Aspects Of Evaluating The Efficiency Of Introducing Innovative Method And Technology Demand Side Management In Smart Grid System

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***Abstract* - The most important task when introducing innovative methods and technologies Demand Side Management (DSM) in Grid System is prognostication, evaluation of performance and management of introducing innovative technology.**

***Index Terms* - Smart Grids, Demand Side Management, Technical Innovation, Statistics Models, Simulation Models, Cluster Analysis of consumer, Energy Efficiency**

I. INTRODUCTION

Smart grid system requires the introduction of innovative methods and devices to increase its efficiency.

Being presented for the introduction in smart grid system, the innovative DSM method [1,2,6,7,8] and innovative device of DSM [3,4,5], are based on regulation of voltage in immediate vicinity to consumers.

The core consists in a method [2] according to which the voltage of loading is regulated not by a power part of a network, but by electromagnetic connection of winding of volto-additional transformer with the currents which are 15-20 times lower than power current. The capacitance of the regulated device is not more than 5% of the loading capacitance.

The experience in using technical innovations [2,3,4,5,6,7,8] made it possible to solve several global problems:

- to exclude the use of intermediate high frequency conversion which resulted in a dramatic reduction of standard measures to provide electromagnetic compatibility (screening, usage of a considerable amount of spark quenching RC-circuits etc);
- to increase the efficiency factor of converter devices;
- to reduce mass-dimensional characteristics;
- to simplify the regulation of power cascades containing a lot of power elements;
- to design such structures of protection and control devices in a more compact and multifunctional way.

The integration of the suggested innovative method DSM in Smart Grid may become in future a considerable contribution into a well-known method of regulating voltage with the help of switching anzapf power transformers. In mass introduction of the innovative method and device there can be provided a centralized management of electrical consumption from the console of the engineer of the energy network.

The experience of the usage also showed that the suggested innovative method of demand side management allows to cope with the following tasks in smart grid system:

1) to improve the quality of electric energy;
2) to save up to 10-15% of electric energy;
3) to economize material and financial resources by 10-50%;
4) to provide uninterrupted work of the equipment responsible for production of science intensive products;
5) to reduce electro energy losses by 20 – 35% in the networks from the places of the installation of the device DSM throughout all the transition network, including the electrical station;
6) to increase the stability of the work of synchronous generator at power stations;
7) to reduce considerably, up to 20%, current load in supply lines, which will lead to increasing the time between reconstruction periods, thus realizing demand response, the number of potential technological connections to electrical networks.

To evaluate the efficiency of the introduction of the presented innovative method and technology Demand Side Management in Smart Grid System, this works researches simulation models based on the use of general systematic laws.

In this paper, two paradigms of the simulation modeling are used: the traditional system dynamics, suggested by J. Forrester, and a relatively new paradigm of agent modeling . The solution to the problem of spreading innovative products with the use of system dynamics is based on the works of Frank M. Bass. The simplest working model of this task has been realized and is available for researches in the system of simulation model AnyLogic [9-10].

Approaches to prognosticating and evaluating the efficiency of the introduction of the Innovative Method And Technology Demand Side Management In Smart Grid

System referring to certain regions and clusters of consumers are considered further.

II. Model Of Introducing Innovative Technology DSM

The first moment of the development concerns the necessity of simultaneous modeling several clusters of electrical energy consumers and, at the same time, the technology DSM. Thus, for example, in Fig. 1, Cluster 1 presents a number of small enterprises, Cluster 2 – medium-sized enterprises. Consumers of certain branches, private consumers, etc. can appear as other clusters. Clusters can influence one another, as will be considered further.

