УДК 621.316

SMART GRID: NEW PROSPECTS OR NEW PROBLEMS? (Part 1)

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In the paper observed modern conception for future electrical grid building in Russia and in West countries and disclosed hazards accompanying transition to Smart Grid.

Key words: smart grid, electrical grid, relay protection, reliability, intentional destructive electromagnetic impacts.

1. Smart Grid Russian-style

The following is a part of the transcript of the meeting between Vladimir Putin, Chairman of the Government of the Russian Federation, and Oleg Budargin, Chairman of the Management Board of JSC FGC UES (Federal Grid Company Unified Energy System), published on website of government of Russia (http://premier.gov.ru/events/news/9429/).

– Vladimir Putin: I would like to draw your attention to the creation of the so-called smart grids.

– Oleg Budargin: The work has already been started. We will not just see everything and control everything. It will diminish losses, boost energy efficiency and make power supply steady. We will get rid of risks.

While he did not mention the required amount of investments or expected economic impact across the whole power network, he reported that the required ***money had already been included in the 2010–2012 investment program of the company (total investment amounts to 519 billion rubles)***.

What is the "Intelligent Network" or “Smart Grid”? Why are they going to invest so much in this technology, as it seems, while the economic impact is unknown?

An attempt to find the clear definition for Smart Grid, which involves such a large capital investment, surprisingly showed that no one in Russia really knows what is this all about and where this significant sum will go. Am I kidding? No! The following quotes from different specialists prove this:

"In Russia, Smart Grid technology has several alternative names – one is difficult to understand in Russian “Smart Grid”, others are more descriptive – “Intelligent Power Network”, “Intelligent Electric Power System” and “Active Adaptive Power Network”. Presently, there are numerous definitions of Smart Grid while each involved party (such as Power Company, power consumer, power facilities Automation Company, system integrator, etc.) recognizes different functionality and tasks for Smart Grid". [1].

"Different sources define Smart Grid differently. In Russia it is known as “Intelligent Power Network”, “Intelligent Electric Power System” or “Active Adaptive Power Network” [2].

“For a start, let’s give the clear definition for the term of “Smart Grid”. I repeatedly realize that there are serious divergences and even adverse opinions on the understanding of Intelligence in connection to power line or electrical network both between electricians and public" [3].

Let’s look at the background. The first time this term appeared was in 1998 in an article of one of the western specialists [4]. It also appeared in the title of article by Massud Amin and Bruce Vollenberg: “Toward a Smart Grid”[5]. In the beginning in countries in the West, this term was used only to promote certain brands of special controllers designed for managing operating modes and synchronizing unstable voltage and frequencies of standalone wind power generators with mains. Later, this term, also only as a gimmick, was used for microprocessor-based electric meters capable of collecting, handling and evaluating data with follow-on transmittal through communication lines or on the Web. Such synchronizing controllers for wind power generators and microprocessor-based electric meters of different brands were available on the market before the appearance of the "Smart Grid” term. This name appeared much later as an advertising gimmick aimed at the canvassing of customers and was used only in promotional articles for the special controllers mentioned above. Recently, however, it has been applied to data collection systems and the handling and monitoring of power equipment [6]:

“As a whole, the Intelligent Network (Smart Grid - “smart” or active-adaptive network) is a distribution network combining integrated tools for control and monitoring, IT and communications providing significantly higher network efficiency while en-

hancing the quality of energy supplied to the community by supply and retail companies and public utilities. The new distribution network will be based on following solutions:

– SCADA system providing comprehensive network control

– Data channel (including cable bus based on second generation PLC)

– Family of tele-automatic and tele-control digital units managing and controlling 6-20V devices, which are installed inside medium-voltage cells during manufacture".

This is the way that the *Smart Grid* term is used in the West [7]. However, Russia, as always, goes its own way thus enormously expanding the meaning of a well-established term:

***Western Smart Grid** is a digital technology with two-way communications encompassing all parties involved in production, distribution, storage and consuming of energy.*

***Russian Smart Grid –** is an all-inclusive upgrading and innovating development of **all electric power industry units** based on advanced technologies and country-wide balanced design concepts [8].*

Actually, in Russia this Western term covers the whole electric power industry. So there is a logical question – why do Russian power industry bureaucrats need to extend the interpretation of this Western term so much that it loses its original significance?

