SOLUTIONS FOR SELECTION OF FEASIBLE FUNCTIONAL MODELS OF POWER STATIONS BASED ON THE RENEWBLE SOURCES

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Abstract
Utilization of the renewable energy sources in island power station. The aim is to improve quality and safety of human life. Searching for suitable applications of implementing the functional models for long-term tests and validation of results.

Keywords: photovoltaics, power station, quality of life, ecology, extreme emergency

1 Concept of Verification of the Project Solution's Outputs

Renewable sources of energy, particularly based on the silicon photovoltaic panels are achieving an extraordinary advancement since the beginning of this millennium. Despite the fact, that their working principle is known already one hundred years, any massive progress hadn't occurred before the end of previous millennium. An extremely high price of investment into series production was a reason why there hasn't existed any assumption for sales due to such high price of product. Development charts of world's prices are known, but we don't mention them here.

The global warming of planet, justified by environmentalists as violation of carbon equilibrium caused by industrial activities of people, meant an expressive impulse for development of this area. It is beyond our cognizance to judge a competence or misleading tendency of these justifications, but power of their arguments and voice meanwhile transferred into behavior of countries at both local and international forum. Well-known is the Kyoto Protocol and the obligations of signatories resulting from it.

The Photovoltaics, as a source of electric energy that directly converts energetic radiation of sun into electric energy, offered itself as an alternative source of electric energy in addition to sources utilizing fossil fuels or nuclear energy. The legislatives of the World's economically most significant countries, as well as of European Union have included the obligations creating the regulated support for construction of photovoltaic power stations in such way that they will produce a significant percentage of world's energy consumption within short time period. It may be presumed that also lobbyists of investors have played an outstanding role in adjusting the legislation, which just in time sensed out an extraordinary investing opportunity. For illustration only we state that European countries set such conditions, that even at gradually decreasing subsidy to the purchasing price of supplied photovoltaic electric energy in years 2005 – 2011, the economic return of investment was shorter than 7 years at stable support of purchasing price in period form 15 to 25 years! (In Slovak Republic only 15 years) [1]. This called out the immense technological engagement of producers of photovoltaic panels, frequency inverters, engineering systems and supplementary electrical equipment.

What happened in this area from 2000 till 2012?

- Production of panels increased at least 100 times [2]
- Price of panel decreased to 1/10 (today under 0,5 EUR/W) [3] , [4]
- Several thousands of companies producing components were established, mainly in West Europe, USA, China and India. In the course of time absolute majority of companies moved its production into China.
- In some countries the photovoltaic electric energy reaches even up 5 % of total consumption of country, but regarding the extremely high subsidies, the subsidy of photovoltaics constitutes up to 20 % of final price for consumer.

The positive effect of this photovoltaic boom consists above all in fact that technical level of photovoltaic panels has been changed by jump. In particular, the efficiency of commercially available panels increased within 10 years to double and at a present the panels with efficiency of 20 % are available! In addition, the reliability of panels increased. I note that within the Project we pay big attention to the issue of panels´ reliability and continuously observe in details the reliability of more than 500 panels of all presently known principles from different manufacturers, which means evaluation of parameters´ variations for up to 35 000 photovoltaic cells.

The reliability of panels produced before 2000 reached values $\lambda < 10^{-6}$, what meant in the practice as many as 30 % failure during the expected life time of 25 years.
Today's reliability is higher by one or two orders. The main contributor of this effect was technological development of silicon ingots´ production. Consumption of the silicon crystals for the photovoltaics presently exceeds its consumption in production of the active semiconductor elements. A cheap way of drawing the silicon ingots was managed, where failure occurrence is lower by one order and diameter exceeds 200 mm.
The disillusionment from green shock meant in worldwide measure an expressive decrease of subsidies for purchasing the energy from photovoltaics. An unpredictability of its supply dependent on sunshine is considered as its primary deficiency. In this connection, it is worth to note that the subsidies for purchasing the photovoltaic electricity were not, or were only very few restricted in the poorest countries of Europe (Bulgaria, Romania). Nowadays (year 2013), Romania is the primary Eldorado for photovoltaic investors. Model is set similarly as it was before 2011 in Czech Republic or in Slovakia: building up the 1 MW power station is legislatively easier than building up the 2 kW small roof power station on the family house. It is not a surprise that substantial part of economical problems in the Spain is brought about by the huge farms of photovoltaic power stations in this country, where investors from around the world have grouped.

