INTRODUCTION OF SMART GRID IN RUSSIA: FEASIBILITY STUDY

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Abstract

The introduction of smart networks leads to an increase in the reliability and efficiency of production, transmission and use of electricity, reducing power losses and the time of emergency shutdown, the introduction of renewable energy sources, reducing carbon dioxide emissions, improving the quality of customer relations, identifying theft of electricity, creating a market for high-tech products. The modern development of the energy industry in Russia is also focused on the development of a highly efficient and safe infrastructure with the use of modern efficient equipment with intelligent power systems, on the local implementation of renewable energy generation. The article discusses external effects and feasibility of smart grids in Russian energy sector on the basis of active-adaptive grid. The targets of smart grid development are analysed. The authors developed an econometric model of electricity consumption in Russia depending on the influence of indirect factors. Using econometric analysis, authors predicted three scenarios of electricity consumption in Russia depending on the amount of energy losses in the networks, the volume of production of electricity, including energy from renewable sources.

Keywords: electricity, economic efficiency, smart grid, energy efficiency

JEL Code: O330, O320, O250

Introduction

In the last one and a half or two decades, in the global electric power industry, specialists observe an active introduction of smart grids. The term itself appeared only in 1998 in one of the articles of a Western specialist (Gurevich, 2010). However, the processes of intellectualization of electrical networks in connection with the rapid development of information technology, and scientific and technological progress in the generation, transmission and metering of electricity began much earlier. The electricity industry is changing due to new technologies available in generation, demand, and system controls (Ramos, Jonghe, Gómez, & Belmans, 2016). The transition from power systems burning fossil fuels to renewable energy sources can produce much-needed benefits, ranging from less air pollution to more energy security, or broader access to energy, up to the establishment of a new economic paradigm, the so-called "low-carbon economy" (Moroni, Antoniucci, & Bisello, 2016). The ambitious energy targets trigger new investment needs and call for new ways to plan, construct, and operate network infrastructures (Cambini, Meletiou, Bompard, & Masera, 2016). New renewables (NR: wind; solar; modern biomass and biofuels; tidal, wave and ocean energy) are widely claimed to be clean, indigenous and sustainable sources of energy (Khatib, & Difiglio, 2016).

According to Bloomberg New Energy Finance (BNEF), global investments in the Smart Grid have reached $ 14.9 billion by 2014. In the United States, since 2007, following a major power grid accident, the creation of the Smart Grid system has become one of the priority national projects. However, the largest investor in Smart Grid is China ($ 7,323 million), which in this indicator surpassed the US ($ 7,092 million). Large investments in the development of smart networks are carried out in the EU, Japan, and Brazil (Smart-Grid.ru, 2016). At the same time, investments in RES are increasing. Already, the average annual growth rate of energy consumption in the world related to renewable energy sources (wind, solar energy, geothermal energy, energy from household waste and biomass) is 15% - 17%, while oil - 1.5-2% (Matyushok, 2013). At the same time, significant investments in the development of energy networks led to an increase in electricity tariffs in Australia, Spain, the United States and a number of other countries (Energosberejenie.org, 2016). The electricity industry is beginning to use business intelligence technology to facilitate management analysis and decision-making (Lukić, Radenković, Despotović-Zrakić, Labus, & Bogdanović, 2016). The dynamics in the transition between old and new power system business models involves tensions between incumbent and new business actors, a centralized versus a distributed technological paradigm, and a societal shift from a passive to an active user role in its value chain (Wainstein, & Bumpus, 2016).

1. Smart Grid in Russia

The implementation of the process of intellectualization of the electric power industry, the introduction of certain technologies and the launch of pilot Smart Grids can not be a panacea to all existing problems in the industry, but these innovations help to solve a number of system tasks and looking at the processes in the industry in a different way. The research of INEI RAS in the field of creating electric power systems on the basis of an actively adaptive network in Russia shows attractiveness and efficiency of investments in this area, the need for restructuring plan of the energy networks, the paradigm shift for the electric power industry. The range of possible economic effects in the UES of Russia related to introduction of the pilot Smart Grids was estimated by the specialists of JSC "STC FGC UES" (Table 1, the characteristics for 2020 imply the implementation of the smart energy system project on the basis of an actively adaptive environment in the amount of 25%).

