WIND AND GEOTHERMAL ENERGY RESEARCH AND EDUCATION AT THE FACULTY OF MECHANICAL ENGINEERING OF SZIU

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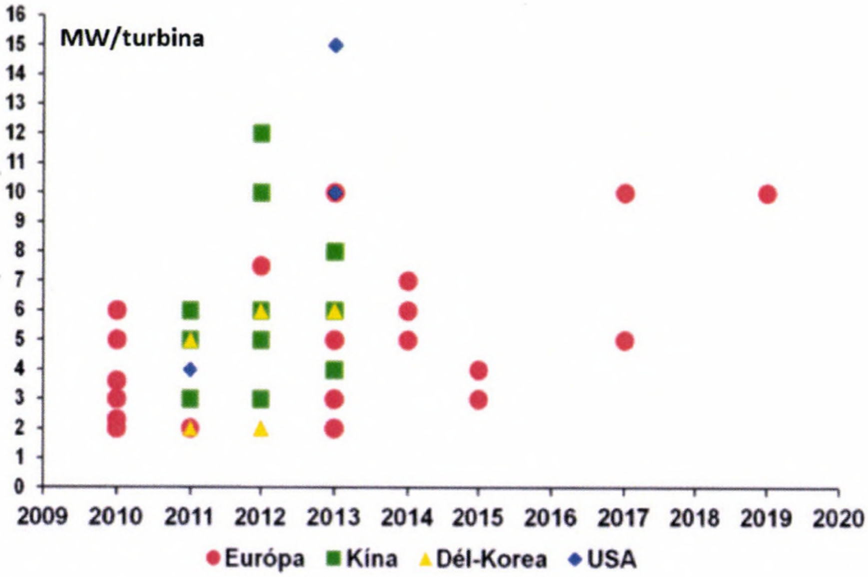
Summary

- The Faculty of Mechanical Engineering of Szent István University has made significant efforts to create the "LOW-CARBON" economy and for the use of renewable energies already from the middle of 1980s. The present article summarizes the works connected to the wind and geothermal energies.
- The wind and the geothermal energies are very popular all over the world. The use of wind has stopped dead in Hungary in spite of that a considerable investors' interest and intent can be observed.
- About the towns and in certain agricultural plants and farms, the use of geothermal energy is significant and a further development is expectable due to the advantageous geological conditions in Hungary.
- It is improbable that Hungary will perform the ambitious plan of renewable energy use (14.65 % in the year 2020) without a more considerable utilization of the wind, the solar and the geothermal energy than that of the present ratio.

Keywords': research of wind and the geothermal energies,

About wind energy

The development of the utilization of wind energy, on an industrial scale, started practically in the years 1990s in Europe and in the United States. While in 1997 only a capacity of 60 to 80 MW was active, in these days an electric-power capacity of 240,000 MW is available all over the world and the forecast to 2020 is 1,500,000 MW. (The previous forecasts have proved under-estimated for all periods.) The turbines have changed a lot as well in spite of that they kept the original form but the horizontal-shaft three-blade model has remained the most successful design. Today the 2-MW-power wind turbines are erected in the greatest number however the serial manufacture of the 6 to 8-MW models has started as well. In addition, in China, already 10 and 12-MW pilot plants too were put in operation. A unit of 15 MW power will be erected in 2013 in the United States (Figure 1). Instead of the dense "forest like" wind farms, already – less frightening – sparsely erected plants will appear in the future (Figure 1).



Europe -China -South Korea -USA

Figure 1. The expectable development trend

Energetic wind measurement

The Szent István University began to deal with wind energetic measurements in the 90s, and established the Hungarian Wind Energy Scientific Association (Magyar Szélenergia Tudományos Egyesület) for this purpose which is active at present as well. The Association carried out so-called energetic wind measurement differing from the meteorological tests in the Hungarian regions Komárom and Kisalföld. It was proved that these areas can be suitable for the erection of wind power stations or wind parks. In the following test, the group carried out measurements in the region Kulcs – about 10 km to the north from Dunaújváros – with such topographic conditions where an advantageous wind course can be expected (Figure 2). The results gained in this area of especially advantageous relief were similar to those of the region Kisalföld. After a one-year measurement series and the feasibility study the first wind power plant of 600-kW capacity connected to the main was erected with the collaboration of E-ON. Before this a 270-kW wind turbine at Várpalota which was erected by the TRANSELEKTRO. In the case of this plant, the Faculty of Mechanical Engineering of Szent István University carried out the type tests according to the European standards, and proved that the station provides the energetic values according to the rated performance.