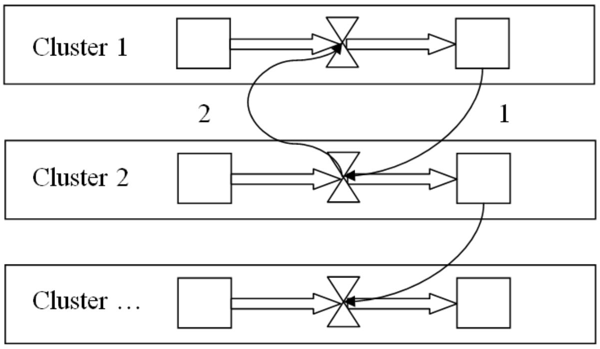

Fig..1. Clusters of electric energy consumers, introducing the technology DSM

Fig. 2 shows in detail a part of the model of System Dynamics of introducing innovative technology demand side management in Cluster 1. In the model the number of *potential consumers* and the number of *those who have the new devices installed* are presented by Stocks *PotentialAdopters* и *Adopters.* Near the stocks, Fig. 2 presents their original magnitudes. Thus, for example, 5 thousand *PotentialAdopters* is the number of small enterprises in the region under consideration. Such a number of small enterprises are to be found at present in the city of Novosibirsk (the source: Small and medium-sized entrepreneurship of Novosibirsk http: //www.mispnsk.ru /publications/issledovaniya.html). The number of small enterprises which installed the new devices *Adopters*, at the beginning of modeling was chosen to be equal to zero.

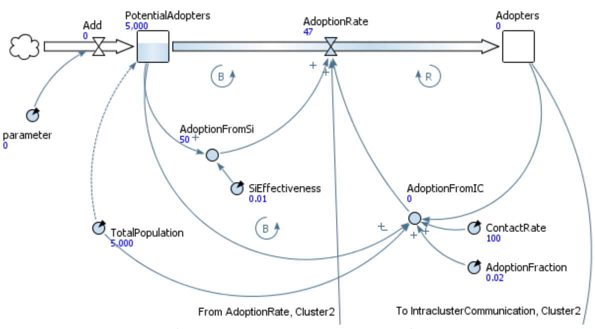

Fig. 2. The model of systematic dynamics of introducing innovative technology of demand side management for Cluster 1 of electric energy consumers in Novosibirsk

In the presented model the connection between Stocks is the flow of introducing the devices *AdoptionRate*, transforming potential consumers of *PotentialAdopters* into consumers of the product *Adopters*. The following factors that influence the stocks and the flow are chosen: the system of directed information influence - *AdoptionFromSi* and Intracluster Communication – *AdoptionFromIC* (analog of *Word of mouth*). The regulated parameter for the factor of the System of directed information influence *AdoptionFromSi* is its efficiency - *SiEffectiveness* (the level of 1% is accepted), and for the factor of intracluster communications - *AdoptionFromSi* — the quantity of population *TotalPopulation* (5 thousand small enterprises), frequency of contacts - *ContactRate* (100 contacts a year) and the force of conviction *AdoptionFraction* (2%).

The first feed back in the model is negative, balancing, self-correcting. Strengthening the factor *AdoptionFromSi* increases the number of *Adopters* and decreases the number of potential consumers *PotentialAdopters*. It restricts the growth of the factor and leads to its reduction. The second feedback in the model is also balancing: the increase of *Adopters* under the influence of intracluster communications *AdoptionFromIC* increases the number of *Adopters* and decreases the number of *PotentialAdopters*. It also restricts the growth of the Factor of *AdoptionFromIC* and results in its reduction. The third feedback in the model is positive, enforcing. The increase of the introduction of innovative device of demand side management under the influence of *AdoptionFromIC* increases the number of *Adopters*. It results in a larger number of *AdoptionRate* under the influence of *AdoptionFromIC*, and, with time, in the drop of influence of the System of directed influence on the flow of *AdoptionRate*.

Functional dependences between the elements of the model are usually not shown in the diagram, so they are given separately. The flow of the introduction of innovative device of a demand side management *AdoptionRate* is given as a derivative with time of *PotentialAdopters* with the minus and *Adopters* with the plus, as in (1).

$$d(PotentialAdopters)/dt = -AdoptionRate;$$
$$d(Adopters)/dt = AdoptionRate; \qquad (1)$$

The model assumes the following suppositions:

1. The system of directed information influence and intracluster communications influence the flow of *AdoptionRate* additively and with a similar weight, as in (2).

$$AdoptionRate = AdoptionFromSi + AdoptionFromIC \qquad (2)$$

2. The flow of introductions of innovative technology of DSM under the influence of the system of directed information influence is the product of the parameters of efficiency of the system of the directed information influence and the number of potential consumers, as in (3).

