ION ANTONESCU[1] **Points of view**

PREMISES FOR CREATING THE DATABASE AND KNOWLEDGE BASE OF AN EXPERT SYSTEM FOR DYNAMIC MANAGEMENT OF RENEWABLE ENERGY RESOURCES UNDER UNCERTAINTY CONDITIONS

Abstract: *The paper presents the concepts and methods for the design and generation of the database and knowledge base of an expert system aimed to help the manager to trigger optimal decisions to economic and technical problems in the field of renewable energy under uncertainty and risk conditions. The database structure, the necessary fields and the data sources for renewable and non-renewable energy sources and generators are presented. The structure of the knowledge base and some decision methods and techniques used by the inference engine in order to connect the database and the knowledge base for generation of an optimal decision are also depicted.*

Keywords: *renewable energy, database, knowledge base, expert system, dynamic management.*

1. General concepts on energy, dynamic management and expert systems

Human kind uses two types of energy: intra metabolic energy originating from food and allowing the body to operate, and extra metabolic energy, allowing deployment work in most sectors of human activity: transport, water supply, agriculture, industry, construction, trade, etc. and having a significant impact on various social issues such as: environmental protection, health, national security, poverty, education and standard of living.

Energy management can have different meanings. From the economic point of view, the most general definition of energy management is judicious and efficient use of energy to maximize profit (or minimize cost) and enhances the competitiveness of a company.

There are two main objective of a energy management system (Warnier, van Sinderen and Brazier, 2010):

- The system should minimize the total energy consumption;
- The system should minimize the energy fluctuations.

These two objectives can be in conflict. Energy providers can prioritize one over the other by providing incentives.

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The energy management system’s objectives provide the following system's requirements:

1. The system should be flexible enough to optimize either of the two objectives; minimize the energy consumption or minimize the fluctuations in energy consumption;

2. The system should be able to adapt its behaviour at runtime and change the main objective, depending on feedback from the environment;

3. The users should be able to customize the system to their specific needs, setting limits to the adaptive behaviour of the system.

The global resources of classic fuels are depleting and have non-uniform distribution. The use of classical fuels is also associated with various risks such as pollution and global warming. It emerges the necessity of partial or total replacement of conventional energy systems with systems that use renewable energy sources. The scientific research in the field of renewable energy is growing faster, fact proved by the great number of patents, which have also an impact to the classical energy sources based on fossil fuels (Noailly and Shestalova, 2013).

In this context arises the need for a management of renewable energy sources.

Since the use of both renewable and classical energy sources is a process with a high degree of uncertainty and risk, energy management should be a dynamic management.

Dynamic management is a kind of management that takes in account uncertainty and risk and enables the change of its objectives accordingly to them. It can provide fast responses in case of critical situations, according to real-time adaptation processes executed by direct owners having access to knowledge of their enterprises.

Implementation of dynamic management without the help of computers is hard to achieve since it requires a large amount of work to meet the objectives of the current processes in real time. There are two classes of applications that can help the implementation of a dynamic management:

- Decision Support Systems or DSS;
- Expert Systems or Knowledge-Based Systems.

Decision support systems (DSS) are computer-based information systems that provide decision-making support activities in economic or organizational. A DSS system can serve management and planning services of an organization to help make decisions, to solve problems whose data can change quickly and are not specified in advance (unstructured decision problems and semi-structured).

Expert systems are computer programs that can reproduce the behavior and decision-making mode of a human expert to solve specific problems of a particular domain. They are specific generation computers will. In expert systems interconnections between data processed are made to meet a set of rules contained in a knowledge base of the system.

The most important component of an expert system is the knowledge (Tripathi, 2011). The power of an expert system resides in the specific, high-quality knowledge it contains about the task domain. In expert systems, knowledge is separated from its processing, i.e., the knowledge base and the inference engine come apart. A conventional program is a mixture of knowledge and the control structure to process this knowledge. This mixing leads to difficulties in understanding and reviewing the program code, as any change to the code affects both the knowledge and its processing.

Expert system contains a knowledge base having accumulated experience and a set of rules for applying the knowledge base to each particular situation that is described to the program. Sophisticated expert systems can be enhanced with additions to the knowledge base or to the set of rules.

The collective knowledge in any organization is an asset (Allen, 2010), and should be recorded and maintained like any other. A knowledge base is a specialized database for collecting, storing and retrieving that knowledge as individual articles. It's a repository of related experiences – problems and solutions, causes and fixes.

Knowledge Management can be described as giving relevant information to the right people at the right time and place (Rahman, 2011). It mainly concerns the using, spreading, sharing, representing and storing of knowledge. Knowledge is categorized into three types, explicit, tacit and embedded:

Explicit knowledge involves the people accessing the information they need. Periodically it is reviewed, updated, or discarded. Only the knowledge which is relevant and important is stored.

