Study regarding the development of an efficient energy management programme for the processing industry

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Abstract - The first part of the paper discusses the necessity of developing an energy saving programme, and presents the main energy consumers of industry and the significant weight held by energy related costs in the turnover of production systems in processing industry.
Further the paper describes and analyses the steps to be followed in developing an efficient energy management programme. Some of these steps are: appointment by the administration board of a manager for energy related issues, an energy audit, including a complete inventory of the energy consuming equipment, the diagram of the process flow, a general view on the operation practice, answers to a list of specific questions, identification of opportunities and their economic assessment, prioritising and grouping them into the fields of: lighting, drives, cooling, ventilation, heating, approval of the energy management programme by the administration board, implementation of the approved programme, starting with the engineering design part required by each established measure.
The second part of the paper shows a way to produce energy using a wind turbine with vertical axis helical rotor shape with good energetic performances even at low wind speed. In a renewable energy system, the energy is generated according to the weather rather than on demand. In the absence of storage, a great deal of this energy will be dumped.
On of the problem with renewable energy is the high capital cost. The energy is diffuse and demands large structures to collect and convert it. The equipment is expensive and comes with a large amount of infrastructure. There is an energy cost associated with manufacturing renewable energy output. Other problem with renewable energy is its intermittency. Unlike fossil fuel, the source cannot be controlled to match demand. The energy is not available all the time, and may not even be easy to predict. To match supply to demand, it may be necessary to store energy, or to reschedule our use of energy, or to use a mixture of different energy sources.
Also, is presented a Monte-Carlo simulation of wind turbine parameters for cumulative frequency distribution for wind speed and for relative frequency histogram for annual energy output.

Keywords - energy management, energy consumption, wind turbine, renewable energy, Monte-Carlo simulation

I. INTRODUCTION

In the economy of a country of a certain level of industrial development, the most significant energy consumer is industry, particularly the metallurgical, chemical and raw material processing branches. In Romania, in processing industry, the main weight in energy consumption is held by the already traditional branches: machines manufacturing, electrical industry and wood industry.

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These consumptions are included in the manufacturing cost of a product and consequently in its degree of market competitiveness. If in the metallurgical and chemical industry energy saving can be achieved mainly by technological amendments involving significant investments, in the processing industry considerable reductions of the energy consumptions can be obtained also by process studies and optimisation of the processing methods and procedures. In principle, in the processing industry, in accordance with the technological process, parts follow a specific route, including working posts, where the processing corresponding to a certain operation is carried out.

For each type of surface to be processed on a part several, either conventional or unconventional procedures can be employed, the selection of the optimum one being determined by the surface shape, the processing precision, the material to be processed and the cost of processing. The processing cost also includes energy costs, directly determined by the efficiency of the processing system.

A major reduction of the specific energy consumptions of the processing industry needs to include studies and analyses of the subsystems composing by the processing system.

The analyses will be then expanded upon other energy consumers involved in the operations costs of the production systems.

A study completed in the U.S.A. has shown that in the industrial sector the main consumers are the electric motors, melting processes, primary and secondary heat treatments, electrochemical separation and lighting processes.

Thus electric motors employ 67% of the electrical energy utilised in industry. The second and third position are held by lighting with 12% and electricity based heat processes, respectively [2].

Another study conducted by a commercial company representative for the machines manufacturing branch of Romania has also highlighted the significant weight of costs generated by the use of electrical energy in the operation of the system that is 73% of the total of energy costs [3].

If further taken into account that at the same company energy costs represent 12.5% of the turnover, the development and implementation of an energy management programme follows as a necessity for increasing the efficiency of electrical energy use, as part of both the manufacturing process and the other components of production systems.

