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Increasing Efficiency of Power Supply System for Small Manufactures in Rural Regions using Renewable Energy Resources

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Introduction

The problem of increasing of efficiency of power supply systems for small industrials in rural areas is described. The power supply in rural areas could be more efficient and cheaper, using alternative power production. The wind energy using is efficient for Latvia condition as alternative energy production. The wind energy using is carousal in achieving European Commission goal to have 20% renewable recourses by 2020. Wind and other renewable using in small industrial production also are vitally important in production cost saving, especially in long therm. Also using of wind and other renewable energy recourses could decrease energy import amount from other countries in Europe. In this time the alternative energy resources using is developed in industrial countries such as Germany, Austria, but in new European countries as Latvia there are a large potential to use renewable energy, especially in such places as rural industrials. The main produces of electrical energy in Latvia are cascade of three hydro electro stations, but more than 30% Latvia have to import from Russia and other neighbour countries. The power supply system building an electrical energy tariffs are important part of industrials expenses in case of new production building or increasing capacities. The alternative energy using allows reducing and efficiency control of enterprises expenses.

Problem statement

The efficient alternative energy recourses in Latvia condition are wind energy (Fig. 1), geotermal energy, solar energy, marine renewable energies and biogas. From mentioned energy resources the main is wind energy for Latvia condition, because of it application simplicity.

The requirements to the design of the modern wind turbines state that a turbine's service life should be about 120 000 hours. It many times exceeds the service life of an automobile that varies usually from 4000 to 6000 hours. Like any machine wind turbine also requires more maintaining expenses with its aging. The blades and gear suffer from the hardest deterioration. The expenses for these parts changing achieve 15 – 20% from the turbine total price.

In future wind power engineering can apply three different achievements in engineering. One of them is connected with power stations of gas co–generation application; the second – with the possibilities of power accumulation; and the third – with application of regulators.

Until now the accumulation systems for wind turbines were applied in bounded situations only, for example, in islands, where the balance between electric power production and demands is necessary. For the larger time interval these systems will be expensive enough. Therefore this approach is unreasonable from the economic point of view in order to apply it for balancing of the turbines productive ability.

The modern development foresees not a long–term accumulation of energy, but a short–term buffer of stochastic components of merely generated power.

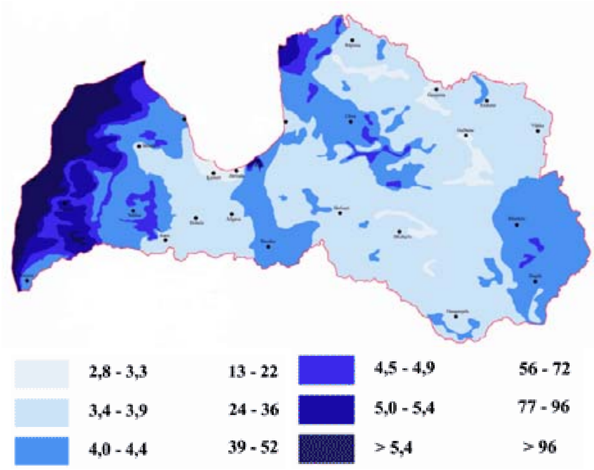

Fig. 1. Average wind speed per year ($V_{vid,}$ m/sek; P, W/m^2) in Latvian territory 10 m height

Latvian agency of environment, geology and metrology realizes the systematic measurements of wind speed only ashore, thus wind speed at the seashore and 10 m height is applied in the calculations (Fig.1). [5].

The applied accumulators and regulators in the generation system can be schematically displayed (Fig.2).