Tacit knowledge is internal knowledge that is context dependent, personal in nature, hard to define and mainly experience based. It may include cultural belief, values, attitudes, mental models.

Embedded knowledge is locked in processes, products and structures. It is difficult to understand and change.

Another important component of an expert system is the database.

A database (Robbins, 1995) is a persistent, logically coherent collection of inherently meaningful data, relevant to some aspects of the real world. The data is organized especially for rapid search and retrieval. The portion of the real world relevant to the database is referred as the universe of discourse.

Another feature that an expert system should have is the ability to work with uncertain or incomplete data. For this an expert systems use fuzzy logic (Siler and Buckley, 2005) and fuzzy numbers (Alecu, 2012) that enables intelligent representation of imprecise concepts, simulating human perception and facilitating the effective analysis of processed data.

Developing o an expert system dynamic for energy management would require the following steps:

- Creation of a knowledge acquisition module;
- Forming of a specific database on renewable and non-renewable energy sources and structuring it in a quantifiable form;
- Creation of a knowledge base on renewable and non-renewable energy sources and its structuring it in an algorithmic form;

- Developing of a meta-knowledgebase on risk and uncertainty factors in energy and structuring it in an algorithmic form;
- Creation of an inference engine organizing the relationships between the database, the knowledge base and the meta-knowledgebase;
- Development of an intuitive explanatory interface allowing the manager to communicate with the expert system.

The architecture of such an expert system is depicted in Fig. 1.

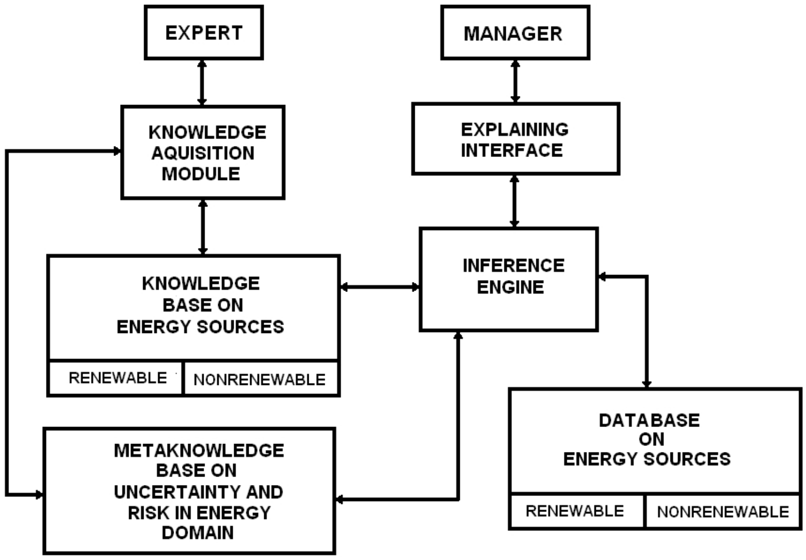

Figure 1. Architecture of an expert system for dynamic energy management.

2. Structure of a database and a knowledge base of an expert system for dynamic management of renewable energy resources

A database for an expert system for dynamic management of renewable energy should contain the values of technical and economical indicators for each type of renewable energy generator that would allow the optimisation of the price / performance ratio as function of the goal followed by the manager. We have established the following indicators as fields of the database (see table 1): specific power per surface unit [W/m^2], specific price per power unit [Euro/W] and specific price on surface unit [Euro/m^2].

Other fields contain energy production estimations calculated using renewable energy data retrieved from international database such as Retscreen International (Retscreen, 2015): annual energy production [KWh/m^2] annual benefit [Euro/m^2] and investment payback time [Years]. In table 1 we present the fields of the database for comparing tree types of photovoltaic cell panels.

Table 1

Structure of the database for renewable energy sources

Generator Type	**Specific Mean Power [W/m²]**	**Specific Mean Price [Euro/W]**	**Specific Mean Price [Euro/m²]**	**Annual Energy Production [KWh/m²]**	**Annual Benefit [Euro/m²]**	**Payback time [Years]**
Monocrystalline cell	146.64	1.67	247.03	266.3589	245.48	9.06
Polycrystalline cell	139.05	1.21	168.64	252.5713	232.77	6.52
Amorphous cell	87.33	0.86	69.84	158.6286	146.19	4.30

Table 2

Knowledge base as a decision matrix

$V_i \backslash C_j$	**C_1 Specific mean power on m²**	**C_2 Specific mean price on Watt**	**C_3 Specific mean price on m²**	**C_4 Annual Energy Production on m²**	**C_5 Annual Benefit on m²**	**C_6 Payback time**
V_1 Monocrystalline	1.0000	0.5165	0.2827	1.0000	1.0000	0.4748
V_2 Polycrystalline	0.9482	0.7122	0.4142	0.9482	0.9482	0.6594
V_3 Amorphous	0.5955	1.0000	1.0000	0.5955	0.5955	1.0000
weight	1	1	1	1	1	1

For the expert system to generate a decision the knowledge base must have the shape of an decision matrix containing the normalised values of the selection criteria calculated based on the values of the technical and economical indicators from the database for the three types of generators.

