One Holistic Vision of the Future Energy Systems

The Future Energy System as a Tissue of Intelligent Energy Systems

Căpățină Octavian

Renewable Energy Department, NEGOIU, Cluj Napoca, Romania

oct.capa@gmail.com

***Abstract*-The aging energy infrastructure, politically controlled fossil resources, the rise of renewable technologies, the geographical distribution feature of renewable energy, climate change exigencies, the increase in domestic electricity consumption have forced the power industry to examine the status and health of the electrical systems. The advancements in real-time processing and computing power made searching for new approach regarding energy systems possible. Solutions are on their way: Smart grid, as a joined space of energy and information, Enernet and Bob Metcalfe's proposal for an analogy with internet. In our turn, we proposed another view to the energy systems and, at the same time, a holistic vision and an analogy with the autonomous functioning of the biological cells. In our view, the energy systems must be thought of firstly as part of the nature; secondly the system must be conceived as a whole that includes consumers, generators, storage facilities, metering infrastructures, grids and rules; thirdly, to get safety and efficiency it must be modular/cellular and able to do its best as well as part of an ensemble as well as stand alone. To achieve this final require we have made an analogy with the biological cell.**

Keywords- ***Energy Systems; Intelligent Systems; Cell Structure; DNA***

I. INTRODUCTION

Today's electrical energetic systems were basically conceived by Nikola Tesla at the beginning XX century and almost what is in function today were conceived a half century ago. There are obsolete and a new approach must be outlined. An integrated vision of the future energy systems means at least to see the energy systems in the nature as a whole and to see all the components of the energy systems instead as today with the smart grid approach. In the approach named smart grid, in the evolution, only some parts of the energy system are shared: grids, metering infrastructure and communication. However, if the vision is not valuable, looking in the future or correct at the starting point, that could lead to a huge loss in the future. To tackle a new vision one must answer to some questions regarding what we really want in the future.

A. Smart Grid or an Efficient and Safe Energetic System?

Today's smart grid – is only a half made thing, because we must see the whole and not just some of the parts of the system. After all, we do not want a smart grid, we want an efficient and safe energetic system**.** Utmost one can accept the smart grid as a step toward an efficient energetic system. The first problem of a system, regardless of its nature, is its efficiency. Consequently the first problem of a system that consumes energy to work properly is the efficiency of this consumption.

Therefore a safe and efficient energy system that can integrate distributed renewable generators and storage facilities is desirable. One must think about an efficient and intelligent energetic system, IES, as a whole [1]. On the other hand, one can observe that very large power plants (including nuclear plants) are no longer desired due to environmental constraints and to transport losses. At the same time, small renewable sources appear everywhere along with the distributed generators concept. The consumers were always distributed; in the future, the generators should be more and more distributed. As a consequence, the original radial grid and the current simple redundant grid would move slowly to a complex cellular grid. However, in the real world, the radial grids still remain the appropriate energetic systems on narrow valleys.

B. Could It Be Enough to Review the Energetic System?

We must think at the same time not only about all the parts of the energy systems (generators, consumers, rules and behaviors, storage facilities) but we must rethink the energy system in the nature as a whole. Along with climate changes which demand cutting drastically carbon emissions, there are two other strong reasons to adopt renewable energy sources:

- to avoid large energetic constructions like nuclear plants and huge hydropower plants and to save the fragile Arctic, or offshore oil in Brazil from the destruction of oil exploration,
- the new oil resources extraction need as large financial funds as the new renewable energy developing

Experts from Global Wind Energy Council, European Renewable Energy Council and Greenpeace [2] have included in their report a roadmap for reducing oil demand by around 80% while achieving economic growth by replacing fossil fuels with renewable energy and energy efficiency. The new energy scenario presented this year states that in the future renewable energy technologies, especially wind and solar, would provide more than 90% of global electricity, heating and refrigerating and more than 70% of transportation needs. Related to transport, the report emphasizes the stringent need for new technologies, in order to reduce vehicle consumption.