II. THE DEVELOPMENT STAGES OF THE MANAGEMENT PROGRAMME

An efficient energy management programme calls for the involvement of the administration board and for the appointment of an energy manager, who should know and comprehend what kind of energy and in what quantity is used by the system. A first stage of the programme development consists in the analysis of the energy bills of the last 12 months. The high energy consumptions between October and March indicate the use of additional energy for heating, while an increase during the summer months is a sign of intensive air conditioning use. A larger demand of energy during one month can be attributed to deficient operation or to an increased production, while a lower demand may reflect a partial disruption of the production system operation. Conversion factors based on the heating power of the fuel will be employed for the analysis of different variants of efficient use of energy.

The energy monitoring technique frequently employed by energy managers resides in comparing the energy bills with those of previous years, of identical periods. Such comparisons, which can be conducted for the unit of fuel and its cost will highlight the trends of energy consumption and allow an analysis of changes.

The second stage in the programme development refers to the energy audit. The analysis of the bills identifies only the area of potential problems. The alternatives of increasing the efficiency of energy use can be established only by an energy audit, which implies several steps.

The first step involves obtaining a complete inventory of the energy consuming equipment. For this, starting from the plans of the buildings diagrams are plotted, which specify the characteristics (dimensions included) of the walls, windows and roof, followed by a diagram of the process flow.

The inventory of the equipment needs to include: the motors driving the machines, also the compressors, heaters and coolers, ventilation and air conditioning equipment, lighting supports, etc. A detailed inventory simplifies the assessment of opportunities and the development of a maintenance programme. For motors the type should be specified, the operation mode, power and working speeds(s). Lighting supports will be grouped by source type (fluorescent, incandescent, etc.), lamp type, ballast (the starting element of gas discharge), voltage, power, number of lamps on one support and type of support.

The second step of the audit includes a general view on the operation practice within the production system. How many hours a day does the system operate and when is the equipment used? What controls are there possible? What are the temperatures and the set of established points? is the equipment fully used? How well is it maintained? This way equipment can be identified, which operate both during working hours and outside them, lights and equipment left to operate idly, by negligence.

Based on the data obtained consequently to these two steps, a manger can estimate the energy consumed by various users and identify opportunities of reducing energy costs. The evaluation can be carried out with or without computer aid.

The third step includes the answers to the following list of questions:

- which is the weight held by energy cost in: the turnover, the production cost, in relation to profit?
- by how much have these weights been reduced over the last three years?
- what reductions of the energy consumption have been achieved in the last year, by what methods, in relation to what type of energy, at what cost?
- what is the budget allocated for the reduction of energy consumption for the following years and what profit will the allocated investments yield?
- what is the efficiency of the use of electrical energy in the production system?
- which are the consumptions and efficiencies in each profit centre, section, for each piece of equipment?
- which is the distribution of the energy consumption among processing machines and equipment, heating, transport, lighting, air conditioning?

The opportunities identified during the energy audit require an economic evaluation by means of costs. In the case of investments, most production systems use the concept of recovery time for an economic efficiency indicator, that is the period in which the consumed resources could be recovered by the value of the annual profits made by selling the products.

Regardless of the methods employed for evaluation, the costs related to installation, annual operation, energy saving and updating in dependence on bank interests have to be known. The total cost has to include also the cost of the feasibility study, of engineering design, of the building process and of the equipment. A recovery time of 2 –3 years is considered acceptable for most production systems, but in accordance with the policy of the production system also shorter or longer periods may be admitted. [4]

III. CHARACTERISTICS OF WIND TURBINE

The helical wind turbine with vertical axis, that will be analyzed and tested for Romanian regions in order to estimate the reliability function and hazard rate, it was designed to generate 1000 W. This type of wind turbine is easy to mount on the roof of a house, having the main advantage of don’t need to be pointed into the wind direction with a system as other types of wind turbines. In the same time it works without any noise and the shape of the rotor make these turbines to be with any damage for the birds [1]. The rotor of this wind turbine was made by the FINEX Company, patented in Romania, and it is with three blades with fiber glass material (Fig. 1), [2].

Fig. 1 Analyzed wind turbine with vertical axis helical type.

