COMPLEX ANALYSIS OF RENEWABLE ENERGY SOURCES FOR ELECTRICITY PRODUCTION

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Keywords: renewable energy sources, complex evaluation, multi-criteria evaluation, decision making.

Abstract

Goal of the study is the system analysis and after that the complex analysis of the renewable energy sources and cogeneration (CHP) including fuel cells. The process of the analysis consists several steps. The first one is the global managerial methods as the PEST and SWOT analysis, where there are the variants evaluated by the qualitative words methods. The second part is based on the multicriteria evaluation by different methods of complex analysis. There is possible to define the positive or negative contributions renewable energy sources in the Czech Republic and also in the EU on the basis of the last two steps. The combination of these two processes makes complex overview of this issue and large flexibility and applicability. The main contribution of this access is in the system effectiveness used for the evaluation and dividing of the subsidiaries and programs of the EU.

1 PRINCIPLE AIMS OF THE PROJECT

The main required outputs and conclusions of the project solution “A complex analysis of alternative sources of energy” were these ones

- The detailed searches of the last RES development and their summary
- Catalogue assembly of the particular representative technical solutions for catalogue utilization as a base of assessed versions (together with searches provide the identification of technology set under CR conditions)
- The preliminary evaluation of suitability of single sources for CR by means of SWOT analysis
- Compilation of a general methodology of solving by means of the method of multicriterial assessment of versions, the criteria proposal and assessment of methods selection
- Compilation of TESES Multika expert system, where the main parts are:
  - Database of technologies
  - Expert skills (creation of expert team, value assignment to single groups (fields) and criteria values to particular technologies)
  - MULTIKA - computing software module for multicriterial assessment of versions by means of chosen methods and for support of assessment results including analyses results.
- Setting an order of RES prospectivity under the Czech Republic conditions.
- Recommendation for consequential researches for specific result application of the project being solved in practice.

2 OVERVIEW OF RES FOR ELECTRICITY

Complex overview of all RES for electricity was made pursuant to detailed studies which dealt with RES in last 5 years and also to modern science and engineering in the world. This overview (updated in the end of 2006) was consulted with pivoted experts from RES branch.

Basic parts of our interest are following:

- Impacting solar radiation – Impacting solar radiation – Direct solar radiation

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- Impacting solar radiation – Energy of water courses
- Impacting solar radiation – Wind energy
- Impacting solar radiation – Energy from biomass
- Impacting solar radiation – Energy of sea waves
- Impacting solar radiation –Thermal energy of environment
- Energy of Earth's core – Geothermal energy
- Rotational energy of the Earth and gravitational energy of the Earth, the Moon and the Sun – Tidal energy
- Cogeneration (CHP)

General division mentioned above is consequently further subdivided according to kind and type of used technology for electricity production. Final detailed division includes all available technologies including those which are for the time being in testing service or being researched.

3 SPECIFIC PROBLEMS OF RES

3.1 CONNECTING RES-PLANTS TO THE DISTRIBUTION AND TRANSMISSION GRIDS

Topic of RES does not include only monitoring of economical and ecological benefits.

RES that we could include between so called decentralized sources are also sometimes used to solve operational problems in distribution grids. To be concrete they can for example improve reliability and stability of the grid on distant places. These places are often supplied by radial power distributions and RES can help with covering energetic peak hours or they can completely compensate other energy sources in case of their outage (this is applies especially to water energy and biomass which can prove continuous source of energy.

On the other hand RES which significantly depend on weather conditions (wind power-plants, photovoltaics, etc.) may cause higher requirements to provide reliable and stable run of distribution grids.

Consultation with operators of particular transmission and distribution grids before installation is necessary. Some questions about choosing the right place of installation, technical conditions, connectivity and especially operational problems must be solved.

Pivotal indicators are:

- location of primary RES
- output of RES
- voltage level
- topology of the grid
- stability of the grid
- character of electric energy consumption in specific location
- influence to environment

3.2CONDITIONS FOR CONNECTING AND OPERATING RES TO THE GRID

Regulations for connection of RES to the grid are in competence of Energy Regulatory Office (ERO).