Tab. 1.Target indicators of the development of the intellectual power system in the UES of Russia,%

Condition	Smart Grid pilot projects	Target indicators of the intellectual grid in the UES of Russia	
		2020 г.	2030 г.
Reduction of the forecast maximum load	10—20	2,5	10
Decrease in final power consumption	5—15	2	8
Reduction of losses in networks (relative to the reporting level)	20—50	7,5	30
Reduction of the required power reserves in generation (relative to the reporting level)	20—30	5	20
Increase in capacity of intersystem connections	5—10	2,5	10

Source: http://www.ntc-power.ru/ies-aas/predicted_effects/ -OJSC "STC FGC UES"

All experts agree that the power grid complex both in Russia and in most other countries of the world needs a radical upgrade. "Since no fundamentally new ways of producing and transmitting electric power have been proposed recently, a new cycle of development of global energy sector has no opportunity to make a qualitative leap during the renovation process. The launch of discussions and developments in the field of smart grid and digital substations was an attempt to create this fundamental qualitative leap artificially. The success of this attempt is a debatable question " (Medvedev, 2015) . Smart Grid is a kind of golden key that opens chest with investments. Nevertheless, the author concludes that it is necessary to engage in "smart" networks.

When comparing an upgraded system with an absolutely new project, executed in compliance with modern energy-efficient standards, the later is more lucrative in the horizon of 5-10 years (International Energy Forum, 2015). Obviously, small-scale local renovation of existing infrastructure is not effective way to upgrade power grid, and long-term investment in the energy is better. Long-term approach has prolonged effect in the future, and it is especially important because many infrastructure projects will be operated 20-30 years or more. In this case, energy efficiency and a future transition of enterprises to a new technological platform should be of equal importance for decision makers.

At present, Russia is one of the largest electric power producers in the world, but Russia does not implement of Smart Grid elements on large scale. Meanwhile, the current situation in the energy networks of Russia is such that they are badly worn out. When in the West the relative losses in the networks are 4-8% of the electricity supply, in Russia, according to the International Energy Agency, losses are around 10%, and according to experts - 13-15%, and in some networks - 30% or more (Vorotnitskiy, Ovseichuk, Kutovoi, 2015).

To substantiate feasibility of i an intelligent power system on the basis of an actively adaptive network, authors developed an econometric model based on the statistical data of Enerdata, an information and consulting company specializing in energy on a global scale.

2. Methodology

Analyzing the available statistical data, we compiled a model of electricity consumption, the prerequisites of which are the following: the consumption of electricity depends on the volume of production from all sources of generation and the amount of electricity lost when transferring to the end user. Since we are interested in the contribution of renewable energy sources to final consumption, the production is represented by two values: production from traditional sources of generation, and the share of electricity generated from RES (without hydro generation). Consequently, the consumption of electricity, as a dependent variable, can be expressed as a nonlinear function of the form:

$$EL\_CONS = F\ (PROD\_UNRE,\ LOSSES,\ RE\_TOTAL),$$

where

EL_CONS - volume of electricity consumption, GW * h;

PROD_UNRE - electricity production, GWh;

LOSSES - volume power losses GWh.

RE_TOTAL - the share of electricity production from renewable energy sources (without hydro)%;

Using the Eviews software, we obtained an estimate of the non-linear multifactorial econometric model for OLS with correction of standard errors by the New-West method (Fig.1):

$$LN\left(EL\_CONS\right) = -1.35 + 1.2LN\left(PROD\_UNRE\right) -$$
$$-0.14LN\left(LOSSES\right) + 0.14RE\_TOTAL\ \left(0.22\right)\left(0.01\right)\left(0.01\right)\left(0.09\right)$$

when R^2 = 0,998, n = 25, DW = 1,71.

2.1. Trends

Review of the model based on prevailing trends over a twenty-five-year period allows us to draw the following conclusions:

1) the elasticity of electricity consumption for its production is 1.2, which means that with the growth of electricity production from traditional sources by 1%, its consumption with the same two other exogenous variables will increase by 1.2%;

2) the elasticity of electricity consumption by loss of electricity is negative -0.14, i.e. With a loss of 1% and constant electricity production, consumption will increase by 0.14%.

3) an increase in the share of electricity generated from renewable energy sources by 0.1 percentage points, while the total amount of electricity produced remains unchanged, leads to an increase in consumption by 1.4% because of the qualitative characteristics of energy sources (availability, environmental friendliness, flexibility, monitoring of generation of electricity, etc.). This indicator is significant only at the level of 15%, however, we apply the obtained estimate as acceptable for making the forecast.