2 Photovoltaics – what source is it?

At building up the power stations supplying energy into distribution network (GRID-ON), we were interested mainly in the fact that this energy is „green“, maybe the greenest of all the known sources. However, in the performed research within this Project we had also another priority. We consider the solar energy for our application as only one available or at least as the most available in the territory resp., where we would like to acquire and utilize it.
The GRID-ON power stations and way leading to them, as it was briefly outlined in the previous chapter, we understand as a positive impulse – breakthrough in until then very slow development of the photovoltaics. Although the photovoltaics have been developing expertly and scientifically since the beginning of the sixties, the development didn't reach such level to be applied in the common life of people. And if so, it was only demonstrative. Only overspanning the stagnation of commercial utilization by means of generous granting policy of governments resulted in above described extraordinary speed of industry's development.
Today, from our position it is useless to judge reasons and their rightness in development of GRID-ON systems during the end of the first decade of the third millennium. For us, the important conclusion is as follows:
For our intention to develop, project and produce the photovoltaic power stations for enhancement of the human life, we had obtained – thanks to commercial development of GRID-ON systems – the excellent technical resources for an acceptable prices [5] . At establishing this research (in 2008) we anticipated that development would go in this way, but reality markedly overcame the expectations.
While the recognition of resources for implementing the target constituted a framework of our research in the first years, today's laboriously acquired databases of expert system are rewritten in only three-month periods! While two years ago it was possible to find maximum 2 – 3 ways to the target behavior for given application through 4 layers (energy balance, designing CAD-CAM means, database of available elements, and expert system, implementation), nowadays thanks to second and third layers we can find tens of ways! This will allow to improve the quality of future solutions by extended searching using another 2 layers - required comfort and price level.

3 The extension of research intention

An assignment of the areas and activities for the applicator of this Project's outputs (also for its validator), by electrification of which the human life will be of better quality, is every time an incentive from outside. It is not allowable to force the author of technical solution to make any extra-disciplinary decisions. The author of technical solution can know the problem of human life in various environments, human positions and further criteria only as a laic, human, but not expertly with linkage to all possible relations.
On the other hand, the professionals solving the problems of people in non-standard situations mostly don't dispose of the technical knowledge that could help them to find the proper available technical facilities for solving the particular problem of given group of humans.
During solving this Project, but also beyond its frame and financing we have created a consulting forum between our solving persons and professionals in area of health service, educational system, environment protection, international help, integrated emergency system, control of navigating systems and communications, agriculture and defense. We had own objective to specify the area for which solution of our validation functional sample of power station for renewable sources, dominantly focused on the photovoltaics, was determined [6] .
The result of these discussions presents a set of areas, which can be sorted into several groups, while it may be expected an expansion of number of these groups in accordance with the degree of cognition and experience acquired from applications and cooperation of likewise aimed research teams.

These groups are as follows:

- Health service
- Human nutrition
- Education and culture
- Informatics
- Activities in extreme emergency
- Drinking water and watering of nutritive crops
- Accommodation
- Special agricultural activities (cultivation of medicinal plants in their natural environment, pastoralism in the outlying areas, beekeeping by nomadic way)
- An independent group consists of community activities, which however can be individually, partially separated into above mentioned groups.