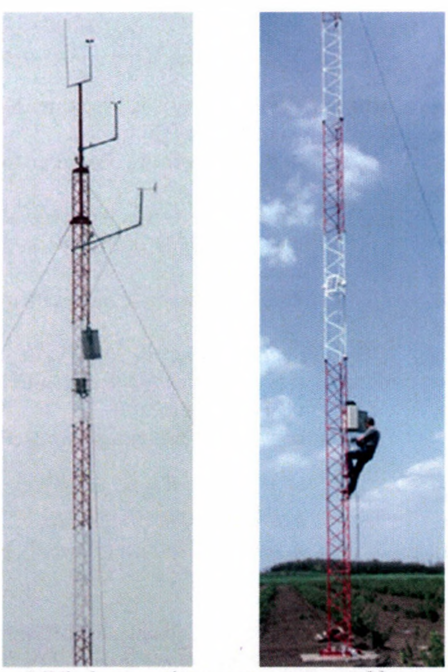
The first Hungarian wind turbine connected to the main (Kulcs 2002)

24-MW wind farm; btw. 2007 and 2009 Kisalföld

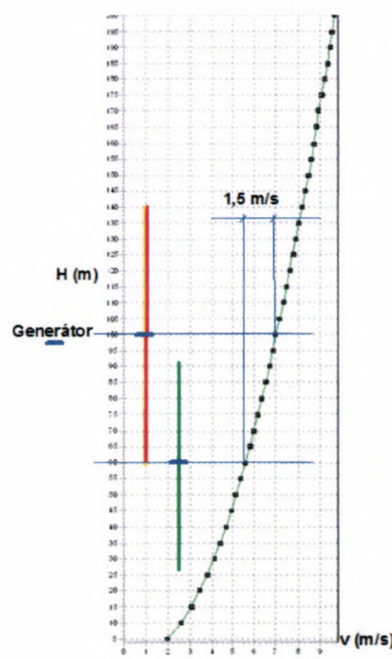
Figure 2. Wind power plants in Hungary

Wind measurement experiences

Having these experiences, the Faculty started improving different facilities such as erecting or siting stable as well as transportable wind measuring masts; these served expressly for energetic-purpose wind measurements. By these, the measurements were carried out above the height of 40 m, usually at least at two positions above each other in order to determine the exponential wind profile valid from the ground surface (Figure 3b). At the beginning the test data processing were carried out by the traditional methods but, considering that six or seven hundred thousand pieces of data had gained during each of the one-year measurements, later on software solutions were bought from Denmark (WindPro and VASP). These facilitated that energetic-purpose wind tests could be carried out on about forty sites in Hungary in the frame of the first SZÉCHENYI PLAN.



a) Wind measuring mast – upper and lower section



b) Vertical wind profile plotted against mast height

Figure 3. Measuring device and result

In co-operation of the OMSZ (National Meteorological Service), the University of Debrecen and the SZIU, the wind map of Hungary which serves the best the preliminary selection of wind farms even now was completed. The bought software pieces allowed carrying out different model calculations as well. Amongst others, we analysed the interaction of the turbines in the wind farms, the economic design of the electric power network, determining the distance of the so-called flicker effect of the wind mills, the propagation of noise and the construction of noise maps etc.

Development trend in Hungary – characteristics of development

The first plant was put in service in December 2001 in Várpalota. Up to the end of the year 2010 a capacity of 329.6 MW was installed (Figure 4). In 2009 a call for tenders on a capacity of 410 MW had been was planned but the announcement was failed thereby no wind power plant is being constructed at present. Expectably, it will be possible to erect again wind farms or higher-capacity turbines only in 2015 if the call for tenders was advertised in 2013 considering that, from the call, at least one year and a half is required for putting the plant connected to the main in service.

