Regularities of Electricity Generation in Lithuania

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Abstract: - Self–organized criticality is a state characteristic for wide range of natural and artificial systems. The distinguish feature of such systems is the parabolic dependence of agents number N from magnitude m. As a rule, agents of big magnitude are rare and small magnitude agents prevail. This distribution can be found in various areas such as economical, biological systems etc. These systems are dynamically stable and the permanent adaptation is guaranteed.
In this work is shown that Lithuanian electricity energy system is in SOC state with the dynamic equilibrium. Using optimization methods we can see that large present generators are not useful because of big expenses in electricity transmission. On another hand, if generation would be decentralized as much as possible, transmission losses would be minimal, but organization and maintenance of generation would cost. However existence of both extremes is optimal in dynamic sense, because in the future when new economic electricity transmission materials appear (superconductors) large generators will be in great demand and when effective methods of controlling and administration will be created, then small generators will be in demand. Therefore we can assert that state of electricity energy system is optimal with respect to SOC.

Key-Words: - Self-Organized criticality, Power law, Dynamical equilibrium, Generation, Permanent adaptation.

1 Introduction

Energetics is one of the most complicated real systems that we meet as consumers or as interested participants of political and economic decisions in various situations. Electricity systems comprise power stations (generation), high voltage power lines (transmission) and low voltage power lines (distribution), which are linked together, as outlined in the following diagram, to supply electricity to consumers.

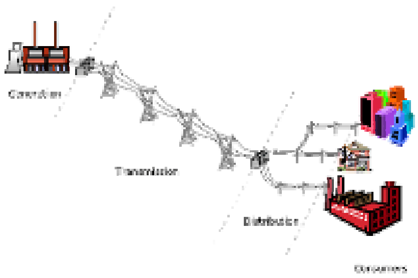

Fig.1. Electricity system.

Maybe all that system could be similar to market model? But we will start from the smaller part – Generation. Generation is initial and the most important part of that system. It is rather diverse and complex. That is why we will try to analyze it from the self-organized criticality point of view.

Self-organized criticality is a way of viewing nature. The basic picture is one where nature is perpetually out of balance, but organized in a poised state – the critical state – where anything can happen within well-defined statistical laws. The state is established solely because of dynamical interactions among individual elements of the system: the critical state is self-organized.

Self–organized criticality (SOC) is a state characteristic for wide range of natural and artificial systems. The distinguishing feature of such systems is the parabolic dependence of agents number N from magnitude s:

$$N(s)=s^{-\tau} \qquad (1)$$

As a rule, agents of big magnitude are rare and small magnitude agents prevail. Taking the logarithm on both sides of equation above we find

$$\log N(s) = -\tau \log s \qquad (2)$$

This shows that log N(s) plotted versus *log s* is a straight line. The exponent τ is the slope of the straight line. What does it mean that something is a straight line on a double logarithmic plot? Mathematically, such straight lines are called "power laws", since they show that some quantity N can be expressed as some power of another quantity s. This distribution can be found in various areas such as national system of companies, biological, economical, ecological systems etc. Maybe it's the same in electricity generation? These systems are not stable in a lot of places, but their SOC is absolutely stable and the permanent adaptation is guaranteed. Because in subcritical or supercritical states the system aims the critical state inexorably. Self-organized critical systems evolve to the complex critical state without interference from any outside agent. The process of self-organization takes place over a very long transient period. The complex state is at the border between predictable periodic behavior and unpredictable chaos. However, precisely at the "critical" point where the transitions to chaos occur, there is complex behavior, with a 1/f-like signal. Complexity is a consequence of criticality.

2 Problem Formulation

Presented SOC theory is used analyzing "competitors" distribution model [2] with respect to Lithuanian electricity energy system according to generation of electricity. How generation is distributed according to amount of power plants? Does dependence satisfy SOC theory in our case? Therefore we are interested in generation dynamics; let's compare data of last two years (1998,1999).