Every single producer has to have a license for electricity production and has to stand related legislative and regulations for running these grids. As he stands these conditions, there should be no problem to connect his RES to the grid and to start production.

During this study we realized, that it's necessary to make calculations for every single example which help us to find weaknesses of the grid and analyze state of the grid before and after RES connection. Models of distribution or transmission grids are used and while respecting configuration and parameters of the grid we get monitored parameters as following:

- change of voltage after connecting of RES
- course of voltage in the whole grid before and after RES connection
- max. output of RES, that could be connected to the specific grid
- influence of some RES parameters (power factor, impedance, etc.) to the grid operation

3.3INFLUENCE OF RES ON THE TRANSMISSION AND DISTRIBUTION GRIDS

There are many discussions relating to the influence of some RES, e.g. wind power-plants on the transmission and distribution grids. Wind power interferes above all in its big power variability whereas wind power-plants power depends on the cube of the wind velocity. Instantaneous wind velocity varies in our country very quickly. The wind power-plants power balances also very hard in Germany – it could increase very quickly and also very quickly fall and this is hardly controllable in the system. Differences could be, e.g. with Danish company E.ON, even 600 MW during a very short period. That's why a standby electric power supply shall be at disposal and the power goes up in price.

The solution to this could be the power storage or power prediction of the wind power-plants. But such predictions are not too accurate even in Germany. Power failure are solved in different ways – e.g. the Danish company ELTRA, with 6000 MW of witch 1900 MW in wind, is connected with Norwegian hydraulic power plants that are able to start very quick (within 5 minutes). This situation isn't fully comparable with the situation in CR.

In any case applies, that wind power-plants request the resource increasing and the better regulation. The installation of several hundreds of MW wind plants can't be considered to be a situation when demands on standby power shouldn't be increased, it is totally vice versa. The expert's estimates comply on that point, that the market price of the wind power including incurred but to the network operator undefraied costs on deviations is markedly lower than with other RES.

According to the international rules of operation of network every country is obliged to maintain in an active (operative) resource the capacity appropriate to the biggest resource in its system. The biggest resource is a reactor of the nuclear power plant Temelin with the power of 1000 MW. This one covers the wind plants together with the others power plants, however the comparison of wind power-plants with the failure of the nuclear power plant Temelin is not accurate, because it is the same power and the same failure but to cover the variable deviations of wind requires the entirely different standby electric power supplies. These shall be quickly controllable and currently permanent run but unloaded at full capacity, whereas the failure of the big block requires the same in the first minutes indeed, then the load accept the other that shall cover the permanent constant power-cut.

4 RECHERCHES

To fulfill the first aim the following methodology was chosen. A comprehensive summary of all RES sources for electricity is made on basis of detailed study searches, which was dealing with RES in last five years and on basis of new science and technology in CR and in the world.

The search methodology presumes that the up-to-date information is available on internet now. Scientific and professional reputable journals of the field of RES and interest associations or universities processing annual reviews of situation in sub section are the most relevant with regard to the given research objectives. The sequence of relevancy of these sources gives the following order:

1. University database and libraries – magazines and scientific publications, special offprint
2. Research and interest organizations and associations – special syllabi and reports
3. Reputable popular science magazines
4. Internet in general, movies, universities, research institutes
5. Books

The detailed syllabus of the current situation in the world was compiled so that the brief search report on the last current progress and future trends was made for any energy source in question.

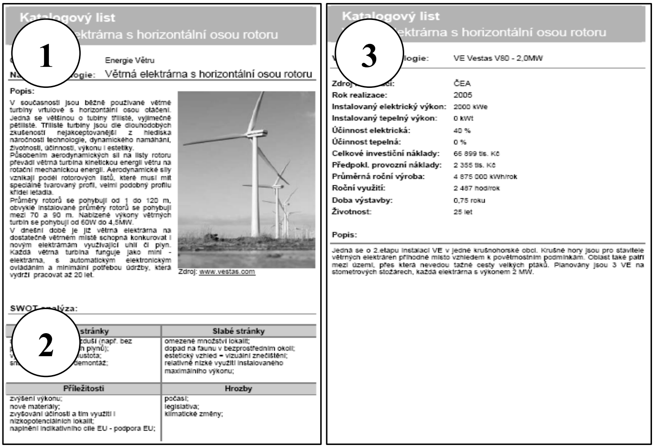
A part of searches is a data collection for values determination of the relevant criteria which are input for the self-analysis, the assessment and the comparison. As an example we can name the investment and operating costs, influence to the environment etc.