The rotor was mathematically designed and tested in experimental conditions on the car adapted as a mobile laboratory, where it was measured the next parameters:

- output power of turbine [W];
- wind speed [m/s];
- rotational movement of rotor shaft [rpm];
- air temperature [°C]

Also, it was measured the following parameters:

- turbine rotational speed;
- wind speed;
- system voltage;
- system current.

Because the rotational movement of the rotor shaft is of maximum 120 rpm, it was needed to use a device that increase the rotation movement and ensure optimum conditions of working for the permanent generator magnet. The electric current is three fazed and it is needed to use a device to modify it in order to be measured as good accuracy as possible the current generated at different number of rotor shaft rotation.

One rotor can generate a power of 600 W, at the wind speed of 12 m/s, and by mounting on a common axle of two rotors it is obtained a total power of 1200 W.

IV. MONTE CARLO SIMULATION OF PARAMETERS OF WIND TURBINE

Since the beginning of the XX century, an intensive development of the use of Monte Carlo method has taken place due to a massive increase of the new generations computers' processing power. At the same time, the formalism linked with the Monte Carlo method application has been intensively developed [4].

Particular role in learning the reality could be attributed to the methods using occurrences treated as random, but only a development of sciences associated with random processes, provided rational basis to evaluate methods and the results of examining these processes.

It turned out that, rational treating of the occurrences, whose natures - as random - is essentially irrational, can be the source of useful knowledge about objectively learned reality. Formalized approach to learning the reality – thanks to the random reality created by people – found its place in science under the name of Monte Carlo method, which can be associated not only with a world's hazard capital, but also – what is important – also with elegance, as the Monte Carlo method itself, and eternal longing of people for power, either material or intellectual. The Monte-Carlo technique is a device for modeling and simulating processes that involve chance variable [4]. By studying the distributions of results, we can see the range of possible outcomes and the most likely results. Using simulation, a deterministic value can become a stochastic variable. We can then study the impact of changes in the variable on the rest of the spreadsheet.

Recent popularity of the triangular distribution can be attributed to its use in Monte Carlo simulation modeling and its use in standard uncertainty analysis software. The triangular distribution is also found in cases where two uniformly distributed errors with the same mean and bounding limits are combined linearly [3].

The Monte-Carlo simulation of parameters of helical wind turbine with vertical axis includes elements of reliability theory and notions of probability and statistical inferences. In our simulation process we used triangular distributions because the input data can be obtained very easily and it does not require laborious investigations.

The most important parameter that influence the reliability of wind turbine with vertical axis it is wind speed. In this case, interesting results may be expected from the implementation of the Monte-Carlo simulation. Considering the wind speed between 4 m/s and 6 m/s for Romanian analyzed region, it can be determined the cumulative probability expressed by cumulative frequency curve for these data and looks like in Fig. 2.

Cumulative distributions functions are usually presented graphically, where we plot the cumulative frequencies at the class boundaries. The resulting points are connected by means of straight lines, as shown in Fig. 2, Fig. 4 and Fig. 5. The normal probability graph paper is a useful device for checking whether the observations come from a normally distributed population, but such a device is approximate. One usually rejects normality when remarkable departure from linearity is quite evident [2].