C. What Is the Political Solution for the Energetic System?

If we want an integrated view of the future energetic systems, then the political aspects must not be avoided. And here we want to put emphasis on only one aspect. Today's world is led by democrats under strong interests, by autocrats, by religious leaders, by insane persona, and all more or less educated. A Romanian foreign minister said that he had the proof that God exists: the world leaders' power was only matched by their ignorance and still the world continues to exist, because God wants this! So what technically could be an advantage, a huge grid that mitigate the renewable problem along with strong and concentrated generators, like nuclear and hydro plants, could be the weak point of the future energy systems. Modular/cellular systems able to work not only integrated in a larger system but to work properly isolated if necessary could be the better solution from this political point of view. An energetic system must be divisible in smaller systems which can work autonomously.

II. RENEWABLES WITH THEIR DRAWBACKS

There is no doubt that renewable's share in the energy sources is on the growth. Germany has managed renewable energy production in such a manner that those sources had reached 20% of the total national power consumption in 2011 and are expected to reach up to 30% in 2016 [3].

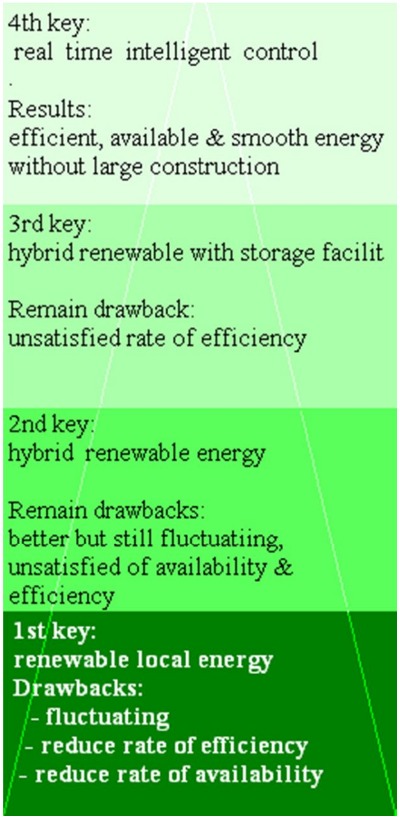

Figure 1Conserving nature in a less carbon paradigm

If the real future solution for mankind is renewable energy, for more reason as was here presented, then one must see that the renewable energy, as local and distributed energy systems, comes with some drawbacks: high fluctuation rate, reduced rate of availability and efficiency. If the systems are isolated these problems are more acute, if there are connected to the grid the problems are significantly reduced but still there. The renewable energy systems are rather small and distributed systems. The problems of renewable energy, with its arbitrary feature, should be translated through grid to the whole of the energetic system. In other words an ensemble could mitigate problems of its parts in case the parts with problems don't have a high weight in the whole ensemble. In the Figure 1, from bottom to top, these drawbacks of the renewable energy systems are presented. The solutions identified to overcome these problems are outlined too in the same figure.

Even a mix of renewable with storage facilities - that improves the problems of availability, efficiency and fluctuating - is susceptible to lose energy if the system is not properly managed.