The answer is cited below:

"In my opinion, our fundamental issue is that in our country the struggle of people always precedes the struggle of ideas. For state power agencies the development of Intelligent Networks means huge public finance and each department tries to "cash in on it". Also, there are numerous ideas that alike but some are "parallel-perpendicular" initiatives, which are not possible to completely align and balance together" [9].

As it happens, in Russia the Smart Grid concept is nothing but a battle of different industrial and power entities for the state financing.

This is implicitly proved by Sergey Shmatko, Minister of Energy of Russia, when he declared in his complimentary speech at a roundtable discussion: "Smart Grid – Smart Energetics – Smart Economics" that transition to "Smart Energetics" will allow significantly transforming the present energy layout and **push the development of power industry, implementation of innovations and new equipment at plants and by design institutes assigning an applicative meaning to developments of Russian scientists** *[10].*

Other central figures of Russian Energetics echo this idea emphasizing that the Smart Grid is nothing less than the whole electric power industry of the Russian Federation:

"Smart Grid is a summation of power lines of all voltage classes, active electro-magnetic transformation devices, switching units, protection and automation equipment, IT and adaptive control systems" [11].

"Building of Smart Grid should be deemed as strategic lines of distribution network development and can be divided into four major fields of development:

1) Power equipment, technologies of energy transmission and distribution

2) Process management

3) Special communication and data devices

4) Automated energy accounting and control systems" [2]

Certainly, there is nothing wrong with subsidizing the power industry by the government as this field really needs some innovations and the upgrading of of worn-out equipment. But why the Smart Grid? The truth is that this popular term is a "golden key" that is able to open door to the State Treasury. So it is used by all who are seeking a piece of the state pie, and each one does it in its own way. For example, the CEO of OJSC ELECTROZAVOD thinks [12] that Smart Grid is nothing but production manufactured by his plant including even furnace transformers:

– HV supply transformers and autotransformers for power stations and 35 – 750 kV power lines

– Shunting, current-limiting, grounding reactors and filter chokes along with other reactors of 0.5 kV-1,150 kV classes

– A wide range of 3-750 kV voltage and current transformers with enhanced precision of measurement (up to 0.2; 0. 2S)

– 10 kV dry- and oil-type transformers with capacity of 25-4000 kVA

– Furnace transformers for electric arc furnaces, induction furnaces, electro-slag re-melting and ore-smelting furnaces, secondary metallurgy plants, etc.

Another author [13] considers Smart Grid as superconducting cables and reactive power compensators:

"Smart Grid assumes using reactive power and voltage adaptors, power concentrators, superconducting cable lines and short-circuit current limiting devices. This year the up-to-date reactive power adaptor STATCOM will be put into service at Vyborgskaya power station (400 kV) to improve the steadiness of electric energy exported to Finland. An asynchronic reactive power compensator will be activated at the 500 kV Beskudnikovo substation for maintaining optimum voltage and increasing network transfer capacity. This will result in a steadier power supply for consumer from North and North-East regions of Moscow city".

Above are just a few examples of the numerous attempts of different entities to wheedle money out of the government to finance their own projects under the guise of the Smart Grid. The issue is if the investment program will be capable of covering everything – from furnace transformers and super-

conducting cables to reactive power compensators, or, as usual, this whopping sum will be ladled out and the broadcast campaign will end until the next hot oversea byword appearance.

2. Smart Grid: Western-style

While the "Smart Grid" term is twisted in Russia, in the West this term is misused as well. Over recent years this term was significantly transformed and lost its original meaning. Today it covers almost all power industry - from power production systems and grid structure and configuration, to metering and information-measuring systems, automated control systems, communication between power facilities and relay protection. As we can see, today this term has no clear definition and is used differently by different authors, so it is not possible to get a clear understanding on the root of the Smart Grid. Articles of some authors where the term Smart Grid is used in the header are focused on construction principles and configuration features of power mains while others on establishing communication channels and data transmitting principles, or on environmental issues and alternative power sources. As is readily apparent, the application of this term has been made absolutely senseless.