In the following, we will try to explain how our renewable source of energy under consideration can bring progress and improve quality or protect human life, eventually. All the considerations originate from the assumption, that problems are solved in the territories where electrical socket supplied from distribution network is not available. Here we also don't solve an economical availability of solutions that we offer. As mentioned above, the total price level of these resources thanks to the considerable development of the GRID-ON systems in the past also dropped substantially and these will be expressively available also for the poorer countries and regions.

4 Determination of parameters for validating functional models

The four areas were selected first of all due to the limitation of financial resources and extreme time severity of verification, for which there will be designed, built up and verified functional models of power stations based on the renewable sources, with the dominance of photovoltaic source. We came from an appraisal of the urgency of demands required by above mentioned groups and from availability of specialists for these groups, who are able to cooperate in preparation of assignments and having capability and willingness to be involved unselfishly into validation of functional models.

The following areas were selected:

- Health service
- Accommodation
- Activities in extreme emergency
- Beekeeping
- Sheep pastoralism at the outlying areas migrating farms in the Slovak conditions is very interesting area. However, this case misses any farming subject willing unselfishly participate in long-term tests of the functional model.

4.1 Health service

Every health service has an aim to provide medical care at such level which as much as possible corresponds to the current world's level. For the area, where until now the medical care wasn't provided, even the presence of health worker with first aid bag means some advancement. Our pilot functional model of power station for health service is just focused on such conditions [7], [8].

The health care can be divided into: diagnostics and treatment,
medicament treatment,
prevention.

Within frame of above mentioned consulting forum there have been defined parameters of minimum equipment for medical ambulance, capable to provide for all above mentioned functions in the outlying location. Based on this information, a quantification of energy consumption for individual instruments and equipment was prepared in the following structure:

- examination instruments
- computer equipment
- sterilizer
- refrigerator
- lighting
- air-conditioning
- heating

In tropical and subtropical areas, the air-conditioning can be supplied from power station only during the surplus of energy supply. The heating was excluded from the potential appliances. Based on getting acquainted with current condition of this technique, a container system of medical ambulance was designed, where a standardized steel container for transport of goods is used as transporting packing of power station and ambulance, and after being transported to the destination it serves as basic static carrier of photovoltaic panels and wind turbine, and after installing of power station serves as ambulance. The idea of container ambulances and hospitals is not new and is utilized in the world. But idea of utilizing the renewable energy as the main power source for medical ambulance is new or innovative, respectively. We have studied several types of such ambulances from various manufacturers with the aim of appraisal of its suitability also for purposes connected with power station's transport and installation. We accepted a solution with standard heavy 20 feet ISO container, which is transportable by using the common forwarding means.

Basic technical parameters

Container dimensions:	W: 2540 mm, H: 2540 mm, L: 6000 mm
Volume of compartment for batteries and inverters:	3 m^3
Daily consumption of ambulance:	15 kWh from battery
Supplementary consumption of surplus energy:	air-conditioning 10 kWh per day
Emergency energy reserve (without sunny days):	10 kWh
Maximum consumption of appliances:	4 kWh
Maximum consumption in emergency:	200 W
Maximum power of wind generator:	3 kW (in 400W functional model)
Backup source of energy:	Diesel aggregate
Maximum power of diesel aggregate:	6 kVA
Life of batteries:	1500 cycles, up to 4 - 5 calendar years

4.2 Accommodation

A half of human race live in dwellings without electricity supply. This situation couldn't be changed quantitatively in foreseeable time with respect to the necessity of enormous investments into equipment for energy generation and distribution on the central production base.

The second extreme is presented by the unconnected households in areas, where the electric connection is feasible. In both cases the reason is same – shortage of money – either at investor, or absence of permanent stable income at side of consumer [9].

The connection of household to the electric supply, even though with limited power, means gigantic jump in living standard of such people. Would somebody from civilized community be able to imagine own life without light, fridge or TV, and other products? Maybe during two weeks of romantic holiday?