5 REGISTER OF TECHNOLOGIES

Register of technologies was made as kind of complete summary of data and information. It contains 36 standardized variants of RES and CHP.

This register together with recherches and expert survey made the base for establishing of criteria rates for each of technologies. It includes:

1) A general technology description
2) Results of the SWOT analysis of the relevant type RES
3) Parameters of the concrete examples of power plant installations.


Katalogový list
ektrárna s horizontální osou rotoru

1

Energie Větru

Větrná elektrárna s horizontální osou rotoru

Popis:

V současnosti jsou běžně používané větrné turbiny vrtulové s horizontální osou otáčení. Jedná se většinou o tubiny třílisté, vyjímečně pětilisté. Třílisté turbiny jsou dle dlouhodobých zkušeností nejakceptovanější z hlediska náročnosti technologie, dynamického namáhání, životnosti, účinnosti, výkonu i estetiky.
Působením aerodynamických sil na listy rotoru převádí větrná turbína kinetickou energii větru na rotační mechanickou energii. Aerodynamické síly vznikají podél rotorových listů, které musí mít speciálně tvarovaný profil, velmi podobný profilu křídel letadla.
Průměry rotorů se pohybují od 1 do 120 m, obvyklé instalované průměry rotorů se pohybují mezi 70 a 90 m. Nabízené výkony větrných turbín se pohybují od 60W do 4,5MW.
V dnešní době je již větrná elektrárna na dostatečně větrném místě schopná konkurovat i novým elektrárnám využívající uhlí či plyn. Každá větrná turbína funguje jako mini - elektrárna, s automatickým elektronickým ovládáním a minimální potřebou údržby, která vydrží pracovat až 20 let.

Zdroj: www.vestas.com

SWOT analýza:

2

stránky	Slabé stránky
zduší (např. bez h plynů); ustota; demontáž;	omezené množství lokalit; dopad na faunu v bezprostředním okolí; estetický vzhled = vizuální znečištění; relativně nízké využití instalovaného maximálního výkonu;
Příležitosti	**Hrozby**
zvýšení výkonu; nové materiály; zvyšování účinosti a tím využití i nízkopotenciálních lokalit; naplnění indikativního cíle EU - podpora EU;	počasí; legislativa; klimatické změny;

Katalogový list
ektrárna s horizontální osou rotoru

3

logie: VE Vestas V80 - 2,0MW

Zdroj ací:	ČEA
Rok realizace:	2005
Instalovaný elektrický výkon:	2000 kWe
Instalovaný tepelný výkon:	0 kWt
Účinnost elektrická:	40 %
Účinnost tepelná:	0 %
Celkové investiční náklady:	66 899 tis. Kč
Předpokl. provozní náklady:	2 355 tis. Kč
Průměrná roční výroba:	4 875 000 kWh/rok
Roční využití:	2 487 hod/rok
Doba výstavby:	0,75 roku
Životnost:	25 let

Popis:

Jedná se o 2.etapu instalací VE v jedné krušnohorské obci. Krušné hory jsou pro stavitele větrných elektráren příhodné místo vzhledem k povětrnostním podmínkám. Oblast také patří mezi území, přes která nevedou tažné cesty velkých ptáků. Plánovány jsou 3 VE na stometrových stožárech, každá elektrárna s výkonem 2 MW.

6 SWOT ANALYSIS

SWOT analysis was applied as a basic method for separation of appropriate technology for conditions in the Czech Republic. The following summary of main technologies was its result.