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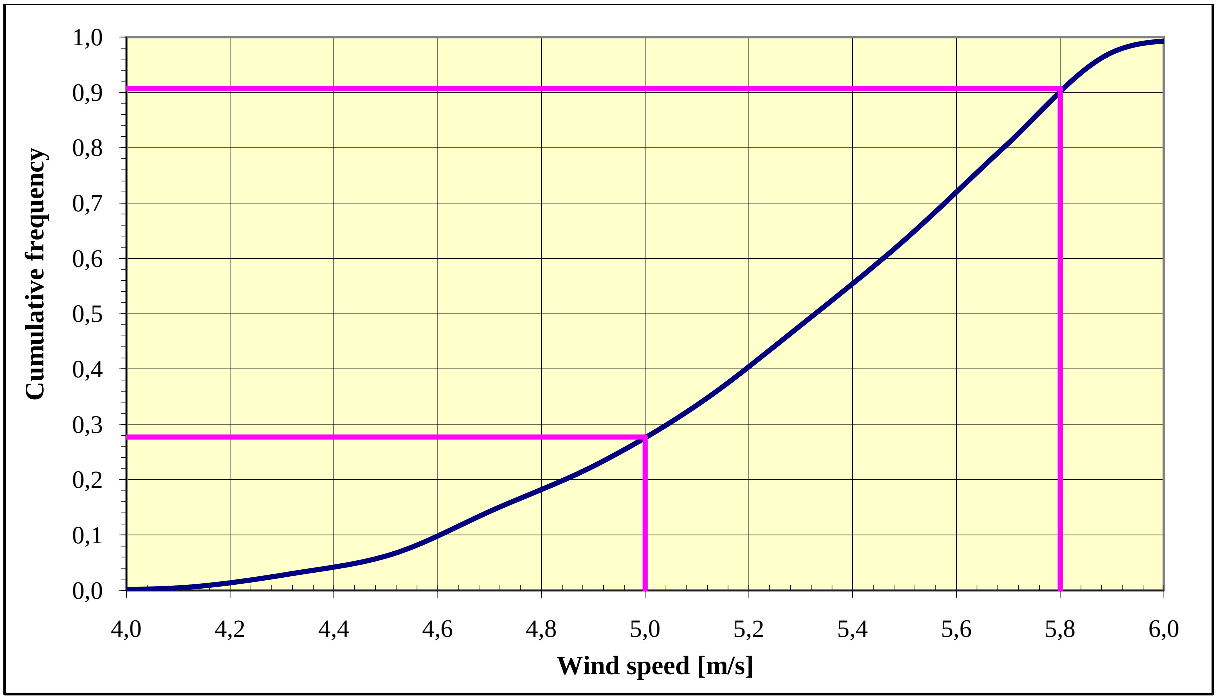

Fig. 2 Cumulative frequency distribution for wind speed using Monte-Carlo simulation

Another measure of helical wind turbine reliability is the annual energy production. In a similar manner, it can be simulated the daily and annual energy output. As a result, the simulation data are represented by relative frequency histograms (Fig.3) and diagram (Fig.4). Cumulative distribution curve indicates the probability that it will be obtained the daily or annual energy output. Each time when the simulation is executed, the cell will be updated to show a random value drawn from the specified distribution.

