1 3.2 \end{cases} , \quad (7)$$

After software calculation, the values of the unknown coefficients are obtained.

$$a_0 = 0.0568652133$$
$$a_1 = -5.296105639$$
$$b_0 = -18.5877247547$$
$$b_1 = 102.3527308527$$
,(8)

The function takes the form:

$$D = 0.0568652133.P_{wind}^2 - $$
$$- 5.296105639 P_{wind} - $$
$$- 18.5877247547 V_{wind}^2 + $$
$$+ 102.3527308527 V_{wind} + $$
,(9)

The calculation program is written in the C programming language and recursive functions are used to calculate the determinants. Due to the many interruptions and the large amount of memory required to use such functions, it is necessary to transfer the data and the calculation from another device with sufficient memory and speed.

Fig. 3. *View of developed software for calculating systems of linear equations*

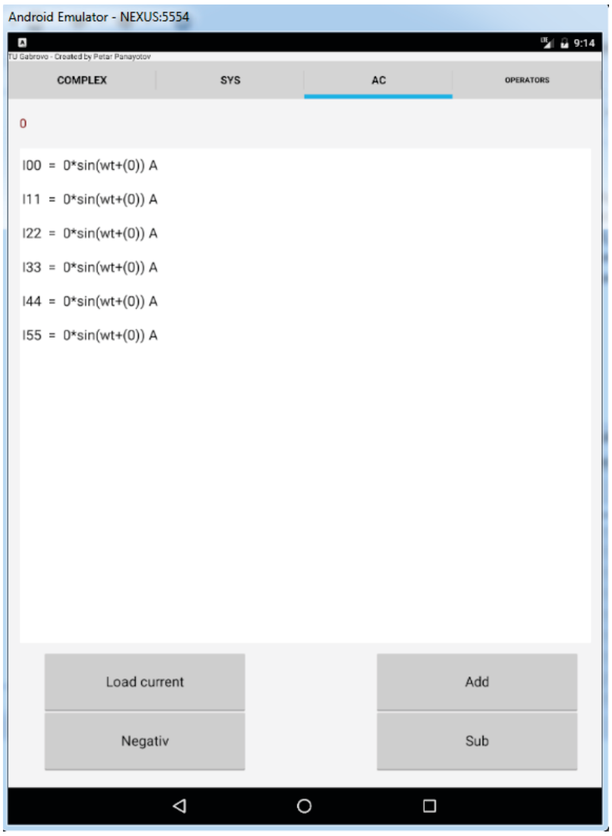

Fig. 3. *View of developed wind generator controller data acquisition software*

Fig. 3 and Fig.4 show the software developed for a mobile device for data collection and calculations from the wind turbine controller. The application software is developed in the Delphi programming language. After pressing the "Load current" button, a procedure for transferring data from the controller to the mobile device is started. Repetitive measurement data may be input to the mobile device as wind speeds and loading may be repeated. The software considers which measurement has already been taken and if there are repeated values it ignores them.

The program for solving systems of linear equations is different from the existing ones because the coefficients can be complex numbers. This allows the calculation of transients when inductances and capacitances are involved. The software should be further developed for measuring stations, through which transient processes in given schemes will be determined. This will largely allow controllers to control DC-DC converters in start and stop modes much more precisely. Since the output voltages and currents from the wind generators are sinusoidal in nature, a trigonometric approximation should also be developed. With a sinusoidal input voltage to a DC-DC converter, the pulse-width modulation must follow the law of voltage variation. This removes expensive high capacity capacitors from the circuit but complicates the control of the converter.

CONCLUSION

In many cases, microcontrollers cannot handle complex calculations that require speed and a large amount of memory. On the other hand, mobile devices are getting faster and more powerful. Their computational resources far exceed those of microcontrollers and can be used to perform complex calculations that control circuits in DC-DC converters could not handle.

In addition to computing, mobile devices can be used to store large databases, and through appropriate "artificial intelligence" software, they can transmit commands to actuators such as microcontrollers, DC-DC converters, and other hardware circuits.

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