$$AdoptionFromSi = SiEffectiveness \times PotentialAdopters \quad (3)$$

3. The flow of introductions of the innovative technology of DSM under the influence of intracluster communications *AdoptionFromIC* is the product of the quantity of *Adopters who introduced the device*, the number of contacts *ContactRate*, the force of conviction *AdoptionFraction* and the share of *PotentialAdopters* in the population *TotalPopulation*, as in (4).

$$AdoptionFromIC = Adopters \times ContactRate \times AdoptionFraction \times PotentialAdopters / TotalPopulation \quad (4)$$

The current results of the experiment are constantly presented on the elements of the diagram. Fig. 2 shows the parameters of the first step of the experiment.

The main results of modeling the introduction of innovative technology of demand side management in Cluster 1 of electro energy consumers of the city of Novosibirsk RF are presented in Fig.3. It is clearly seen, that if the producer plans, for example, to provide Cluster 1 with the innovation device DSM within about 5 years, as in the given example, then their production program, with the chosen parameters of the model, must correspond to the presented curves (Fig.3). At that, the peak of the introduction of the innovative device DSM in Cluster 1 should be expected by the middle of the third year of the project (the maximum of the curve *AdoptionRate*), and the production must be ready for it..

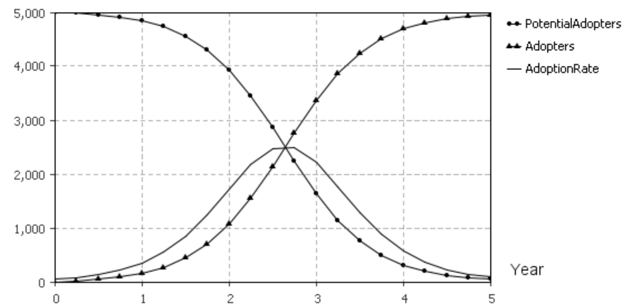

Fig. 3. The results of modeling the introduction of the innovative technology demand side management in Cluster1 of electro energy consumers in Novosibirsk

Thus, experiments with the model give the possibility to develop more correct production decisions. Besides, the company producing the innovative product can increase the number of potential users (*TotalPopulation*). It can be done, for example, due to initiating repeated introduction, entering new segments of the market, allowing to increase the efficiency of DSM and the energy system. In the model in Fig. 2 an additional flow (*Add*) is introduced from the outward environment.

As an additional alternative of the method of systematic dynamics, an agent method is used in the work. In Fig. 4, on the left, there is shown a diagram of states of the agent model of introducing the innovative technology DSM for Cluster 1 of electro energy consumers, which describes the transition of the consumer from the usual state into the state of the introduction of the innovative technology DSM.

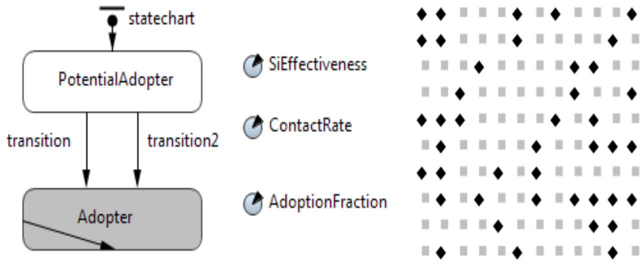

Fig. 4. The agent model of introducing the innovative technology DSM for Cluster 1 of electro energy consumers

The advantage of the model is its visibility. On the computer screen, you can watch in model time the transition of consumers from the usual state (light squares) into the state of the introduction of the innovative technology DSM (black rhombi), Fig. 4, on the right. It is also useful that consumers can be tied to a concrete map of the region. It is important for us that the agent model gives the same results as the systematic dynamic one. That is, the graph of the introduction, obtained from the agent model, coincides with the graph in Fig.3.

The results of modeling the introduction of the innovative technology DSM simultaneously in two clusters of electro energy consumers is shown in Fig.5. The first graph presents the prognostication of the dynamics of introducing the innovative technology of demand side management in the cluster of small enterprises (5 thousand), the lower one – in the cluster of medium-sized enterprises (300) in Novosibirsk (RF). It is assumed additionally in the model that medium-sized enterprises can take into account the statistics of the introduction of the innovative technology demand side management in small business enterprises - connection (1) in Fig.1and connection *To Intracuster Communication, Cluster2* in Fig.2. As a result, the introduction of the technology DSM in the segment of small enterprises stimulates the introduction of the technology DSM in the segment of medium-sized enterprises. That is why the peak of the introduction in Cluster 2 comes earlier: not by the middle of the thirds year, but by the end of the second year (the lower graph in Fig.5).