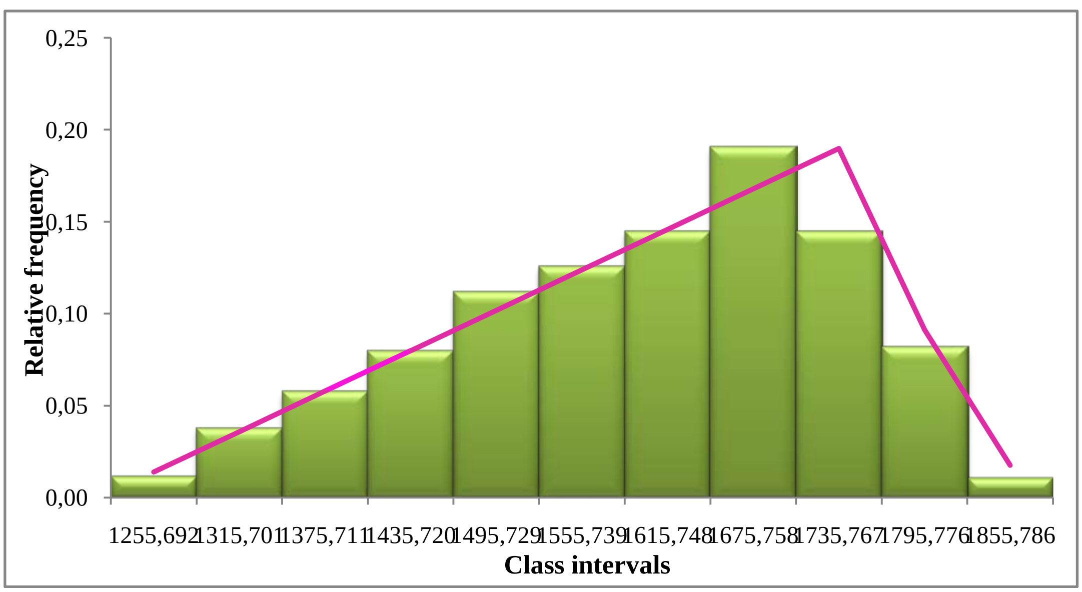

Fig. 3 Monte-Carlo simulation of relative frequency histogram for annual energy output.

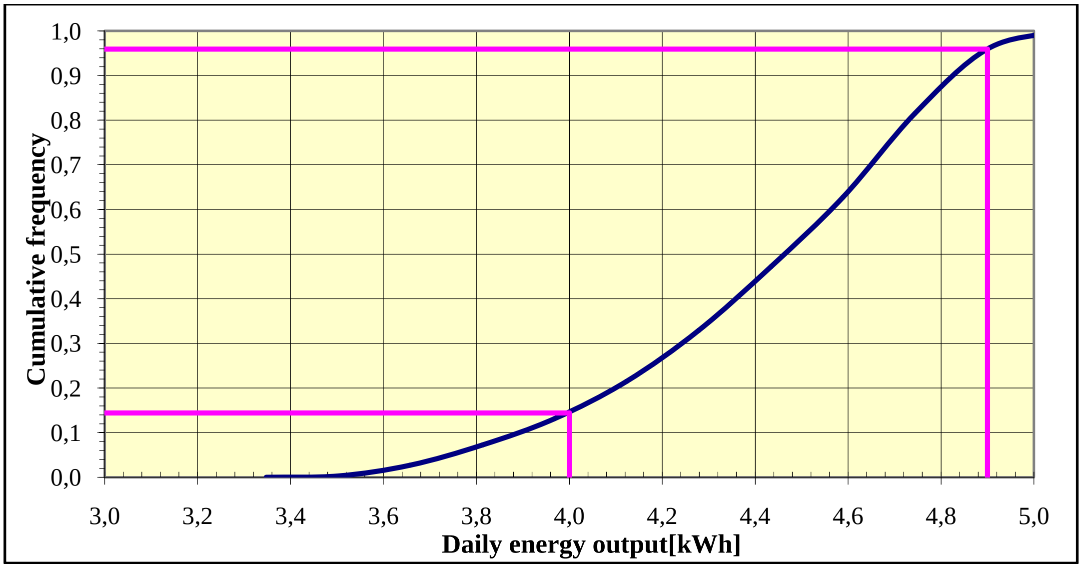

Fig. 4 Monte-Carlo simulation of cumulative frequency distribution for daily energy output.