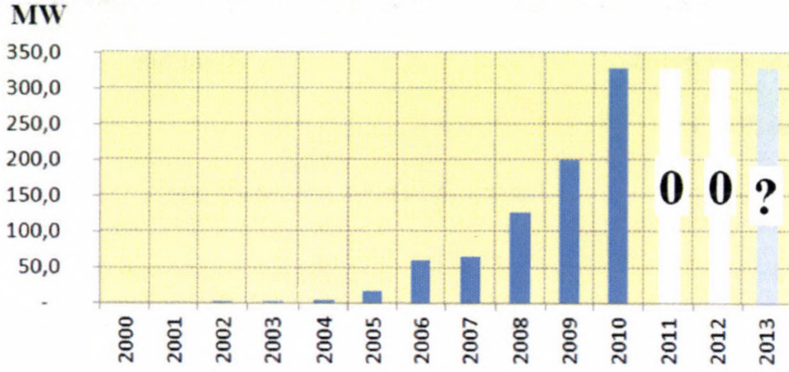


Figure 4. Development of the wind power capacity in Hungary

According to the suggestions based on the results of the Hungarian measurements, the most modern wind turbines will be imported. As another result of the tests, it was established that, taking the topographic conditions and surface frictions into consideration, the erection of wind power plants with 90 to 110-m tower height is expedient in Hungary. The degree of friction is considerable at lower heights and the power-yield potential is much lower. It is true of the plane area in Hungary as well but there the effective height must be increased because of the windbreak shelter-belts.

For checking the measurement results, the SZIU built a self-designed wind tunnel. After the tests the dismounted anemometers were re-calibrated in this tunnel and the measured results could be fully accepted if the measured values corresponded to the certificates provided by the TÜV (Technical Inspection Association). For the qualification of wind power stations, the professional terminology introduced the utilization factor according which the (sites) can be compared.

The expectable 620 to 625 GWh/year planned with the capacity of 330 MW[1] in Hungary proved to be 615 GWh/year (MAVIR (Hungarian Independent Transmission Operator Company) data, 2012). The country-wide average capacity utilization factor (Kf) is 21.2 %; it includes the putting in operation and the stopping cases as well. Even a value of 23 to 25 % was indicated for certain wind farms in accordance with the data of the earlier issued wind map.

The relationship of the theoretical maximum performance of the wind power turbine is –

$$P_{max} \cong \frac{16}{27} \cdot \frac{1}{2} \cdot A \cdot \rho \cdot v^3 \quad [W]$$

where $Pmax$ = theoretical maximum electric power of the wind turbine (W)
A = area swept by the rotor blades of wind turbine ($D2\pi/4$) (m^2)
ρ = density of air in the actual state (kg/m^3)
v = air velocity in the operating range (usually 3.5-25m/s)
16/27 = Betz's maximum efficiency factor.

The effective power is lower due to the aerodynamic, mechanical and electric efficiencies but the self-consumption of the system decreases it as well.

Accordingly, the annual energy production is –

$$E = k_f \cdot P_n \cdot 8760 \quad [W]$$

where k_f = capacity utilization factor
P_n = nominal power (generally lower by cca 10% than P_{max})

The cause of the advantageous Kf result is that the siting conditions were well considered and the fact that more modern

[1] The present wind power capacity (330MW) substitutes for an annual amount of natural gas of about 200 million m^3 and at the same time the emission of cca 400,000 tons CO_2 can be avoided (these mean import gas of approximately 14 milliard HUF value and CO_2 of 1.0-1.8 milliard HUF value).

plants were erected in Hungary while in Germany – where less modern plants were sited in the years 90s – the value of Kf was only 17 to 18 %.

Due to the rapid development, the wind energy will be competitive already in the year 2018 or 2020 with the quoted prices of electric energy. This is the forecast of the EWEA (European Wind Energy Association) and the German electric supply companies as well. In spite of these, today the wind energy still requires certain subvention – but only the produced energy without erection investment and only for 6 to 8 years until the invested capital and its interests will be recovered. The life of the plants is 25 to 30 years accordingly they supply essentially cheaper energy than that of the power stations using fossil fuel. Only the repair-and-maintenance costs determine the price of energy.

Education – energy policy

The learning of wind energy in the form of a facultative subject was introduced in the curriculum of the Szent István University. Taking the increased interest of students as well as the expectable progression of renewable resources into consideration, the Faculty established a specialized energetic engineering course. In the frame of that, besides the general energetic knowledge, the students learn chiefly the utilization of renewable energies, the establishment of systems and the adjunct engineering equipment. With the help of the researches, three PhD dissertations, several diploma pieces and TDK (Student Scientific Society) essays could be completed.