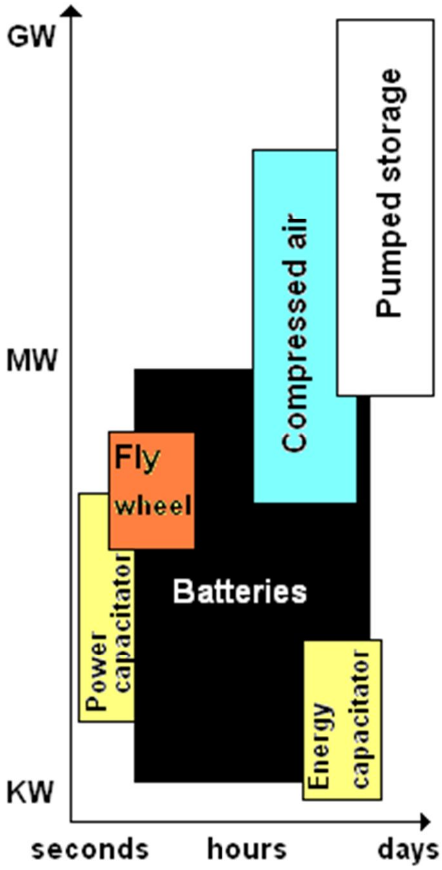

Figure 2 The storage technologies in a power-time diagram

As the renewable technologies differ and a mix of renewable technologies could mitigate their main drawback, so are the storage technologies different from one to another and only a mix of storage technologies could be the answer of the 3rd key. In the Figure 2 are presented in a diagram of power-time the most used storage technologies today. For example in some applications there batteries and high power capacitors are desirable, while in other cases the solution is a mix of fly wheel and tank of compressed air and so on. All these different types of energy sources, different types of storage technologies and different types of consumers make more and more acute the need of harmonization to reach together safety and efficiency. As the renewable energy sources will have an increasing share in energy sector, the problems of it brings along – unavailability, fluctuation and efficiency - must be dealt with. And this job of harmonization could be done by a new component – a real time intelligent controller. We will revisit this situation later on, starting from another point of view.

III. INTELLIGENT ENERGY SYSTEMS – INTELLIGENT: GENERATORS, CONSUMERS, STORING FACILITIES AND GRIDS

An energetic system as a whole means generators, storage facilities, consumers, lines, measurements and operation rules. An intelligent energetic system, IES, is composed of i) intelligent consumers, ii) intelligent generators, iii) intelligent storage facilities, iv) intelligent (today smart) grids, v) metering infrastructure and, very importantly, should be accompanied by vi) behavior rules and vii) real time management of the power flows. At the same time, IES must be scalable in both directions, up and down.

The IES concept is applicable to a small, a local, a national or to a continental level. Every IES level, except the continental one, at the same time must have the advantage to be integrated in an upper level and to survive in a case of upper level failures.

A. Intelligent Consumers

In this new vision, what does an intelligent consumer mean? An intelligent consumer must decide alone to go into standby or to accelerate the working or loading cycle. Appliances like washing machine, boilers or electrical vehicles will start and stop working according to their own decisions based on the owner program and the energy prices! Another example, in some instances, certain medical devices could require a safety energy supply, meaning that other consumers under the same fuse, which are not useful for the immediate medical task must go into standby. Besides the price decision every consumer could be placed on priority levels. New industrial hipoenergetic technologies will be developed that reduce the peak of consumption curve. And these new industrial technologies should be intelligent so the expected cumulative effect will be significant.

B. Metering and Communications

Metering infrastructure and communications is another component of IES and should assure remote services. The IES assumes a communication layer too, regardless of the type of communication technologies used (wireless or broadband over power line etc). But transmission technology used must have at least some characteristics, such as: bandwidth, IP-enabled digital communication, encryption and cyber security support. At least in a simple and isolated energetic system, "sui generis" information, however spread in the system, is the generator frequency. And a lower frequency could mean for an intelligent consumer to delay its working, or for an intelligent generators to bring more power into the system. In a more sophisticated energetic system the information about the available power is not enough, consumer must at least know the tariff plan. In a future approach the tariff plan could be more flexible than it is today in Romania.

C. Storage Facilities

There are many storage technologies (Fig. 2), every one is suitable in some conditions and applications. To improve the efficiency of energy systems one answer is the use of storage facilities and better yet the intelligent integration of renewable with the storage facilities. From the efficiency point of view one must emphasize that storing means more than those storage facilities where the output is just electricity. "Storage", in larger interpretation, means thermal final use - as heating or refrigerating (Fig. 3) too. Storing exceeded power through heating water could be another way to increase the overall efficiency of the energy systems; the minimum condition is that at least one component of the system must be intelligent.

