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Increasing Efficiency of Electrical Supply Model for Small Enterprises in Rural Regions

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I. INTRODUCTION

The constant increasing of prices for electric energy and instability of power supply in rural regions raise a question of its efficiency increasing and possibilities of application of alternative power sources. One of such possibilities is the use of wind generators and appropriate converters.

There is a large experience of alternative power sources application in Latvia but no recommendations and tools to provide the consumers with a support in the question of choosing the most effective model of electric supply.

Modifying a typical scheme of consumption a small producer can obtain such system's configuration that will give a possibility of fast estimation of the further investments repayment period and safe of electric energy.

Nowadays the harmonization of electrical energy consumption is very important. The objective of energy research under FP7 is to aid the creation and establishment of the technologies necessary to adapt the current energy system into a more sustainable, competitive and secure one. It should also depend less on imported fuels and use a diverse mix of energy sources, in particular renewables, energy carriers and non polluting sources. The article presents a formalized system of a small industrial enterprise and proposes a visual model that provides possibilities of electric supply model evaluation facilitating effectiveness of the system with aim of increasing effectiveness of power supply.

II. PROBLEM STATEMENT

For the saving of energy the small enterprises have a possibility to use alternative sources and different converters and regulators of electric energy [1].

Application of wind electric stations (Fig.1.) in Latvia has particular advantages as it is used at the places where the speed of the wind is >5 m/s.

First two wind generators in Latvia were installed in 1995 in Ainazhi. From 1999 a wind generator operates also in Uzhava but in 2002 in Grobina a wind station park was built on the basis of 33 wind generators. Nowadays there are wind generators with a total power 26,9 MW in Latvia.

III. WIND ENERGY APPLICATION

In Latvia an average value of the speed of wind is about 6 m/s. Power of an electric station reaches 2-3 MW. The higher is the power the lower is the cost of the produced electrical energy. But the wind energy is not produced all the year, thus the question of different energy sources for one process supply and development of models for the effectiveness evaluation for each particular case of production is of top importance.

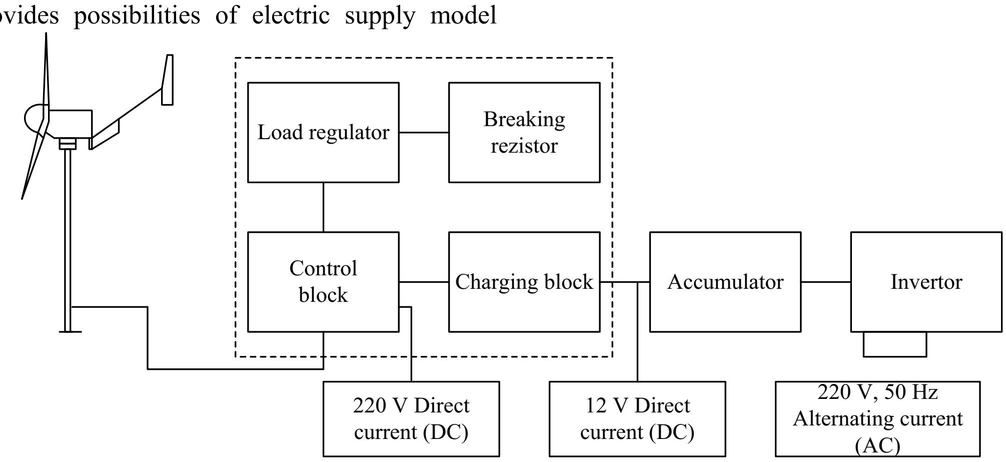


Fig. 1. Block scheme of wind generator

The correspondence of wind power to the quality requirements is described with different parameters. One of them is the amount of hours per year when the turbine operates with full (rated) load. This value depends on the regime of the wind, place of the turbine and height of the turbine rotor axis.

The second parameter characterizes the level of wind power station self-supply – what part of the power is necessary for the operator from that full generated at the station – is also considered for the increasing of effectiveness. The investigations of the German program „250 MW" proved that with own turbine an owner can cover 60% of the annual consumption of electricity, but only under the condition if the turbine generates at least 5 times more electric energy than it is necessary for the household needs [3].

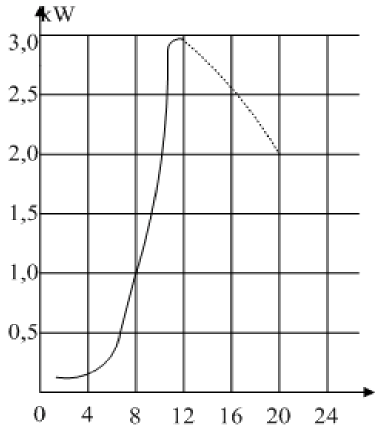
In Latvia wind power devices with low number of rotations can be used, these devices can operate according to the circumstances of Latvia (low and middle speed of wind). For the use of wind power devices with low power (0,1 - 10 kW), the following circumstances are necessary: the devices should be easy to maintain for the longer life service, it should have appropriate dimensions, mass and cost.