- Geothermal energy – the main reason to choose this technology is independence on weather and constant heat supply. The weak points are investment costs which are rather high and influencing economy of the whole project. The opportunities for expanding are found in cheapening of the whole technology, usage of new localities which are more favorable for this technology.
- Biomass – a pretty dynamically developing technology. The main advantage is usage of biomass as energy source with production of lower emissions compared to fossil fuels. Disadvantages of this technology are noisy operation and exacting maintenance, the huge opportunity is a usage of various kinds of fuels. The essential factor which is a big menace for using of this technology is a lack of crop and a content of undesired components in fuel.
- Wind energy – the undisputed advantage is, that it doesn't produce any proper emissions and a relatively quick building-up. The disadvantage of this technology is an impact to the local fauna and flora and an aesthetic building appearance. To improve performance and take advantage of new materials belong to the main opportunities. Influence of weather – producing (not producing) of electrical energy belongs to the menaces.
- Photovoltaic – to the strong points belong a performance modularity and reliability. It doesn't produce any emissions. The improvement of panel efficiency belongs also to the opportunity. Weather and silicium sources are the menace for photovoltaic power stations
- Cogeneration (natural gas) – this technology uses both approved technology (a combustion engine) and new technologies (fuel cell). To the strong points belongs the efficiency of the whole system. To the most often weak points belong noise and necessity to cool the overheated parts. An opportunity of this technology can be seen in the modulation of lower power equipment and in price-cutting. The menace is for sure the fuel, natural gas. Trend in prices and sources presents the biggest menace for this technology.

7 MULTICRITERIAL ASSESSMENT

7.1 Selection of appropriate methods of decision making is directly influenced with a group of important factors, as follows:

- The purpose of decision situation solving. Is the main the task of decision maker the selection of the best option, the choice of efficient options group, the exclusion of non-efficient options or option ordering from the best to the worst?
- The predominant criteria type (qualitative, quantitative)
- The possibility to lay preferences among the single criteria (to determine order of importance) and to quantify these preferences, if appropriate. (To determine the criteria weights)

- Criteria integrity, that means if the criteria values are defined (known, detectable) for all comparable options (some methods don't enable to work with non-completed criteria).
- The software availability for calculation. With respect to the complication of the superior methods and from this arising intensity to amount of calculations it is unimaginable to evaluate without specialized software.
- The intangible position of decision maker, which depends largely on his skills and knowledge. If the principle of complicated methods isn't known and understandable enough for him, these methods seem to be like "black boxes" in which he puts input data on one side and receives result on the other one. That can create no confidence in these methods and as a result he prefers some simple, less sophisticated but for him "clear" solutions.

Eventually there were three methods used to calculate this multicriterial assessment. *Lexicographical method, Method of global target function, Electre III method*

7.2 Proposed criteria groups for RES assessment

Technical criteria

The technical criteria describe the technical obstacles of single technologies, the coefficient of their readiness for setting in the commercial activity, technical parameters of produced electricity and if the technology enables an efficient usage of produced warm, coefficient of hazard in the building-up season etc.

Economic criteria

These describe the project economy on the level of assessment from the investor's point of view that is conclusive for the project execution or not execution.

Social criteria

These describe the social project implications and their benefit for solving of social and socio-economic problems of the eligible regions and states.

Ecological criteria

These describe the particular benefits of single technology for environment components and for increment of conformity with the principle of the permanent sustainable development of society.

Strategic criteria

These criteria describe the long-term project effect for power industry in CR and for the situation in further spheres of the national economy – e.g. agriculture.

7.3 Criteria weights

After final calculation we got quite interesting results. The strongest weight got economical criteria, especially criterion E1, which represents minimal redemption price of electric energy – it's necessary to provide high enough profit to cover all investment costs during the source lifetime.

On the other side of scale were criteria T10 (problems with liquidation of source after its lifetime), T6 (risks during the construction like prolongation of constructing etc.) and T5 which characterizes time necessary for installation.