Besides, if the resources of the production are limited, the growth of introduction in the segment of medium-sized enterprises can impact negatively the flow of introductions in the segment of small enterprises (connection (2) between the flows of segments 1 and 2 in Fig.1 and connection *From Adoption Rate, Cluster2* in Fig.2). That is why the peak of the introductions of the innovative technology DSM in Cluster 1 comes later: not by the middle of the third year, but by the beginning of the fourth year (the upper graph in Fig.5).

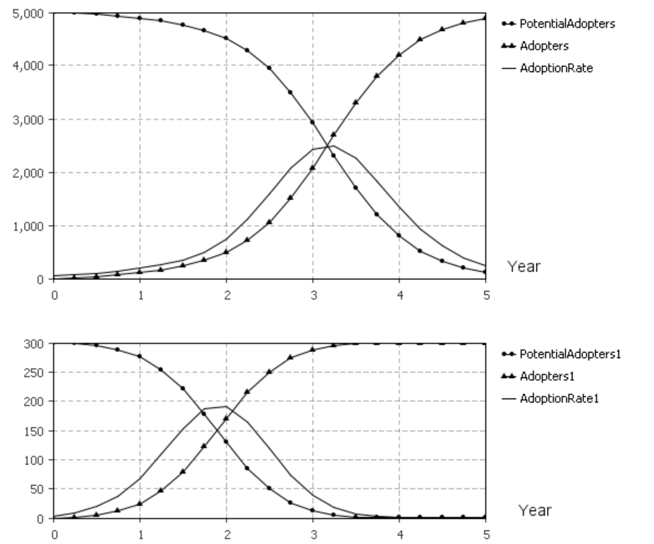

Fig. 5. The results of modeling the introduction of the innovative technology DSM simultaneously in two clusters of electro energy consumers.

The results obtained in the course of modeling allow to evaluate the efficiency of the introduction of the innovative method and technology Demand Side Managementв Smart Grid System.

III. Model of Evaluating the Efficiency of the Introduction of the Innovative Technology DSM in Smart Grid System

As the main measurement of the efficiency of the introduction of the innovative technology DSM in Smart Grid System, the authors have chosen the index "technological connection to electrical systems". This choice among the multitude of other useful properties is determined by a whole number of reasons. This is a general tendency of rapid growth of the number of contracts on technological connection to the electrical networks, the constant perfection of the Smart Grid System because of it, the strengthening of the control of state bodies.

The model of introducing innovative technology of demand side management in Smart Grid System, developed by the authors, is presented in Fig.6.

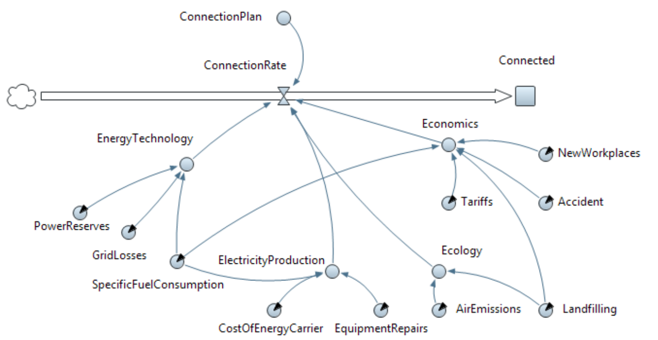

Fig. 6. The model of System Dynamics of introducing innovative technology of demand side management into the energy supply system.

In Fig.6 the flow *ConnectionRate*, the flow of technological connections to electrical networks - *ConnectionRate* transforms an uncertain number of applications about the technological connections to electrical networks (the cloud symbol instead of the storage) into real connections (storage *Connected*).