As can be seen from the results (Fig. 1), the equation is statistically significant (F-statistic = 4924.195, p-value = 0.00). Determination coefficient R 2 = 0.9986 indicates that 99.86% of the variation of a dependent variable is reproduced variations of the independent variables.

2.2. Scenario Analysis

The resulting econometric model can be used to compose scenario forecasts for electricity consumption. We make several assumptions for each factor that determine the level of consumption.

1. Scenario of growth of electricity generation by the trend (modernization). (Fig.2.)

This scenario is based on the trend forecast for electricity generation and the share of electricity from renewable sources. The period for identifying the trend has been determined since 1999 in order to reduce the impact of the crisis of the 1990s. Losses in electric reduced according to the forecast of experts from ERI RAS: the reduction level of 22% by 2030 compared to 2012 caused by implementation of smart grid . However, given the statistics on electricity, loss reduction in the last 3 years is not observed, so that the authors assumed that reduction of losses will occur from 2015 to 2030 at a CAGR of 1.6%.

Fig. 1: Results of model evantion in Eviews

Equation: EQ03 Workfile: MODEL КОСТЯ МАРТ 2016::Untitled\

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Resids

Dependent Variable: LOG(EL_CONS)
Method: Least Squares
Date: 03/01/16 Time: 17:49
Sample: 1990 2014
Included observations: 25
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 3.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOG(PROD_UNRE)	1.200443	0.009097	131.9642	0.0000
LOG(LOSSES)	-0.141371	0.011624	-12.16226	0.0000
RE_TOTAL	0.136084	0.092073	1.478006	0.1542
C	-1.351476	0.221862	-6.091525	0.0000

R-squared	0.998580	Mean dependent var	13.55698
Adjusted R-squared	0.998378	S.D. dependent var	0.108468
S.E. of regression	0.004369	Akaike info criterion	-7.882971
Sum squared resid	0.000401	Schwarz criterion	-7.687950
Log likelihood	102.5371	Hannan-Quinn criter.	-7.828880
F-statistic	4924.195	Durbin-Watson stat	1.707961
Prob(F-statistic)	0.000000		

Source: Calculated by authors

2. The basic scenario (slow) (Fig.2).

Results obtained with the second scenario using the method of adaptive prediction Holt-Winters. Electric power generation, excluding amounts of energy from renewable sources and the loss of the network predicted by the method of Holt-Winters on the basis of 25 periods since 1990. Electricity generation from renewable energy sources is predicted based on the average annual growth rate (1.158%) for the period 1990-2014, and a total electricity production - by the method of adaptive prediction.

3. Pessimistic scenario (Fig.2).

The third scenario assumes the negative development of the energy sector, in particular the lack of modernization. The forecast period of production and power losses is calculated on the basis of trends since 1990, the growth of the share of energy from renewable sources is calculated on the basis of trends since 1999

Calculations conducted on the basis of an econometric model show that in the three scenarios for the forecast of its production ratio forecasted electricity consumption is 0.9670, 0.8840 and 0.8320, respectively, which is higher than the actual ratio of production and the actual energy consumption in 2014 (0.8210). This fact demonstrates the effectiveness of the program on the implementation of smart energy systems based on active-adaptive network.

When making decisions on the design and implementation of smart grid using renewable energy sources in the energy complex of Russia, decision makers should take into account not only the direct effects expected, assessment of new technologies and cost control systems, but also an assessment of the external (externalities) effects. These effects show the extent to which the creation of smart energy systems based on active-adaptive network meets the economic and social needs. It can be considered the main significant effects of the following:

• reduction of harmful impact on the environment;

• an innovative development for the economy;

• improvement of energy security;

• an increase in the reliability of power supply through automation of management for energy flow, development of small scale generation, and development of microgrids;

• the creation of favorable conditions for economic integration and competitiveness through management performance networks (throughput, responsiveness, dynamic pricing, etc.);

• raising the level of productivity, quality and safety through the use of automated remote monitoring and control systems.