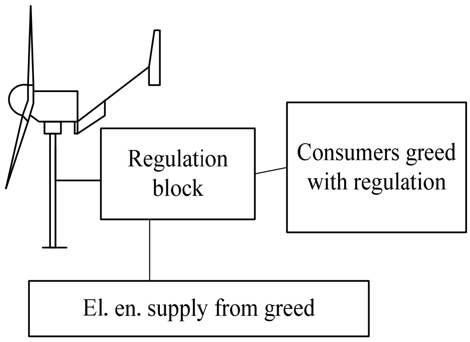

Fig. 2. Schematic electrical energy consumption greed for small industrials

Alternative energy and regulation scheme application allows achieving up to 20% reduction of energy consumption [1].

Instead of wind energy the other alternative energy recourses could be applied, or it could be combination of energy resources.

On the base of small typical electric supply scheme taking into account the possible modifications the day–night control systems of electric supply are also important for operative reaction to the changes of load, wind speed and other parameters.

The Institute of Mining and Metallurgical Machine Engineering (IBH) at Aachen University, Germany in close collaboration with the Institute of Machine Elements and Machine Construction (IMM) of the University of Dresden and in conjunction with several partners of German industry develops an integrated simulation and multi–sensor condition monitoring system for wind turbines within the project "SIMU–Wind" [3].

Mathematical problem formulating

Mathematically describing the effectiveness of alternative electric energy sources application the following designations will be used in this work:

- E – the set of power producers $Ei \in E$;
- R^S – productive system $R^S i \in R^S$;
- $R^S i$ – elements of the productive system;
- X^S – maximum productive power of each system;
- $X^S_k(t)$ – productive power of each system at each given moment;
- $E^S_k(t)$ – consumption of electric energy for each subsystem at each given moment;
- C – expenses of electric energy consumption for each system;
- $C^S(t)$ – expenses of the system electric energy consumption at given moment.

Let's find that $C^S(t) = X^S_k(t) \times E^S_k(t) \rightarrow \min$.

Mathematical description of system model

The hide energy of wind is dependent in geometrical progression on its speed: duplication of the wind speed produces eight times increasing of energy [2].

For the calculation of wind speed with more than 10 m height the following expression is applied:

$$V = V_m \left(\frac{h}{h_m} \right)^{1/\alpha}, \quad (1)$$

where h – the expected height of the wind turbine shaft, (m); V_m– the height of wind speed measurement, (m/s).

At the height more than 10 m factor α equal to 5,0 is applied.

With a constant speed of flow wind energy is defined according to:

$$W=\pi \cdot \rho \cdot D^2 \cdot V^3/8=0{,}5 \cdot \rho \cdot (D^2 \cdot 0{,}7854) \cdot V^3, \quad (2)$$

where: W – power in watts; ρ – air density (typically 1,22 at sea level – kg/m^3, 15°C and 760 – millimeter of mercury; D – Diameter of prop (in meter); V – Velocity of the wind (in meters/sec).

Under real conditions the wind speed is constantly varying, thus for the calculation of wind energy value the following is applied with the use of above mentioned (2):

$$V = \sqrt[3]{\frac{\left(T_1 V_1^3 + T_2 V_2^3 + \ldots + T_n V_n^3\right)}{T}}, \quad (3)$$

where T – full time of measurement, (100%); V – discrete value of the wind speed; T_n – percentage time for the given wind speed V_n.

So we could say in a 8,9 m/s wind and a 1,8 m prop there is (2): $W=0{,}5 \cdot 1{,}22 \cdot (1{,}8^2 \cdot 0{,}7854) \cdot 8{,}9^3=1094$ W passing through the prop.

Unfortunately we cant capture all of it and most blades range in the 20% to 40% range so we need to add this into $W=0{,}5 \cdot 1{,}22 \cdot (1{,}8^2 \cdot 0{,}7854) \cdot 8{,}9^3 \cdot 0{,}4=437$ W coming out of our blade at the shaft.

The generator or alternator we are using isn't 100% efficient so we need to add this into the formula. We can say that our blades are 40% efficient and our generator is 60% efficient so. Our overall efficiency would be (0,4•0,6=0,24) 24%. So now we add that into the total and $W=0{,}5 \cdot 1{,}22 \cdot (1{,}8^2 \cdot 0{,}7854) \cdot 8{,}9^3 \cdot 0{,}24=262$ W.