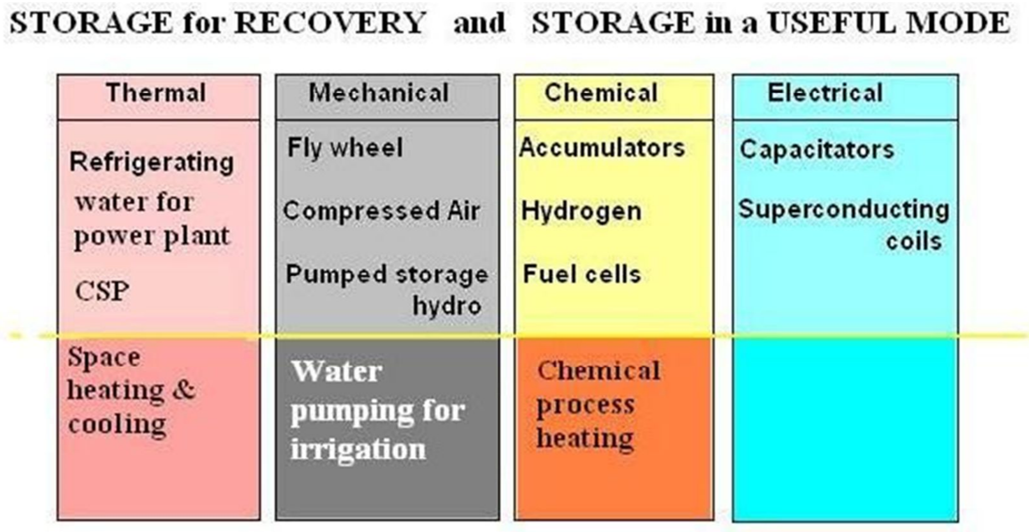

Figure 3 The kind of storagy technologies

D. Rules and Consumer Behavior

Rules and consumer behavior means, of course, a correct attitude with regard to consumption, which implies an intelligent behavior of all: the human beings, corporations, industrial processes (from the energy point of view) and appliances. The best and the simplest rule is the tariff constraint but its hourly prediction plan must be known. And until the new paradigm of intelligent system as a whole, the great industrial consumers are themselves accommodating to get maximum power in the night.

E. Electrical Vehicle

EV is a new electric device - it is both a consumer and a storage device. In the future, when a large fleet of EV's is expected, using them without the IES rules could be a disaster, while, in the case of using them in an intelligent "environment", their storage facilities could have a significant advantage over system stability and efficiency.

All these could happen at a higher level if all consumers are themselves intelligent and are used in an intelligent IES context. Intelligent consumers as well as intelligent storage facilities or intelligent generators are very plausible now, technically and financially. Once the IES concept will be accepted, in the developing phase, the components of the system will be accommodated with consequences of IES. Significant financial effort must be exerted in the generator and communication spheres. Another effort must be done in the domain of rules and standards. Part of these rules or all of them can be encrypted in every cell. After the rules and the standards are agreed upon the new generation of energy devices will appear, and for the next 20-30 years the present energetic components will work together with the new intelligent energetic devices. However IES, seen as a global entity, should change the current view on energy systems.

IV. STRUCTURE OF AN ENERGY SYSTEM AS A TISSUE COMPOSED OF CELLS WITH EMBEDDED BEHAVIOR

The structure of the IES must be modular. Such a structure has the advantages of being open, like a tissue of cells. The generic IES is composed of cells or a cluster of cells. The subdivisions of the IES are in their turn a smaller IES and so on. The IES must be able to operate isolated, to integrate subdivisions or to be integrated. It is very important that some subdivisions or cells could temporarily operate in an autonomous mode. In other words, even the structure of IES must be smart. Not all cells must contain all the types of components. In some cells the storage facilities could be missing, while other cells could be composed only by generators and consumers. Ideally, every cell must have multiple redundant ties to grid (Fig. 4). Some IESs are frontier IESs, behind them are wild mountains, ice or desserts.