3 Problem Solution

Electricity in Lithuania is generated by power plants of three types: nuclear, thermal and hydro power plants. (In our investigation, type of generated energy is not important). According to the installed capacity and generation, state company *Ignalina Nuclear Power Plant* is the top of electricity producer. *Lietuvos Energija AB* owns two thermal and two hydro power plants. There are about 30 small private hydro power plants.

Table 1. Generation of Lithuanian Power Plants (GWh)

	1998	1999	2000
State company Ignalina Nuclear Power Plant	13554	9862	8419
Lithuanian Power Plant	*1695*	*1092*	*706*
Vilnius Combined Heat and Power Plant	711	816	909
Kaunas Combined Heat and Power Plant	236	421	304
Mazeikiai Combined Heat and Power Plant	*433*	*373*	*298*
Combined Heat and Power Plants, own by industrial interprices	60	64	98
Klaipeda district Heating Utility Power Plant	32	32	37
Kaunas Hydro Power Plant	*391*	*388*	*313*
Kruonis Hydro Pump Storage Plant	*478*	*447*	*304*
Private Hydro Power Plants	26	24	26
TOTAL	17616	13519	11414

During 2000 Lithuanian power plants produced 11.4 TWh of electricity, of which 8.4 TWh was generated by state company *Ignalina Nuclear Power Plant*, 1.6 TWh – by *Lietuvos Energija AB* owned power plants and 1.4 TWh – by municipal and private power plants. Subsequent to reduction of export in 1999 the electricity generation was 23% lower than in 1998, in 2000 - 16% lower than in 1999.

Data of two years were put into groups by generation: from 1 to 10, from 10 to 100 and so on. On the log-log plot they look like that:

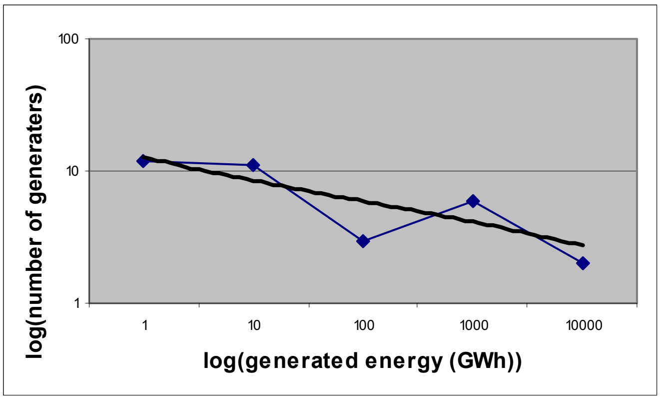

Fig.2. Distribution of generators according to generated energy in logarithmic scale (1998)

log(producers) = - 9.2 *log*(generation)   (3)

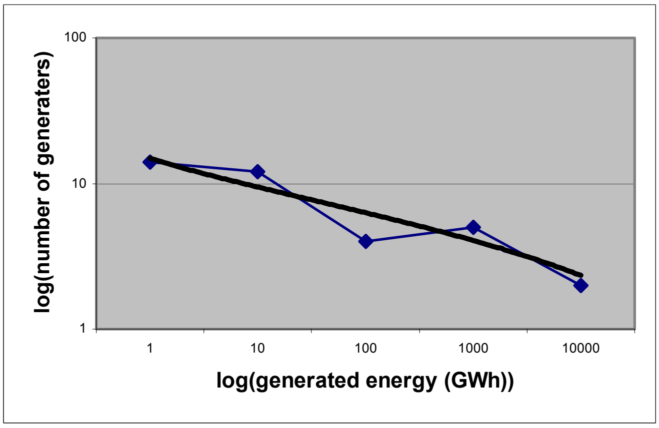

Fig.3. Distribution of generators according to generated energy in logarithmic scale (1999)

log(producers) = - 7.8 *log*(generation)   (4)