For the C_1, C_4 and C_5 criteria the normalised 1 value represents the maximum value and for C_2, C_3 and C_6 the minimum value.

For each criterion we have introduced a weightening factor allowing the manager to establish, based on its experience or using a fuzzy logic technique, the importance of each criterion according to the followed objective.

The inference engine can now take a decision in uncertainty conditions using one of the following techniques (Nicolescu and Verboncu, 1999):

Proportionality technique Bayes-Laplace:

$$V_{optimum} = Max_i \frac{1}{n} \sum_{j=1}^{n} R_{ij} \tag{1}$$

Using this technique the optimal variant is V_3 – Amorphous cell (see table 3).

Minimisation of regrets technique (L. Savage):

The matrix of regrets is determined:

$$r_{ij} = R_{ij} - Max_i\, R_{ij} \tag{2}$$

$$V_{optimum} = min_i\, Max_j\, (r_{ij}) \tag{3}$$

Using this technique the optimal variant is V_2 –Polycrystalline cell (see table 3).

The pessimistic decision technique:

$$V_{optimum} = Max_i\, min_j\, (R_{ij}) \tag{4}$$

Using this technique the optimal variant is V_3 – Amorphous cell (see table 3).

The optimistic decision technique:

$$V_{optimum} = Max_i\, Max_j\, (R_{ij}) \tag{5}$$

By using this technique both V_1 and V_3 are optimal.

Optimality Technique (Hurwicz):

$$H_i = \alpha \cdot A_i + (1 - \alpha) \cdot a_i \tag{6}$$

where:

α – optimism coefficient ($0 < \alpha < 1$);

A_i – the most favorable element of line i;

a_i – the less favorable element of line i;

$$V_{optim} = Max_i\, H_i \tag{7}$$

Using $\alpha = 0.7$ we obtain that V_3 is optimal.

Table 3

Decisional variants

Proportionality Bayes-Laplace	**Minimising Regrets Savage**	**$Max_i\, min_j\, R_{ij}$ Pessimistic**	**$Max_i\, Max_j\, R_{ij}$ Optimistic**	**Optimality Hurwitz H_i**
0.7123	0.0000	0.2827	1.0000	0.7848
0.7718	–0.0518	0.4142	0.9482	0.7880
0.7978	0.0000	0.5955	1.0000	0.8787
Optimum V_3 0.8652	**Optimum V_2 –0.0518**	**Optimum V_3 0.5955**	**Optimum V_1, V_3 1.0000**	**Optimum V_3 0.8787**

It is seen in medium conditions that the optimal variant indicated by the majority of techniques is V_3

The manager can develop what-if scenarios based on these techniques which should allow the decision making in the presence of risk and uncertainty. We have developed so far two scenarios:

A first scenario suposse what happens if the assurance of a minimal level of energy is neede the conditions of dimminishing of solar radiation with 50% due to climatic conditions. In this conditions we use the value 1 for the weightening factors of criteria C_1 , C_4 and C_5 which we consider representative for such a situation and a value of 0.5 for the other factors. In this case the decision techniques indicate both V_1 and V_2 as optimal variants.

A second scenario suppose the liberalisation of the electric energy price. For a decision in this case we use value 1 for the weightening factors of criteria C_3, C_5 and C_6 and a value of 0.5 for the other factors. In this case the decision techniques indicate both V_2 and V_3 as optimal variants.

3. Conclusions

The Management of renewable energy sources is a dynamic management requires decision making under uncertainty. To achieve its goals the management of renewable energy resources should use expert systems based on fuzzy logic. To make a comparison between different generators using renewable and nonrenewable energy, the database of the system should contain technical and economic indicators established to optimize the price/performance ratio of the objective function. To choose an optimal variant the knowledge base of the system should be a decision matrix containing normalized values of representative economic indicators with weighting factors assigned to prioritize them in the decision making, according to the experience of the manager or using fuzzy logic techniques. Thus various scenarios in uncertainty and risk conditions can be done.

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