From a power point of view IESs could be nano (<10W), micro (<10 kW), mini (<1 MW), local, national or continental. We could adopt for the nano, micro and mini IES a more specific name: Intelligent Energy Cell – IEC, in which case the acronym IES should remain for larger systems. Finally, every cell must be intelligent, self managing, having its own encrypted behavior, having its own "DNA". Due to this DNA, or distributed intelligence, in the future, large IES based on IEC could operate efficiently and securely without central dispatchers. Such architecture: IES of IESs, IES of IECs and IEC of IECs simplify coordination and communication without losses in synchronization.

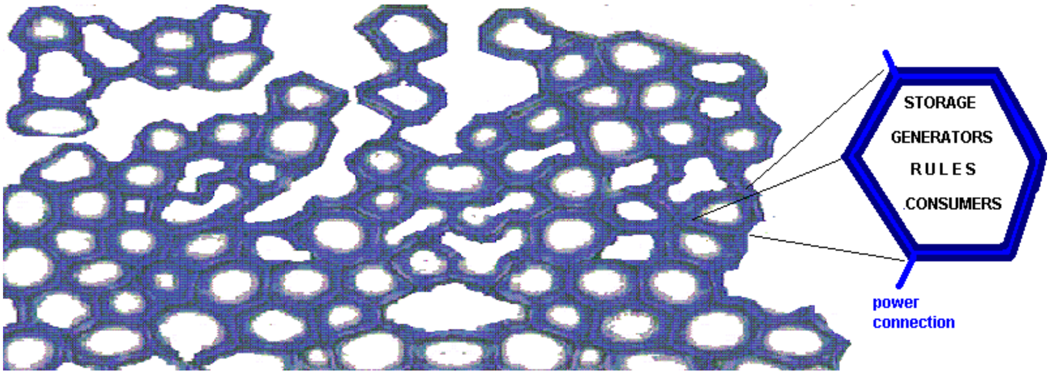

Figure 4 Tissue of cellular IEC / IES: island IES and large IES

V. THE SAFETY AND EFFICIENCY ISSUE - DNA

How will the intelligence of such a system be in the future? Should the intelligence of IES be concentrated as today's dispatchers or should it be dispersed in every cell of the system? A distributed intelligence to every IES/IEC component is one way that reduces the need for central control; more than that it is a condition to avoid large energy blackouts. Another advantage of disperse intelligence to low level systems, paradoxically, does that make it possible for huge system to work better. We imagine it like in biology: every cell has its own DNA, where all the possible interactions of the cell are encrypted (Fig. 5).

The IEC would have its own real time action program. The proper "DNA" - the embedded behavior of every IES component and/or IEC, could be the future of the energetic systems. This encrypted intelligence will manage both the inner IEC relation and the inner relation in the foreign context demands. The external demands for power (peak consume) or for storage capacities (power excess) are enough for a proper DNA to have a mutual and profitable relation in a larger IES context. As a logical consequence, since intelligence is equally distributed to every actor of the IES/IEC, the need for central control decreases. Perhaps it is too soon to see the central dispatcher disappear, but this could happen in the future.

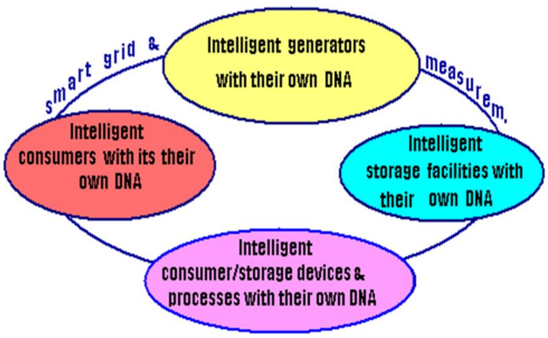

Figure 5 The IES concept

The local intelligence could go so deep that one can try to deny it but still the DNA concept remain; for example on a staircase in tower or on the highway the lamps are turned on only if the precedent lamps are turned on or some movement is encountered. Is that intelligence? Never mind the answer because the behavior of lamp with moving sensors is saving energy.