The teachers of the Faculty attended several energy policy forums e.g. on the preparation of the VET (Electric Energy Law) of year 2005 in connection with the wind energy. In the same year a call for tender was advertised for a 330-MW wind-power-plant capacity. Later the power stations were practically erected in those areas where our wind measurements carried out in the earlier years proved the economical siting of wind turbines. We collaborated in the preparation of the National Action Plan in the latter years, and assisted the elaboration of the National Renewable Energy Programme.

According to the forecast prepared at the Faculty, the electric energy production from renewables rated in the National Action Plan by 2020 can be performed only in the case if the present wind energy capacity of 330 MW will be improved to minimum 1000 MW. Theoretically, this can be achieved in the period between 2014 and 2020.

Geothermal energy

The research of heat pumping of geothermal energy requires first of all the investigations on the top 100-m ground layer. For the determination of the withdrawable heat or the heat reflow into the ground during cooling, the heat conductivity of the top soil layer should be known and it was the goal of our research. The values of this thermal conductivity were determined by the so-called TRT (Thermal Response Test) system. The test is especially important with large systems where 50 to 100 or 200 probes are planned to be placed. In this case, the question is the necessary distance between the probes at which the probes do not influence each other during either heat pumping or heat absorption (i.e. cooling).

In the course of the measurement, the temperatures of the outgoing and the return branches were recorded, respectively. Before the start of the probe tests, the rest state was recorded. As an example, the temperature data recorded along a single 100-m long probe can be seen in Figure 5. The measured temperature values changed between 6.03 and 17.78 °C.

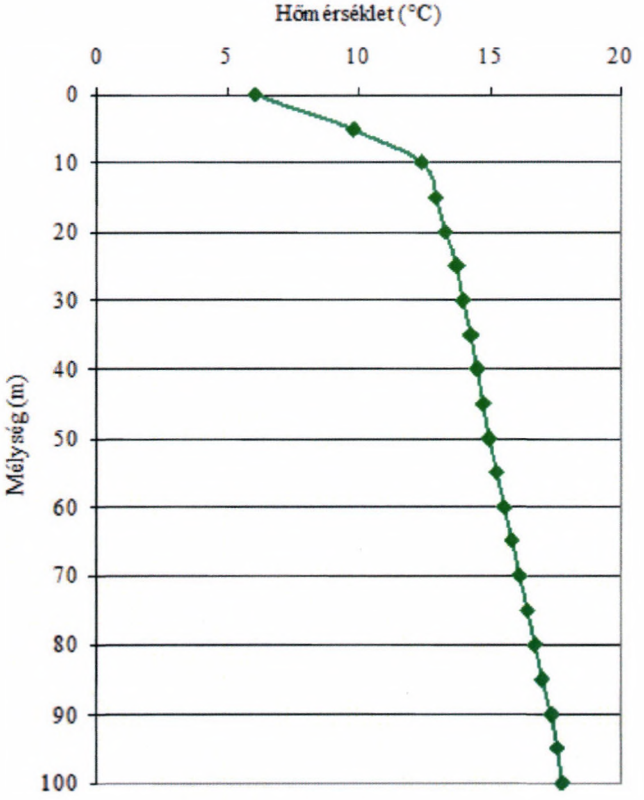


Figure 5. Depth (m) - Temperature (°C)
The undisturbed temperature as a function of the depth (Rest state – TESCO, Pesti út)

The second research project deals with the traditional horticultural utilization of the thermal energy – the pumping-out of the geothermal fluid and the energetics of the injection-back. In terms of the sustainability, the solution of the latter will be one the most important problems in the next period. The injection-back is an essential element since the water reserve is limited and exhaustible and, by an unreasonable use, a very important energetic resource (but later the water reserve itself as well) can be damaged.

In connection with our third research area, we carried out complete energetic measurements with domestic-type heat pump systems. In the present conditions, the use of heat pumps in households can be economical if their floor area exceeds 150 m2 but it is important here again that the system should include both the heat pumping (i.e. the heating) and the cooling as well. It is a general experience that in the summer season a reasonable amount of heat energy is stored in the ground in the case of cooling which can be available at a higher efficiency level in the autumn and early winter heating period. In large-scale systems with vertical closed probe (BHE Bore-Hole Heat Exchanger) solutions during the preparation works (before the final design), the basic condition of the planning model creation and the sustainability is the performance and the evaluation of the geophysical depth thermal test (TRT Thermal Response Test). With the help of the TRT testing (which can also be considered as a scientific approach), the expectable technical parameters can be estimated at a good confidence level. The operating systems planned in this way performed the expected parameter values according to the experiences.

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