	Criterion	Weight
	E1: Minimal price of electric energy	11%
	E2: share of possible inland expenses	6%
	E3: share of expenses for investment	6%
	Env 3: Ecological impacts	6%
	Env 4: Ecological impacts for fauna and flora	6%
	Env1: Degree of operating risks	6%
	St3: Degree of correspondency with EU targets	5%
	Env 2: Possibility of reusing produced waste	5%
	St2: Degree of correspondency with State energetic conseption	4%

	Criterion	Weight
	St1: Degree of correspondency with sector policies	4%
	So4: Degree of possible municipality participation	4%
	So3: Possibility of using low quality lands	3%
	So2: Degree of possible utilization in regions with LFA	3%
	T1: Degree of technology preparedness	3%
	So1: Number of created employee positions	3%
	T3: Annual utilization of installed output	3%
	T7: Effectivity	3%
	T11: Achievable potential	3%

	Criterion	Weight
	T8: Pregressivity of technical solution	2%
	T4: Dependence on outer noncontrollable conditions	2%
	T2a: Technical problems with using in common conditions	2%
	T9: Lifetime	2%
	T2b: Limitations coming from necessity of specific locality	2%
	T10: Problems with source	2%

	Criterion	Weight
	liquidation	
	T6: Risks during construction	2%
	T5: Time of construction	1%
	Economic criteria	
	Environmental criteria	
	Social criteria	
	Technical criteria	

Tab. 1. Criteria weights

8 EXPERT SYSTEM TESES MULTIKA

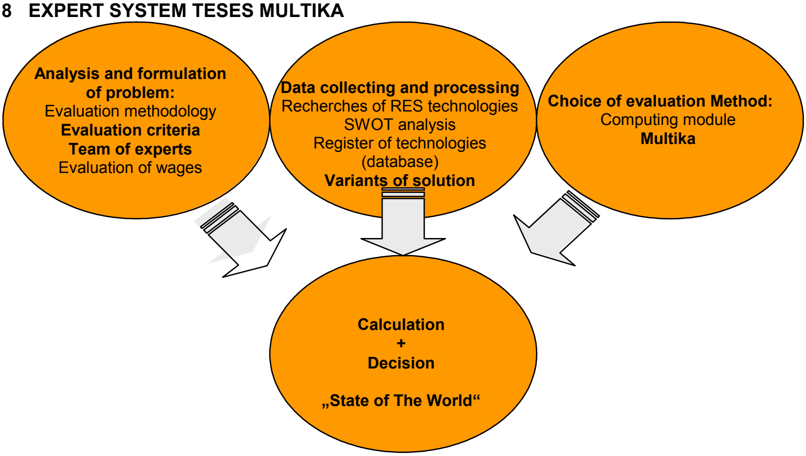


Fig. 1. Scheme of Expert system TESES Multika

The expert system is based on the principle of representative criteria selection and their placing into groups, TESES principle and MULTIKA - program for multicriterial assessment of variants.

Description of steps of the expert system

a) Definition of decision objectives
b) Compilation of the assessment methodology, selection of version assessment criteria and creation of the assessment structure
c) Input data acquisition, search processing and technology catalogue assembly, creation of versions
d) Expert teams vote
e) Setting weights of experts and determination of way of communication among experts
f) Assessment of experts – sorting the weights to single groups (spheres) and criteria
g) Self-evaluation by force of Multika program – the input is the technology base, thus the single assessed versions
h) The sensitivity analysis and the influence of the minimum price to the placing
i) The execution of the chosen solving version and result checking of the executed version – are replaced in our case with the completion of recommendations.

8.1 Database of technologies

It was made up on the base of detailed recherches and data collection. Recherches gave us compact overview of technologies so that when making up the database we were able to focus on specific technologies.

Specific data about particular technologies were obtained from public organizations (Czech

Energy Agency, etc.), audits, companies (producers, contractors) and from the internet.

Eventually there were 164 various technologies in the database.

8.2 Team of experts

Team of experts was set up to classify and compare particular RES. 88 experts from different branches with various opinions were addressed to take part in the team. Each of them was more or less interested in RES issues in some way.

We tried to obtain wide scope of opinions for our survey, including positive as well as negative ones.

Eventually there were 38 experts taking part in our research. That means more than 43% of addressed experts. That surprised us quite nicely and we proved our presumption, that for further similar researches we'll be able to get sufficient team of experts.