Such ensemble could be seen as a device/cell with its own DNA. There is no communication, nor dispatcher, nor other intelligent controller …..

VI. SMALL ISOLATED IES/IEC.

Even in continental areas, like USA, isolated IES/IEC become significant these years [4] and it is normal - due to the renewable development and its wide geographical spreading. In the future such isolated IES will be more and more significant in our life.

In [4] “Utility” refers to generators delivering to the grid and “NUG”, NonUtilityGenerators, to those untied grid generators which deliver energy to local consumers. In other words NUG are what we call isolated energy systems. After [4] who refers to the EIA “*Annual Energy Review, 2001”*, in the 2001 from 3600TWh produced in USA approximately 25% were produced in isolated systems.

The isolated energy system cover many like: islands, remote scientific research stations, some secret intelligence facilities, gas or water pipe line monitoring systems, but also local irrigation facilities or standby renewable generators for disaster situations, etc. A large number of energy systems based on small arbitrary renewable sources would ask for more and more storage facilities like compressed air, pumping water, heating and refrigerating, hydrogen generation, simple batteries or fuel cells and capacitors in order to be efficient and available 24h per day. Isolated IES/IEC is more complex than the grid tied ones and more difficult to be managed due to storage facilities. But storing facilities cost. To reduce this cost and the whole cost of the isolated IES/IEC one must add intelligence. The first IES/IEC that will need or ask for “intelligence” in the future should be the isolated ones; for example a wind or a hydro turbine in a small and isolated energy system to overcome the security problem of the generator, problem which doesn’t exist in a very large system, because a large energy system could be seen as an infinite system compare to small wind or hydro generators added.

As consequence the first implementation of IES concept would cover the area of isolated energy systems, even if it means that the IES concept will be put into operation in a reduced/corrupted form. Today, components are not intelligent, so the future small isolated IES/IEC will be built with these common components plus a new intelligent device – a real time controller (Fig. 6). The DNA of the small isolated IES/IEC serves all components of the cell.

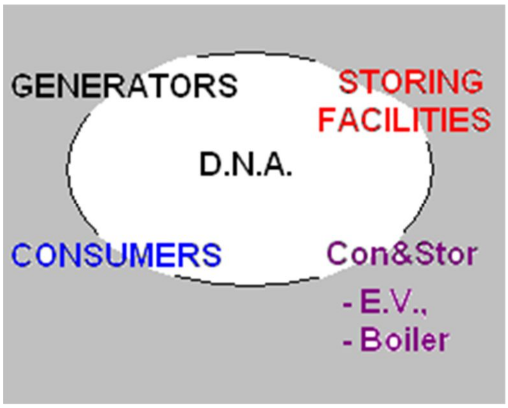

Figure 6 First generation of small IES/IEC

Today, in such small isolated energy systems, the security of the generators is obtained by losing power on diversion loads. But this is not the single problem of the small isolated energy systems. Another problem is the availability of the power or matching the production with consumption in a reasonable financial manner. Controlling the isolated IES/IEC is more sophisticated then controlling grid tied IES/IEC, as a consequence encrypted “intelligence” will appear in this type of systems.

Once the idea is launched, the necessity will be fulfilled with what I mean “DNA” - the component of encrypted intelligence. A practical manifestation of the DNA solution is the intelligent real time controller.

The difference between IES and small isolated IES/IEC is that in the first case the DNA is in every component of the systems, and in the small IES/IEC this intelligent real time controller is one for all components, at least in the first phase of IES developing.