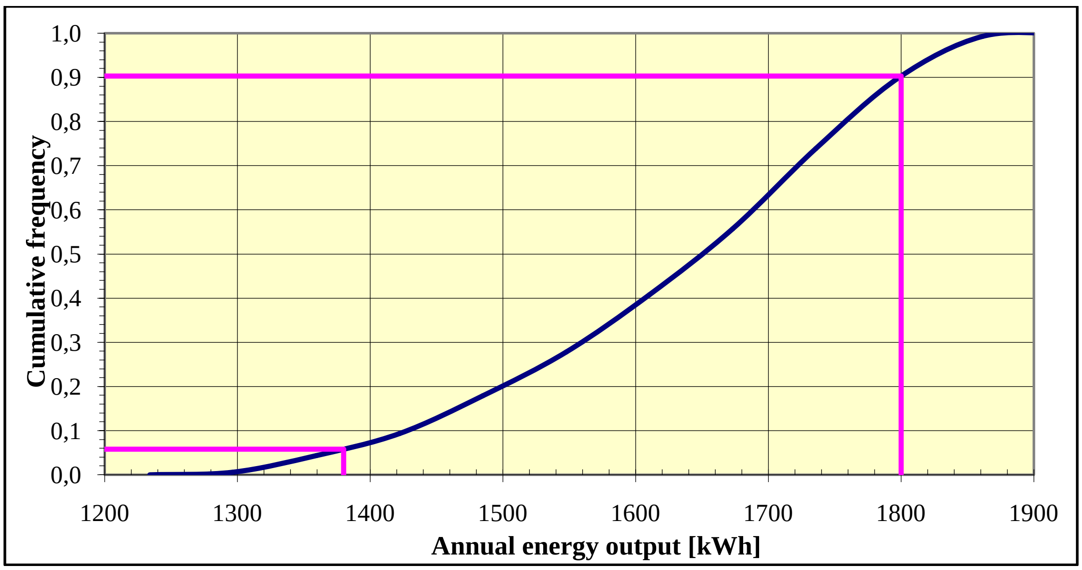

Fig. 5 Monte-Carlo simulation of cumulative frequency distribution for annual energy output.

In Fig.5 it is presented the simulation results of annual energy output according to relative frequency histograms, and it can be seen the standard asymmetric triangular distribution.

Analyzing the cumulative frequency distribution (Fig. 2, Fig. 4 and Fig. 5), the simulation results are presented synthetically in Table 1.

Table 1. Simulation process results

Parameter	Prob$\{x \le x_0\}$	Prob$\{x \le x_1\}$	Prob$\{x > x_1\}$
Wind speed [m/s]	0.269	0.899	0.101
Daily energy output [kWh]	0.144	0.959	0.041
Annual energy output [kWh]	0.058	0.903	0.097

It can be observed that the probability to exceed the maximum value of wind turbine parameters it is approximately 10% for wind speed, 4% for daily energy and 9.7% for annual energy. These percentages are obtained for different intervals set as acceptable limits.

IV. CONCLUSIONS

As it has been proved by a lot of researchers and energy engineers, it will be a very positive and economic solution the replacement of bigger part of diesel generators with stand-alone hybrid energy systems, especially in medium and high wind and solar potential locations. Power systems which can generate and supply electricity to such remote locations are variously termed -"Remote decentralized, autonomous, or stand alone".

The main advantages of this type of wind turbine with helical rotor which main rotor shaft runs to the flow streamlines, from other type of wind turbines with horizontal axis are:

- high reliability;
- in isolated area, with no connection to national network, it can be used with good results a wind turbine with vertical axis helical type;
- simplicity in construction and good rigidity;
- smaller cost with 20 % as similar turbines;
- specific power bigger on the active surface;
- high torque moment at starting;
- at the wind speed bigger than 20 m/s is self-breaking without mechanical components, due to its original shape of rotor;
- it doesn't need orientation after the wind direction;
- it can works to high wind speed, as 50 m/s;
- it is only one wind turbine that is accepted by environmental agencies, because it doesn't kill birds;
- doesn't make noise during its function;

Application of Monte-Carlo simulation allows us to determine the cumulative distribution curve and it helps to estimate the probability to obtain the daily and annually energy output with a specified wind speed. These charts can be used to establish upper and lower specification limits on energy production and this information can be very useful to optimize the parameter and components of wind turbine. Based on simulation principles, it was performed the statistical processing of experimental data. By this means, it were determined the wind speed, the output power and annual energy output.

Considering this parameter, it was estimated the reliability function, unreliability functions, and failure rate. So, the reliability modeling and analysis of wind turbine permits us to understanding and minimizing wind turbine operation and maintenance costs. Information derived from these measurements can help to identify where the problems are. Further interpretation of the data could help to optimize the wind turbine and it could assess if it has been chosen the optimum parameters of the system. After the tests results was demonstrated the advantages of this type of wind turbine with vertical axis, against the other types of wind turbines patented in the world. In the time that will follow, based on the tests in laboratory and in aerodynamic tunnel, we intend to improve its performances.

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