A classic such device consists of turbine, Generator, multiplicator, regulating system, mast orienting according to wind flow. The most expensive part of the system is multiplicator that is not a safe element in maintaining, with not long service and increases the maintaining expenses. Without this part the number of rotations of the generator, dimensions and mass increase. Thus the transfer to the system without the multiplicator should be realized with the minimum increasing of the generator's mass. It is possible applying excitation of constant magnet simultaneously with transferring to the construction of multi-pole generator. Instead of generator an electric machine of multi-pole inductor type could be used but the excitation can be obtained from the cheap barium ferrite magnet. The magnets should be placed within the flow of the armature reaction. The use of constant magnets decreases the synchronous resistance and increases the loading ability of the generator.

The easiest type of the wind power installation regulation is in the case when an accumulator is used in parallel with the load. Under the condition of lull the accumulator takes the entire load but with wind a part of wind installation power goes to the loading of the accumulator. In this case the regulation system is easy and there is a possibility for full utilization of the wind power. This system is efficient if the power of the installation does not exceed 1 - 2 kW, but with higher power there is a reason to apply rectifier-inverter with parallel switching in order to provide the uninterruptable electric supply of the load [1].

The variant without mutiplicator gives a possibility of heating of turbines. For the successful operation of this variant an auxiliary winding should be added into the rotor of generator and connected to the heated elements of blades without using of brushes and contact rings. Applying a low power multi-pole generator with the excitation of barium ferrite magnets the multiplicator can be excluded that gives the possibility to prolong the service life of the device and its safety, to simplify the maintenance process, decrease its initial cost and further expenses. Fig.1 and Fig.2 demonstrate block-scheme of the generator and diagram where the output power dependence on wind speed is expressed in a non-linear form with its maximum at the speed 12 m/s.

Power (kW)



Speed of wind (m/s)

Fig. 2. Wind generator diagram

Most of all in Latvia for wind generation the low-power installations are used (0,1÷0,5 kW). The application of wind installations is profitable for the supply of autonomous consumers especially in the case of small manufacture. They are applied for mechanization, heating and lighting of living and industrial building.

Nowadays in Latvia for the low power autonomous wind installations synchronous generators with the constant magnets are used. Their advantage is high safety, the disadvantage – no possibility to control output voltage without special device.

IV. MATEMATICAL PROBLEM FORMULATING

On the basis of small manufacturer typical electric supply scheme, taking into account possible modifications day-night control systems of electric supply are also important for the operative reaction to the changes of load, wind speed and other parameters. For example, 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]. In the project for wind generator (Fig. 3) develop a new and more accurate condition monitoring system.

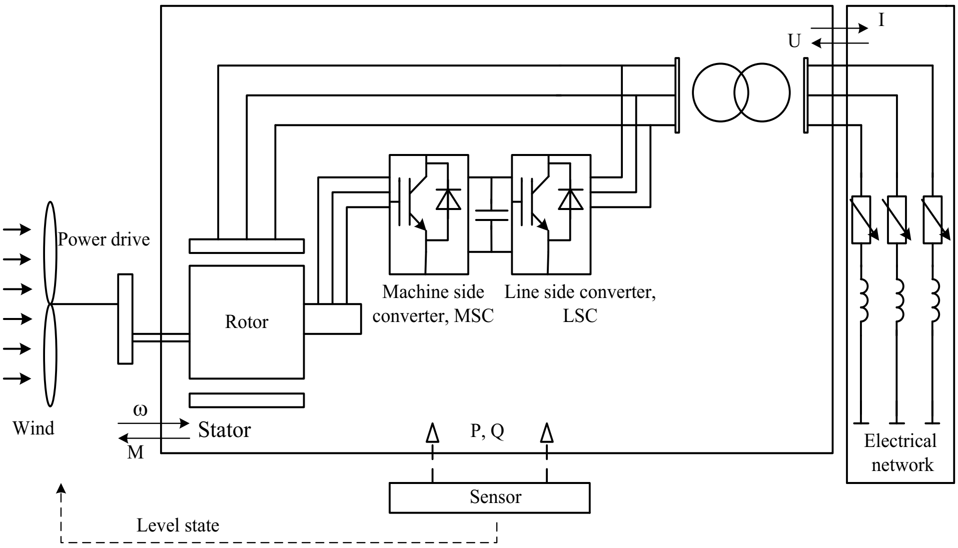


Fig. 3. "SIMU-Wind" VEI scheme

Mathematically describing the effectiveness of alternative electric power 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 $C^S(t) = X^S_k(t) \times E^S_k(t) \rightarrow \min$.