Expert assessment was done by so-called Delft Method. This method consists of two or more phases when firstly all experts are independently enquired. After the first phase each of them is told results of the rest of experts. And then they may (but do not have to) modify their opinions according to other experts.

Following graph represents sums of standard deviations for all experts in dependence on particular criteria in two evaluation rounds. As you can see in the graph, lowest experts' agreement was in Soc1 (Number of created employee positions), Soc3 (Possibility of using low quality lands) and Soc4 (Degree of possible municipality participation) criteria. And that even after second evaluation round in which each of experts could confront his evaluation with other experts. It's clearly visible that social criteria are not discussed very often and contrary to technological and economical criteria impact to social ranks is being left out.

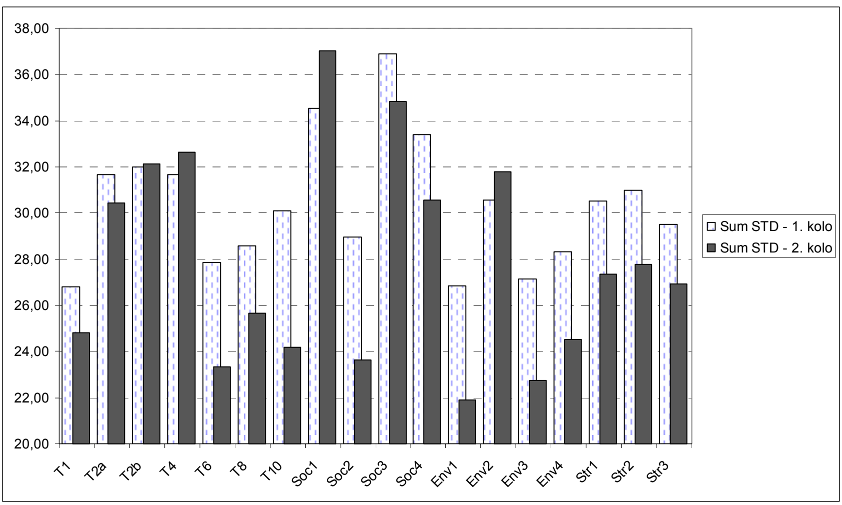


Fig. 2. Level of experts' agreement in specific criteria

8.3MULTIKA - computing program unit

MULTIKA is used for multicriterial assessment of RES variants according to specific criterions. Main goal of this program unit is answering non-trivial questions about variants comparison.

Users may use predefined settings for computing, but while solving specific issues it's possible to personalize settings.

After computing phase MULTIKA automatically runs graphic module, which provides graphic interpretation of results.

9 PROSPECTIVITY OF RES IN CONDITIONS OF THE CZECH REPUBLIC

There were three methods of multicriterial assessment used for computation and the final ranking resulted as weighted sum of standings in each of the methods. (The smaller the number the better the perspective is for using it in The Czech Republic conditions)

	1.	2.	3.	Weighted sum of standings
Biomass	73	31	36	40
Hydro-electric power plants	37	81	58	72
Cogeneration	74	109	77	104
Photovoltaics	125	123	88	121
Wind power plants	67	151	105	150

10 SUMMARY AND RECOMMENDATIONS

For the further development of this sphere the regular monitoring of updating weights and the criteria values assessment may be recommended. This will ensure the project continuity and enable monitoring and bringing the current state data into the subsequent development.

By regular monitoring of the expert opinion development and expert team expansion to the international standard, it is possible to identify current world view to the assigned problems. This enables to expect the development of every technology and to prepare system environment for it. From this reason it is possible to improve the web interface for the expert team not only by user more favorable version, but also by multilingual support. The expansion may also consist in the fact, that every user can define his own expert profile, where he defines his strong and weak points. That will help to set weights for expert system more properly.

It is possible to recommend the monitoring and identification of RES development barriers, in particular for technologies, which come out of the assessment as the most perspective. These barriers should be displaced. In this sphere the model TESES Multika can be used and could be completed for solving of this task. The barriers displacement seems to be an efficient tool for further RES development for the purpose of fulfillment of State energy conception and EU targets.

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