Groups of inhabitants live in the extreme poverty also in our country that misses electric connection in households. The charitable help for these groups is each time only single, it never contribute to life on long-term basis. Just the "island" micro power stations can play a meaningful role in increasing the living standard of disadvantaged and earmarked population, living in unimaginable poor and primitive conditions.

By consulting this problematic with a human-legal and charitable organization, exceedingly active and in field successful, we succeeded in establishment of minimum standard equipment for such household by appliances:

Refrigerator ….. consumption 200 W……..	1,0 kWh/day
Light ……. 5 x 10 W …….	0,25 kWh/day
Radio receiver ...10 W …….	0,05 kWh/day
TV set ……... 100 W ……..	0,6 kWh/day
Other ……...	0,35 kWh/day
Total:	2,25 kWh/day

With respect to the all-year operation, it is necessary to back up the photovoltaic source by the wind turbine. For this type of island power station, the price is the second most important parameter immediately after the technical parameters, and means the base for availability and scope of implementation. We can presume that implementation will be planar – tens to hundreds in one agglomeration. And even the users in term of operation will be absolutely technically unqualified. The power station must also contain a remote monitoring system on GPS base, with central data processing of each power station in real time. The functional model will consist of two types of island power stations (so called the minimum version and standard version) and minimum configuration of monitoring system (128 modules).

This type of power station is extraordinary suitable sponsoring object for individual donators or organizations. Through this one-time grant the donator provides for the beneficiary family help for long-term period (several years), what would allow its cultural and educational growth.

4.3 Activities in extreme emergency

The extreme emergency is a status of society, when the systems securing human lives in case of natural catastrophes, industrial disasters or sudden political events, are failing. The fact, that these events are not exceptional, is proven by recent years´ floods in Czech Republic in 1997 and 2002, underground earthquakes and tsunami waves in Indian Ocean, or earthquake with subsequent tsunami and destroying of seashore and nuclear power plant in Japan. In case of such disasters, first of all usually the electrical distributing network is disabled, from which communication systems are dependant. It is astonishing, how primarily rescue units are insufficiently furnished by communication systems throughout the world. These are mostly oriented at GSM or similar network provider. But this in case of dropout of electrical network collapses fast. We know many instances, when the rescuers had no possibility to charge batteries of their radio-stations, and they were not able to communicate mutually for several days.

And for all that, the fast contact with outside world is basic condition of efficient organization of rescue works. This can be ensured through the individually operated communication nods, independent from function of global communication and energetic networks. At other world catastrophes it was showed, that the most prompt services were provided by the ARES system (Amateur Radio Emergency Service) [10], which is operational in the whole world on voluntary principle without any financial profiting. It is very good coordinated world-wide, while in each moment about one million of its members are capable to engage into the rescue transfer of messages. Also in our country, the ARES is involved in the rescue system its members regularly take part in local and international exercises. The significant element in the ARES system is that its regulations exclude possibility of any financial or by money appreciable profit resulted from this activity.

In our conditions we are trying to build up communication nods under county coordination. The critical thing for functionality of such communication nod is the instantaneous operating readiness of positioned equipment and standby storage of energy with immediate disposition for at least 3 days of operation without the sunlight and wind, and 14 day stock of fuel for the spare (supplementary) supply from diesel-aggregator. It looks that the container mobile configuration is the most suitable for this purpose.

We have consulted topics of this rescue system with national coordinator and also with involved persons of the corresponding body of state administration, and on the basis of information obtained and a promise of cost free participation in long-term tests, we defined parameters of the communication nod with power station based on renewable sources:

Basic technical parameters:

Container dimensions: width 2 m, height 2 m, length 6 to 8 m
Consumption of radio station: 0,4 kW, consumption 9,6 kWh/day
Consumption of other appliances: 2,5 kW, consumption 0,5 kWh/day
Batteries capacity: 28,8 kWh
Diesel-generator power: 4 kVA

Frequency bandwidth of connecting device:
1,8 - 30 MHz
144 - 146 MHz

Connectivity to other telecommunicating devices:
GSM – all operators
Satellite telephone
CB – bands 27 MHz
Microwave internet
Stationary telephone network

Power of photovoltaic panels: 3 kWp

Maximum daily delivery of energy from FV panels:
18 kWh

Maximum number of battery cycles: 200
Other requirements: capability of transport by road communications

4.4 Special agriculture

Even though generally agricultural production (especially vegetable) is not dependent on electric energy, but processing and yielding of agricultural products, as well as animal breeding without electricity would drop to the medieval conditions. During consultation about utilization of island power systems in agriculture employees of agricultural research directed us to two following areas.