Usage of this term in different national programs on reconstruction and modernization of power industry is also senseless as such major programs last for decades within which equipment and technologies are gradually changed and require enormous investments made possible only in portions for individual projects. So the reality is that today we are only able to consider individual components such as the formidable concept of Energetic development as the Smart Grid rather than using the old, well-established and common terms with clear definitions.

2.1. Power production systems. Climate change issues and predicted lack of organic fuel promote the development of alternative sources of electric energy, such as wind generators, solar photovoltaic systems, biofuel generators, tidal wave power generators, geothermal power generators, etc. Pumped storage developments enhancing efficiency of produced energy use is another trend. It is expected that in the future the number of such sources will be connected to different points of a common network. This means that in the future power production facilities will be distributed rather than concentrated, as they are today. The important feature of such sources is relatively low capacity and instable power parameters. It is clear that in order to stabilize the parameters of such sources and provide their automatic synchronization with the grid an intelligent control device is required.

The development of brand new power generator systems and improvement of technical and economic efficiency of existing ones, designing appropriate automatic control devices and communications systems providing information exchange between such sources and other power system units is one of the Smart Grid concept directions.

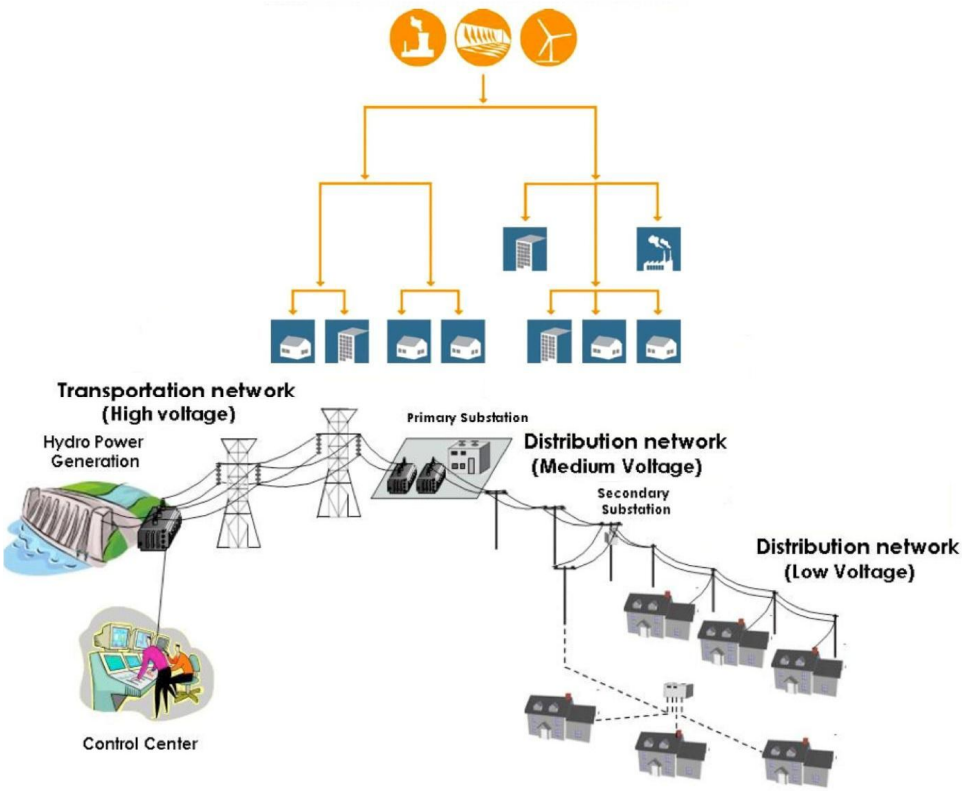

Fig. 1. Structure of a traditional hierarchic electric grid

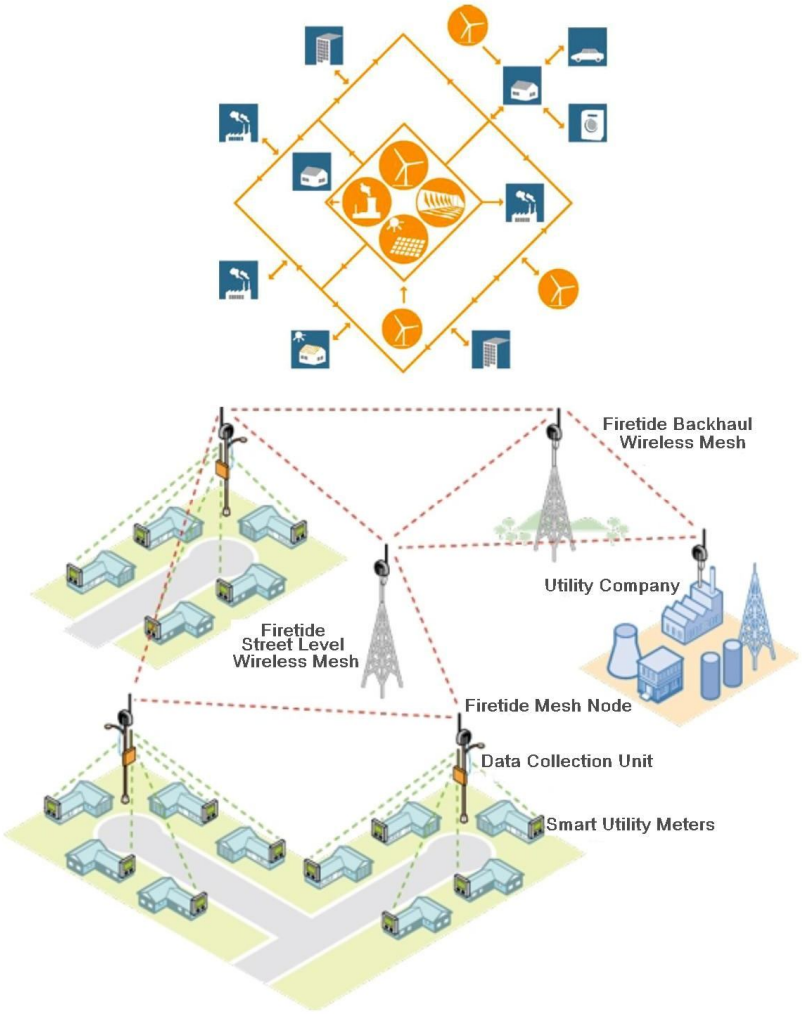

Fig. 2. Smart Grid Structure with Wireless Information Control Network