This is the majority of the losses but there are others that we won't worry to much about at this point. The formulas above will give a close general idea of what your machine might produce.

If knowing what your alternator/generator will do in watts, this one will help determine the size prop will need to run it:

$$D=(W/(Cp \cdot rho/2 \cdot \pi/4 \cdot V^3))^{0,5}, \quad (4)$$

where D – diameter of prop in meters; W – power in watts; Cp – overall efficiency (typically 0,15 to 0,20); rho – air density (1,22 at sea level); V – velocity of the wind in meters/second.

To find the TSR (tip speed ratio) of a prop at a given output...

$$TSR= n\cdot\pi\cdot D/60/V. \quad (5)$$

Example: generator that can produce 500 watts at 1000 rpm. TSR=1000•3,14•2/60/10=10,46. Since 10,5 would be fairly tricky to obtain we can try others. To calculate the speed (n) at a given TSR:

$$n=60\cdot V\cdot TSR/(\pi\cdot D). \quad (6)$$

Example: with a TSR=6; n=60•10•6/(π•2)=573 rpm.

Three–phase mean single phase with 2 extra coils slightly out of phase with first. Basically "Phase" relates to the timing of the magnets passing over the coils at different times. With single phase the magnets and coils all line up with each other and are said to be in "phase".

In a single phase unit the coils are wound opposite of the first. That is to say one is wound clockwise and the next is counter clockwise. If your unit has 8 magnets then it would also have 8 coils. With 3 phases you would have 3 coils for each pair of magnets. For instance 8 magnets can be used and only 6 coils are without overlapping or 3 set of 4 coils in series.

Production energy supply

Typical production line in small manufacture has motor power less than 10 kWh. The production line (Fig. 3) typically consists of such main elements: distribution station; robot; production line; working machine.

The simplified conFiguration of the device is in Fig. 3. Similar conFiguration is timber production – saw–mill; fruit and vegetable packaging production and other small production in Latvia.

Energy efficiency control in other production process requires addition calculations and modeling. This developed methodology and requirements could be efficient for other production lines optimization.

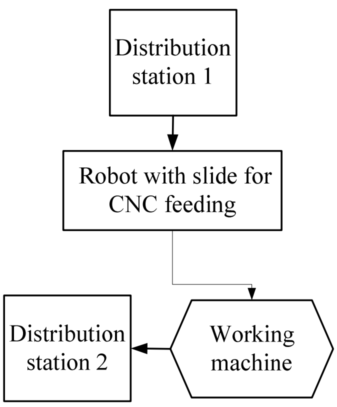

Fig. 3. Simple production lines

For such production lines the various regulators could be applied. For example Eram spol. s.r.o. regulators that operate according to voltage and current control principles. The regulators are based on the doughnut–type transformer operating with feedback and compensated effect in each phase. The functional scheme of the regulator control equipment is in Fig. 4. The control task of the regulator is to observe the operation and realize the regulation according to particular parameters, as well as maintain the output regulator input voltages at the necessary level avoiding overloads. In the case of overloading a by–pass circuit is operating. The equipment connected to each regulator operates in the circuit as a resistance load consuming thus lower electric energy. It is applied as a stabilizing circuit for rotating and non–rotating equipment [4].

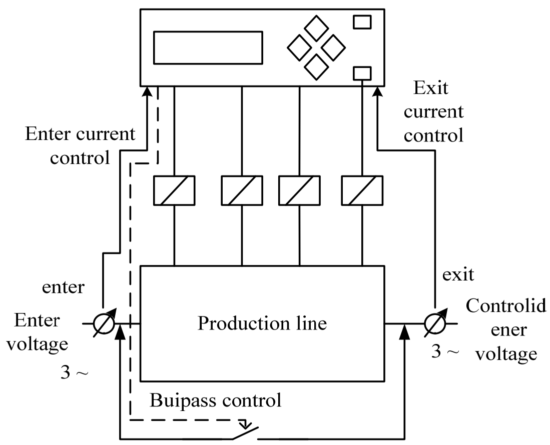

Fig. 4. Control functional scheme of the regulator operation

Self–regulation gives a 20% economy for rotating equipment if that is in satisfactory technical condition. The equipment operates in three–phases or in one–phase with self–regulation. Voltage is in the range from 165 V to 245 V at the output and with controlled current limitation till the maximum value typical for the regulator of the given type.