V. PRODUCTION LINE DESCRIPTION

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

The simplified configuration of the device is in fig. 4. Similar configuration is timber production - saw-mill; fruit and vegetable packaging production and other small production in Latvia.

For such production lines the various regulators could be applied, for example, "ERAM spol. s.r.o." regulators (Fig. 5), 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 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.

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.

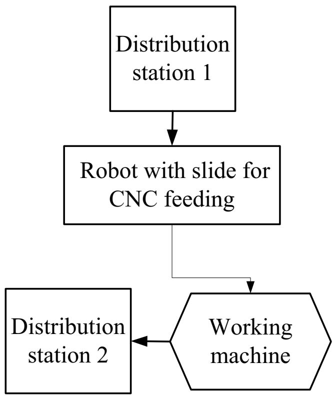


Fig. 4. Simple production lines

The principle of the regulator operation is given in Fig.5. Regulator powers up the asynchronous motor with the core squirrel cage rotor (nominal power 7,5 kW, nominal speed 2900 rpm, nominal current 15,1 A, nominal voltage 400V, 0,72 power factor). The asynchronous motor (M1) is decelerated by asynchronous motor (M2). The monitoring was realized in the one-phase mode for two working states - at the first case using the asynchronous drive power connection via stabilizer and regulator (recording the voltage/current rates measured on the input and output of stabilizer and regulator, the current value detection on the stator winding in the asynchronous motors M2) and at the second case using direct electrical drive power connection from the switchboard 3x400 V, 50 Hz.

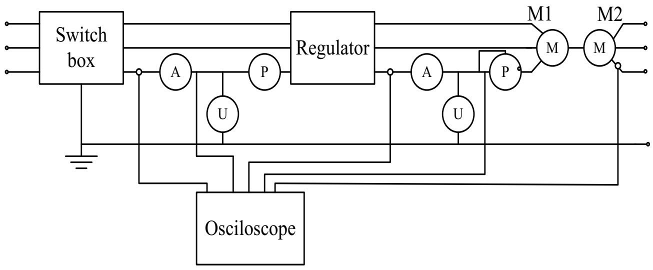


Fig. 5. Block connection of monitoring devices for the case of asynchronous motor connected via stabilizer

VI. WIND POWER USING CALCULATION AND EFFICIENCY EVALUATION

The hidden power of wind is in geometric progression depended on speed: the double increasing of the speed causes an eight times increasing of the power [2].

For the calculation of wind speed on the ground surface more than 5 m the following expression is used:

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

where:

h is a necessary height of wind turbine axis (m),

V_m is the wind speed on the height of measurements (m/s).

For the wind speed that is more than 5-10m a factor α=0,5 is applied.

The power of wind at the constant speed of flow is calculated as follows:

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

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 meters);

V = velocity of the wind (in meters/sec).

Under real conditions the wind speed is constantly varying, thus for the calculation of wind power value in (2) the wind speed cube value is used that is calculated according to:

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

where:

T – full time of measurement (100%);

V – discrete value of the wind speed;

T_n – percentage time for the given wind speed for V_n.

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

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

where:

D = diameter of prop in meters;

W= power in watts;

Cp = overall efficiency (typically 0,15 to 0,20);

ρ = 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:

$$TSR = n \cdot \pi \cdot D/60/V, \qquad (5)$$

Example: generator that can produce 500 watts at 1000 rpm:

$$TSR = 1000 \cdot 3{,}14 \cdot 2/60/10 = 10{,}46$$

Since 10,5 would be fairly tricky to obtain we can try others. To calculate the speed (n) at a given TSR:

$$n = 60 \cdot V \cdot TSR/(\pi \cdot D), \qquad (6)$$

Example: with a TSR=6:

$$n = 60 \cdot 10 \cdot 6/(\pi \cdot 2) = 573 \text{ rpm}$$

Alternative energy and regulation scheme using allows to achieve up to 20% reduction of energy consumption. Fig.6. shows schematic electrical energy consumption greed for small manufactures.

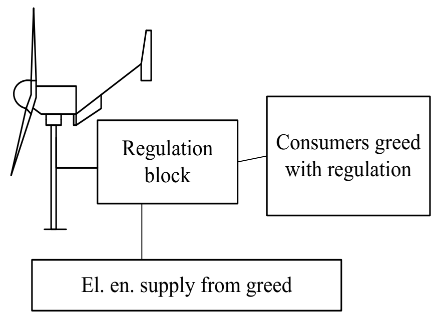


Fig. 6. Schematic electrical energy consumption greed for small industrials

VII. CONCLUSIONS

Energy efficiency increasing potential in rural areas is quite high. The alternative energy production and regulation schemes are not widely used in Latvia region. The is two main problems: consumers education and financial resources. It is important to build educational centre for efficient energy consumption for manufactures, especially in rural areas with possibilities of land use.

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