2.2. Electrical grids. Today, electrical grids are hierarchic (generator, main lines, distribution networks, municipal networks, etc.) [14], Fig. 1.

Most modern electrical grids consist of radial lines with one-way flow of energy. Only some of them are completed. Future Smart Grid networks will not be hierarchic while large consumers will be “mixed” with a large number of relatively low-power energy sources, individual high-power plants, voltage regulators, reactive power compensators, etc. It will be a very complex, unstructured and extended network.

Within this network power flows will not be strictly deterministic. It is obvious that such a complex unstructured grid (which can, in a sense, be compared to the Internet [14]) should have a powerful control system to align the operation of all network components with each other. It demands all components of the network to "dialogue" with each other and with the control center through specific communication networks which are supposed to be wireless. Development of powerful fully-managed network components equipped with self-diagnostic systems and monitoring capabilities, as well as with reliable data transmission and input channels, is one of the directions of the Smart Grid concept development.

2.3. Monitoring and self-diagnostics systems for electric equipment. Both high sophistication of powerful grid components and progress in the computer-controlled systems intensify further development of the health monitor systems for the electric equipment providing early failure prevention on the important components of a network. The law of the aging of electric isolation, knowledge of the trends in composition of supply transformer oil, as well as known features and properties of partial discharges in solid, liquid and gaseous isolation and in vacuum enable creating special indicators and reliable diagnostic procedures for the constant monitoring of the health of important network components constituting another part of the Smart Grid concept.