Usually, establishment of a smart energy system based on active-adaptive grid is accompanied by a number of system-wide effects that directly influence the situation in the balance of the Unified Energy System of Russia. These effects are caused by the qualitative changes in the management of the power system:

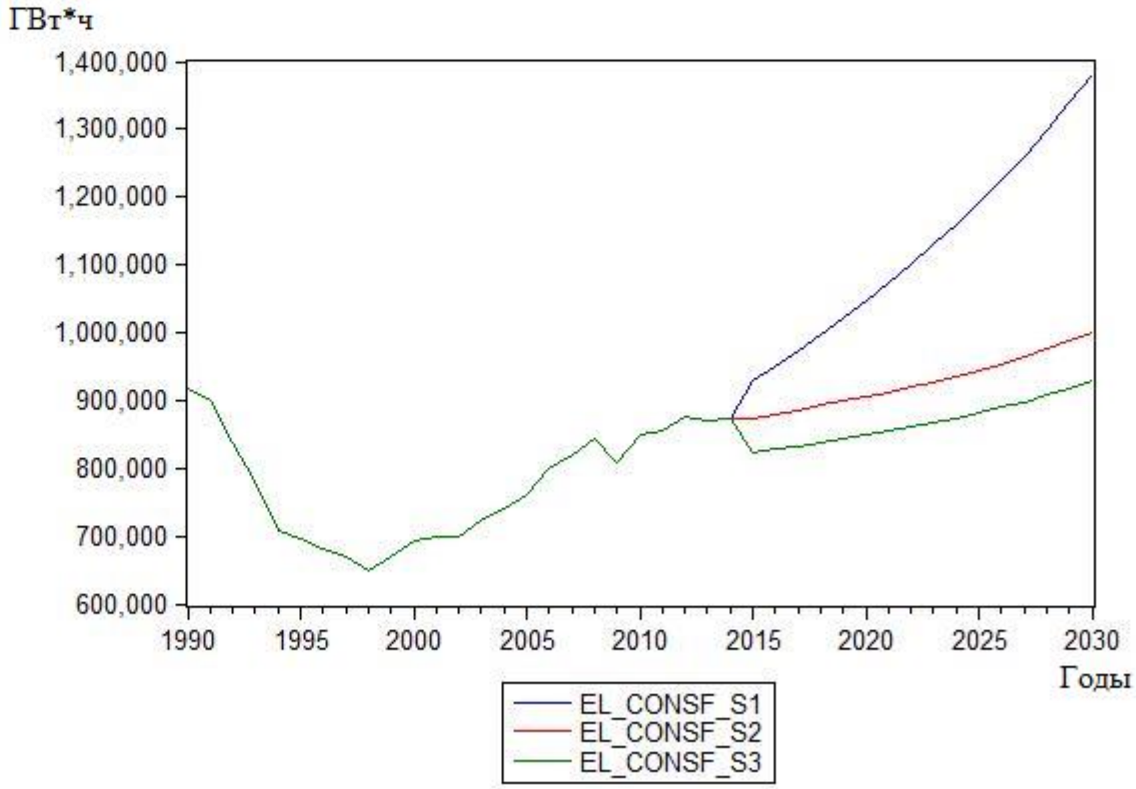
• demand management effects allow you to change the power consumption mode that reduces peak load energy and compresses the schedule;

• effects of loss management in transportation and distribution are based on the load losses due to new types of wires and power equipment;

• effects of bandwidth control of network increase in flows of energy through the introduction of flexible transmission and quality monitoring systems;

• effects of generation control allow to achieve efficient sharing of large and distributed generation. One of the most important effects is the introduction of distributed generation and improving the control of the energy flows through additional production from renewable energy sources;

Fig. 2. Scenario forecasts of production and consumption of electricity in Russia



Source: Calculated by the authors.

• effects of reliability control and power quality management help to maintain a high level of the security of the electric grid complex, quickly solve emergency situations, improve the quality of energy supply, and, as a result, to help customers reduce the economic losses from opportunity cost, damage to resources, equipment and related materials.

These external effects can be quantified, but valuation of these effects is not always possible. Therefore, a proper feasibility study for the introduction of smart energy systems based on active-adaptive network should take account for the direct economic effects, and use expert assessment of externalities as additional conditions.

Conclusion

The conducted scenarios analysis for the development of electric power on the basis of the obtained econometric model, analysis of external (externalities) effects, and pilot project results in different countries lead to conclusion that the creation of intellectual power system with the use of renewable energy in Russia will reduce the amount of the relative level of losses in networks and is a promising direction of development of electric power. However, this will require significant investment, the economic evaluation of the effectiveness which will be the subject of further research.

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