Conclusions

The usage of renewable energy recourses for energy production is actual problem. The development efficient power supply system for each industrial application requires specific analysis. The evaluation of energy consumption, energy storage, generating power and other parameters is strongly connected with expenses and efficiency of system. In future wind power engineering can apply three different achievements in engineering. One of them is connected with power stations of gas co–generation application; the second – with the possibilities of power accumulation; and the third – with application of regulators. The application of this innovation allows the improvement of effectiveness of electric supply systems. But applying the alternative sources of energy it is important to know its possibilities for each producer. On the base of small typical electric supply scheme taking into account the possible modifications the day–night control systems of electric supply are also important for operative reaction to the changes of load, wind speed and other parameters. The paper considers the questions of equipment application in Latvian rural areas where the wind generators can be effectively applied as well as control systems for the rotating and non–rotating operating machines stabilizing the operation with the help of regulator. The regulators can be applied as a substation for switching equipment/transformers, charging equipment and motors with the voltage up to 400 V that suits to small producers' necessities.

4.

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The problem of providing small enterprises with electric energy in rural areas is considered in the article. This process is attended with growing expenses of electric energy supply and systems maintenance. As an example the wind–mill installations the use of which is especially appropriate when the wind speed is more than 5 m/sek at the height of 10 m are taken. A regulator is considered with transformer connection for the stabilization of motor operation that results in decreasing of electric energy consumption. Ill. 4, bibl. 5 (in English; abstracts in English, Russian and Lithuanian).

Н. Куницына, А. Галкина, А. Жиравецкая, Е. Чайко, Л. Рыбицкий. Повышение эффективности обеспечения электроэнергей малых предприятий в сельских регионах, используя возобновляемые энергоресурсы // Электроника и электротехника. – Каунас: Технология, 2009. – № 8(96). – С. 19–22.

В статье рассматривается проблема обеспечения электроэнергией малых предприятий, которые находятся в отдаленных районах и снабжение электроэнергией сопряжено с увеличением себестоимости производимой продукции. Как пример рассматривается использование ветряных энергоустановок, применение которых экономически выгодно при скорости ветра более 5 м/сек на высоте 10 м. В статье предлагается применять регулятор с трансформаторным подключением для решения проблем стабилизации работы электродвигателя, что приводит к снижению затрат электроэнергии. Ил. 4, библ. 5 (на английском языке; рефераты на английском, русском и литовском яз.).

N. Kunicina, A. Galkina, A. Zhiravecka, Y. Chaiko, L. Ribickis. Elektros energijos efektyvumo didinimas kaimo vietovėse esančioms smulkioms įmonėms taikant atsinaujinančius energijos šaltinius // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 8(96). – P. 19–22.

Analizuojama problema susijusi su elektros energijos tiekimu smulkioms įmonėms nutolusiuose rajonuose. Tokiu atveju elektros energijos perdavimo sąnaudos tiesiogiai susijusios su gamybos sąnaudų padidėjimu. Kaip pavyzdys pateikiamos vėjo jėgainės, kurių ekonominis efektas jaučiamas, kai vėjo greitis ne mažesnis kaip 5 m/s 10 m aukštyje. Siūloma pasinaudoti transformatoriniu reguliatoriumi stabilizuojant elektros variklio darbą, kas leidžia sumažinti elektros energijos sąnaudas. Il. 4, bibl. 5 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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