2.4. Communications and data transfer across the electric power facilities. Today, communication and data transfer across the power facilities are realized through different circuits. This includes low-voltage communication networks (low-frequency control cables, coaxial high frequency cables), optical cables, high voltage power

Fig. 3. «Smart» Electric Power Meters

lines, protected directional radio circuits, etc. In recent years such network technologies as Ethernet/Internet have become increasingly applicable. This primarily resulted from their cheapness, prevalence and ubiquity, well-developed technology and communications protocols, as well as from expected jumps in the sizes of data files exchanged across multiple power network components scattered over a large territory. Even now the market offers various electronic sensors, transducers and sensing devices equipped with cheap built-in Ethernet/Intranet modems. Optical communications used in today's relay protection is considered to be too expensive for the extended and universal application within the future Smart Grid concept [15]. However, this process is accompanied with a great deal of fluff as different companies occupying particular sectors of communication and data market try to validate usage of their principles and data systems within the Smart Grid concept. For example, along with allegations that the future belongs exclusively to the standard network applications, such as Ethernet/Intranet, there are statements that the only valid communication is a broadband high-voltage power lines solution [16]. Also, there are quite serious discussions on the application of habitual and common wireless communications such as cellular networks, WiMAX, Wi-Fi, etc., within the Smart Grid [17], Fig. 2.

2.5. Electric power metering system. Microprocessor-based power meters entered the market many years ago without any connection to the concept of Smart Grid. On the contrary, the purely promotional term "Smart Grid" initially appeared only to promote such meters that grew up in a kind of global vision of the future of power industry. Multi-rate microprocessor-based meters capable of performing calculations, communicating with other similar meters, accumulating and transmitting data over the network have been used in energetics for many years. In recent years, simplified versions of such meters have been applied in everyday life. Now the level of the art achieved in this area fully complies with the concept of Smart Grid.

2.6. Smart Grid operating principle. In accordance with [18] the reliable operation of such a complex system as a Smart Grid can be achieved by minimizing the number of individual multi-function data process modules (this means further concentration of functions in single modules). Data sent from multiple components of the Smart Grid must be transferred to powerful servers through networks, processed by computer centers and sent through the network to actuators. According to [18], all the basic functionality of the Smart Grid should be provided at the software level.

2.7. Relay protection. The new Smart Grid concept considers combination of relay protection (RE) with the functions of information-measuring system. The one reason is that the microprocessor-based relay protection devices (MPD) measure current and voltage in vector form, and the other records and collects emergency and actuation data. This data can be used directly in future control-data-measuring systems of the Smart Grid concept, within which the relay protection would be assigned to additional functions of measurement, monitoring and diagnostics of electrical power systems [19, 20]. Apologists of the Smart Grid expect that in future the MPDs will be converted into some data centers connected only to Ethernet [21]. Such MPDs will not have traditional input or output circuits as all the components of the Smart Grid will take advantage of network connectivity (including high-voltage switches) and all commands including those to release circuit breakers will be transmitted as GOOSE messages under standard IEC 61850 [22].

For the input current and voltage circuits, it is expected [23] that the circuits will not be included into the MPD due to transition to non-conventional current and voltage transformers with digital outputs. Furthermore, it is assumed that such transformers will transmit to the MPDs "ready-to-use" digital data about currents and voltages over the network. As for algorithms of relay protection, they are likely to undergo significant changes due to modifications of electrical network design and a significant number of fully-managed network components that can affect the network operation modes, such as high-speed reactive power compensators, high-speed current-limiting devices, etc. However, these are only the first steps towards the reorganization of relay protection. Even today, there are serious discussions on the adaptive relay protection, proactive protection, multidimensional relay protection, fuzzy logic protection, artificial intelligence protection, neuron protection systems, etc. in technical literature.

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«ИНТЕЛЛЕКТУАЛЬНЫЕ СЕТИ»: НОВЫЕ ПЕРСПЕКТИВЫ ИЛИ НОВЫЕ ПРОБЛЕМЫ? (Часть 1)

В.И. Гуревич

В статье рассматривается современная концепция построения будущих электрических сетей в России и на Западе и вскрываются опасности, сопровождающие переход к так называемым «интеллектуальным сетям».

Ключевые слова: интеллектуальная сеть, электрическая сеть, релейная защита, надежность, преднамеренные деструктивные электромагнитные воздействия.