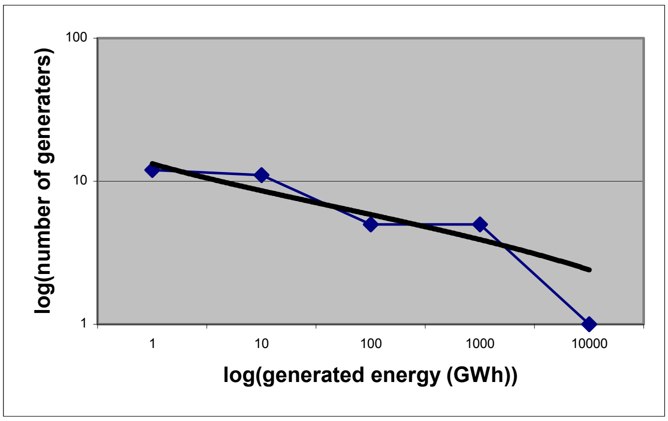

Fig.4. Distribution of generators according to generated energy in logarithmic scale (2000)

log(producers) = - 6.7 *log*(generation)   (5)

After analysis of existing data we can propose that power law above presents critical state with the dynamic equilibrium. This system has been analyzed in extreme generation and transmission cost variation. It is quite possible explanation of such system's state that is called "competitors" model. First it was presented in [2], where there was shown that small agents of the system evenly have been incorporated into the big ones (by magnitude). A few more examples could be concentration of capital, companies' size, distribution of fauna mass in certain areas, national and transnational communication systems. However, in case of energetic system of agents (producers) this model and explanation does not fit at all, because we can't observe direct incorporation of one system element into other, as a rule, into a bigger one, and all elements have weak interaction or even act independent in the system. It means that evolution of this system to critical state is determined by another factors, such as planning of economical evolution, costs of generation and transmission, competition, State and region policy. Mostly in various historical time periods are made different political and economical decisions and programs that help seeking to develop one or other economical branch, one or other sector. Therefore, in certain case one economical sector can be supported while other is frustrated or not stimulated to develop. We can conclude that the origin of criticality in Lithuania electricity system is different in comparison with "competitors" model.

On another hand, it is possible to examine generators from systematic perspective position. In the process of technological development innovations may be "genetically" coded and under the influence of that economical systems and subsystems infrastructure is changing. A system is structurally stable when it is continually ready to accept technological challenges. They can be negative (crisis of raw materials or fuel) as well as positive (superconductivity, other less detrimental ways to transit electricity, effective methods of complex system management). In our case energetics system displays wide spectrum of producers (according to generation), therefore such a system reacts adaptively to any internal or external alternation of situation and it doesn't require transitional period. Although there are necessary to use extra resources to maintain such a system in SOC state in every time period, but the SOC state is effective (optimal) in a long time interval. Having elaborated forecast methods and technologies to predict material and other changes, it would be possible to switch naturally pleated system to another state – multicritical - with different exponents in different magnitude intervals. Then in log-log scale we could get not *straight* line, but broken *one*. Such a system would be minimal according to exploitation expenditures, though it won't be optimal in the sense of long time adaptation. Even if in certain cases forecast is reliable (reserve of raw material), but more often it is not (effective methods of managing and saving, effective transmission of electricity). There are not known (and maybe they are not able in principle) methods of innovation forecast.

4 Conclusion

Using optimization methods we can show that large present generators are not useful because of big expenses in electricity transmission. On another hand, if generation would be decentralized as much as possible (small generators), then transmission losses would be minimal, but organization and maintenance of generation would have high cost. However existence of both extremes is optimal in dynamic sense, because in the future when new economic electricity transmission materials appear (superconductors, for instance) large generators will be in great demand and when effective methods of controlling and administration will be created, then small generators will be in demand.

Therefore we can assert that state of energetics system is optimal with respect to SOC. After deep analysis of main factors, from that depends structure of energetics system, there is possible to create its model of evolution *to critical state*. This model would let effectively intervene into restructurization and functioning of the system.

Would be interesting to compare with distribution of generation system in Nordic countries. The idea of "competitors" model will be useful when consumers will be able to buy electricity directly from generators.

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