The variable *ConnectionPlan* is a planned average annual quantity of technological connections to electrical networks. The variable is the main controlled factor of the flow *ConnectionRate* and is determined on the basis of the flow of contracts on technological connections to the electrical networks. The variable *ConnectionPlan* is formed in the conditions of strict restrictions on energy resources. Here *ConnectionPlan* is set on the level of 1% connections a year.

The following factors are chosen as the parameters of energy efficiency:

- energetic technology EnergyTechnology;
- production factor ElectricityProduction;
- economic factor Economics;
- ecological fsactor Ecology.

The factors of energy efficiency are connected with the multitude of variables are shown in Fig. 6. For the set tasks, a special interest is presented by the variables which influence negatively the efficiency of Smart Grid System, but can be compensated through the introduction of the innovative technology.

In our opinion, such parameters for *EnergyTechnology are*:

- PowerReserves;
- losses of electrical energy in the networks *GridLosse*s.

According to our expertise evaluation, the introduction of any device of the offered innovation technology DSM increases the parameter *PowerReserves* in the model by 10-20%, and decreases the parameter *GridLosses* by 5-10%.

For the production factor *ElectricityProduction*. an important regulated parameter is repairs of the equipment *EquipmentRepairs*, both on the side of the production, and on the side of consuming electrical energy. In our model, the meaning of *EquipmentRepairs* was chosen on the level of 5-10%.

The introduction of the innovative technology DSM in Smart Grid System, allows to improve Voltage characteristics of electricity, that results as well in the reduction of harmful emission into the environment (parameters AirEmissions and Landfilling, influencing the ecological factor Ecology), which gives an additional reserve to Smart Grid System when meeting ecological requirements.

Besides, the reduction of parameters of *AirEmissions* and *Landfilling* improves the economic state of energy production - the factor *Economics* – due to the reduction of corresponding fines. The additional introduction of the technology improves the factor *Economics* due to the reduction of the number of accidents – the parameter *Accident*, and due to creating new working places for their own production *NewWorkplaces*.

Fig.7 shows the results of the simulation. The Y-axis is a number of new technological connections to the electrical networks in % in relation to the current level, which is assumed to be 100%.

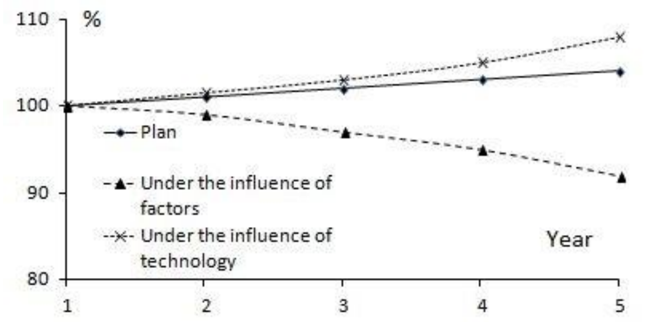

Fig.7. The evaluation of the efficiency of the introduction of the innovative method and technology Demand Side Management in Smart Grid System on the index “technological connection to the electrical networks”.

The evaluation of the efficiency of the introduction of the innovative method and technology of Demand Side Management in Smart Grid System on the index of “technological connection to the electrical networks” showed that the planned values of technological connections to the electrical networks without the regard of the influence of the mentioned factors are presented by the curve "Plan". The consideration of the negative factors results in the reduction of the flow of connections (the curve "Under the influence of factors"). Negative factors can be compensated by the introduction of the innovative technology DSM into Smart Grid System (the curve "Under the influence of technology").

Thus, the introduction of the innovative method and technology Demand Side Management in Smart Grid System allows to compensate the influence of negative factors on the index “technological connection to electrical networks”, which, in its turn, influences positively the efficiency of work of energy systems .

IV. Conclusions

The presented model of the evaluation of the efficiency of the introduction of the innovative method and technology Demand Side Management in Smart Grid System realizes the simplest hypothesis, uses the simplest kinds of connections. They can be developed up to a necessary level of complexity and adequacy of the model. Besides, the model allows to generate the necessary set of realizations for the all-round statistical analysis, for evaluation and management of the project risks, for the formation of the portfolio of projects of the multitude of clusters of electro energy consumers.

The offered models will allow to formalize and make more accurate the evaluation of efficiency of introducing innovative technologies in Smart Grid System.

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