VII. THE AVALANCHE PROCESS

The IES concept has plenty of consequences besides those intrinsic to electrical energy systems. For example if it is accepted that, for the sake of efficiency, the storage facilities also are involved in heating water for industrial and home necessities and refrigerating than new isolation materials must be developed. The power excess existing in the night in the IES could be used to heat water for day usage, flattening the consumption curve. But the usages of the heated water over 12 h ask for better insulation materials. However new technologies like fuel cells, Zn batteries, new photovoltaic conversion technologies and many others are in different stages of developing. And here, in developing new technologies, the great financial effort lays. Adapting the new technologies to the IES concept is the easiest part both technically and financially. As one must view the new energy systems as part of Nature the bio fuel and biomass must be taken into account. One must put into balance what mankind earns from bio fuel and what is lost by deforestation. And here comes another step of the holistic vision – the IES as a part of a new energy system, NES (Fig. 7- the second ring).

VIII. CONCLUSIONS

To develop a new electrical energy system first one must see this as part of global energy system and secondly as part of the Nature (Fig. 7). Thirdly one must have an integrated vision, over **all** present components but also over the future components like EV, or industrial fuel cells that will come. And last but not least the new electrical energy system must survive as numerous autonomous small entities to assure basic services to local communities in a world with substantial potential of individual and state terrorism.

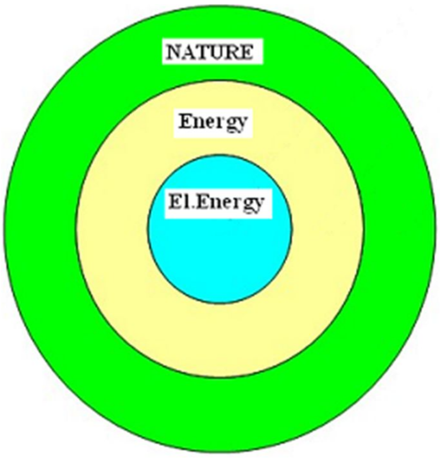

Figure 7 IES as part of Energy and Energy as part of Nature

Nowadays, advances in artificial intelligence, data communications and real-time processing are quite sufficient to support the concept of an IES, which must accommodate suppliers and consumers from a wide range of circumstances, at greater economic efficiency and high level of safety. The intelligent consumers (appliances, industrial processes with rules and smart behaviors) and the special consumer & storage entities will play a major role in the proposed IEC/IES. In the case of such a development, at the end, when all components are intelligent, even a national IES, for example, could work without any central dispatch. Very important for a large IES is that it could be divided into subdivisions which in extreme situations could work in an autonomous mode. The same problems of efficiency and safety as in a large energy system are found in an isle grid, in an isolated small energetic system or in a temporary isolated system from the large system that normally includes it.

REFERENCES

[1] Capatina, Octavian, A New Approach Of The Energy Systems, Energetica nr: 11.2011, vol 59, ISSN 1453-2360, Bucharest.

[2] ***, Energy [r]evolution: A Sustainable World Energy Outlook", by Greenpeace, EREC, GWEC, 2012.

[3] Schreiber, Daniela, Electricity Storage, Intersolar, 5th June 2012.

[4] Masters, Gilbert M., Renewable And Efficient Electric Power Systems, John Wiley & Sons, 2004.

Octavian Căpățînă born in Sibiu, Romania, on 17thApril 1948; graduate: Bucharest Polytechnical University, Electronics/Telecommunication Department, 1971.

He worked (1974-2000) at Cluj-Napoca Computer Research Institute gaining all research level. He built the first Romanian microprocessor computer (1976), he designed a plotter and command units for robots. He wrote two books, published at Cluj-Napoca, Romania, Dacia Publishing House: Designing with microprocessors-1983, Designing with microcomputer one-chip-1993. He was also associate professor at Technical University Cluj where he taught the computers class. He was the executive manager at Astral-Telecom, Cluj-Napoca branch (2000-2006). Since 2006 he work at the Cluj-Napoca Automation Institute, conducting renewable energy projects.