4.4.1 Mobile photovoltaic power station for beekeeping in nomadic way

The migratory way of beekeeping is the most effective method of intensive keeping bees [11]. The bees pick products from blooms of plants and transfer on its body pollen grains between blooms and pollinate them by this, what is secondary utility from collecting the nectar. It is known, that the harvest of industrially cultivated crops (colza, sunflower, all kinds of fruit, and others) commonly increases by 40 or more percent due to intensive pollination. When the beekeeper moves the bee families directly to the field of cultivated crops, multiplies efficiency of bees activities. In the country with different climatic zones it is possible even to increase this efficiency by wandering (migrating) with bees to the blooming plants in such way, as it time of blooming passes. After ending of blooming period in one climatic zone, it is necessary to take the honey away from bees, so they feel a need to pick the pollen again. This normally happens at the basic farm. But this causes time and financial losses, because colonies of bees return repeatedly to the farm. It is ideal to rid the bees of honey collection directly at the area of picking and immediately after to move them to the more northern pasture-land. This withdrawing the honey from bees however at intensive beekeeping requires electric energy for driving electrical devices. And this is just an exemplary possibility of utilization of the photovoltaic power station.
After detailed familiarization with the technology used and working procedures, we established basic technical parameters of power station for nomadic carriage containing technology for honey processing. Such technological carriage is capable to serve for other 5 to 7 simple nomadic carriages at the pasture-land.

Basic technical parameters

Consumption of technological equipment	1 kW
Daily consumption at all-day operation	8 kWh
Batteries capacity	30kWh
Peak power of photovoltaic panels	1,5 kW
Operating life of batteries	200 cycles
Maximum load consumption at off-season period	20W

4.4.2 Mobile power station for pastoralism

In the recent years the meaning of pastoralism increases in the mountainous areas of Europe by reason of decreasing the acreage of intensively cultivated agricultural soil. It is withdrawing from the fixed locations of sheep farms to the migrating ones, which are able to better utilize the potential of pasturage that is in excess. A comfort of workers, who are long time away from their homes and expect in the temporary field accommodation similar living conditions as they have at their homes, is the meaningful element of pastoralism. As the next, it is very strict hygienic conditions for milk processing, which guarantee health protection of consumers. These two conditions cannot be guaranteed without electric energy in the areal of sheep farm. But today's situation is that the supply is provided by permanently running petrol aggregates, which is in the big contrast with ecologic essence of pastoralism [12] .
For this agricultural sphere, the island photovoltaic power station is offered practically as the ideal source of electric energy. The pastoral season takes place in months March to October, when the most balanced solar irradiation occurs within year. This minimizes requirements for multi-day accumulation of electricity during days without sunlight. In case of mobile configuration of power station, it is possible to orientate it to the sun several times a day, what increases even by 40 percent its yield. These possibilities were accepted by agricultural experts with big interest and there is a supposition of high quality testing of parameters and behavior of such power station in practice.

Basic technical parameters

Daily work	15,6 kWh
Consumption of technological equipment and lodge (hour average)	0,65 kW
Maximum power of inverter	3 kW
Mains type	1-phase, 50 Hz
Battery capacity	40 kWh
Power of solar panels	5 kWp
Mobility	Two-angle trailer

Total weight	2000 kg
Operating life of batteries	5 years
Operating life of technology	10 years
Installation time at site	2 hours

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