Sharing energy storage and decentralized PV system

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1. ABSTRACT

Distributed generation (DG) is an important current tendency in the World. The primary goal of all installed DG system is to produce the same amount of electricity that is sufficient for the consumer for normal operation. This electricity produced from a renewable energy source (RES), which close to the point of consumption.

The article reflects an important problem of decentralized energy supply by the hybrid solar-diesel energy station, which includes an energy storage device. The importance of the electricity supply at the intervals of time, when the PV system is incapable to satisfy a requirement amount of electricity is explained. This article analyses the growth of electricity production based on RES and the amount of unused energy from that producing. The main benefits and drawbacks of DG compared to the centralized way of power supply have been explained. This article focusses on the situation nowadays and future developing tendencies of DG in Austria and Russia.

Technical solutions to the problem of development the DG and government support mechanisms of DG have been proposed. The potential scenario of development for these measures has been forecasted. The analysis is based on collection and analysis of the existing empirical data, modeling and literature overview.

2. INTRODUCTION

According to the past decades, the power supply systems have been developing for large-scale units of electricity production [1]. They are composed of high voltage power grids with a large distance of transmission lines. It provides economic benefits, better regulation for operator services, less loss for long distances of electricity.

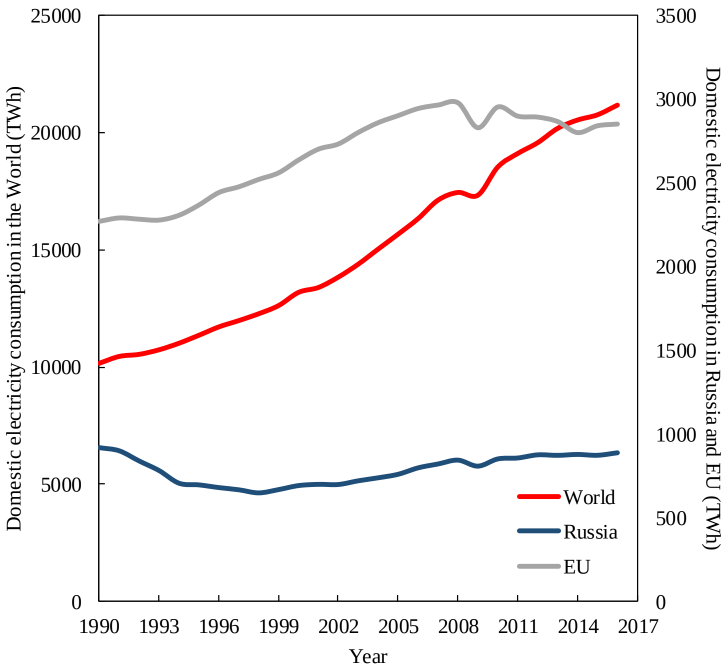

Fig. 1 - Domestic electricity consumption in the World, Russia, and EU [1]

Energy consumption is growing all over the world, which is explained by the population growth, the ongoing process of industrialization, which causes an increase in the consumption of materials, an increase in energy consumption for transportation and extraction of natural resources. At the world level, energy consumption was cut down by 1.5% during 2009, for the first time since World War II. Figure 1 clearly shows a drop in the level of electricity consumption. In 2008, the financial and economic crisis began in the world, which appears in the form of a strong decline in the main economic indicators. The emergence of the crisis is associated with a number of factors: the general cyclical nature of economic development; overheating of the credit market and the resulting mortgage crisis; high prices for commodities (including oil); overheating of the stock market.

Nevertheless, the nature of this growth of energy consumption is questionable. It is based on the use of fossil energy sources; it can cause problems such as overload of power grids, sustainability aspects, it leads to blackouts and has for sure massive environmental impacts.

These problems are more actual for the European Union (EU) countries. The EU countries consume four times more energy per capita than Asian or Southern American countries. There is no doubt that the consumption of energy is properly linked to welfare and a stable economy. Another issue, from the global point of view, is the self-supply of sparsely populated or decentralized areas. It is not cost approved by building and maintaining new transmission power lines and connect those areas with the existing power grid.

The EU wants to achieve the 20/20/20 aims. Which means 20% share of reduction CO_2 emissions in contrast to 1990 levels, 20% share of improvement in the energy efficiency and to raise the consumption of energy produced from RES to 20%. Despite this fact, there are several construction challenges that have to be solved: technical, economic or legislation barriers, and the lack of government support as well [2].

The main advantages of decentralized supply – reduced transmission and distribution costs, reduced fuel costs, reduced requirements for the capacity of central power stations to meet the peak load. The DG has the ability to generate electricity from various sources from traditional sources to RES. As a result, they have become an environmentally friendly alternative for electricity supply.

However, for the remote regions with difficult transportation conditions, which are not connected to the central power grid, the reliable operation of complex, decentralized power facility is the only key to the energy security and safety. The load value in such areas is usually highly changeable, which calls for the simple, reliable, efficient generator. As the result of a high variety of installed capacity needed, natural and weather conditions and safety requirements, it is impossible to propose a universal solution, which will comprise technical and economic benefits.

Decentralized systems with DG have proven to be very cost-effective in many countries. Renewable and hybrid energy systems can replace or supplement existing traditional systems cost-effectively for areas not connected to the centralized electricity. The popularity of decentralized projects with DG has grown so much that it is now a niche-industry in itself – with customer systems being engineered for specific functions [3].

In addition, the optimal size and flexibility in the location of the distributed PV system have been high marked from a technical, economic, and engineering perspective for both the consumer and the generation company [3]. In this paper, we would like to figure out the influencing factors, the benefits and challenges for developing DG and sharing energy storages, especially in Austria and Russia.

3. PROBLEM STATEMENT

3.1. Definition of the DG

Traditionally, the established way of forming the structure of the fuel and energy complex for more than a century has shaped the national vision of distributed generation. Distributed Generation System – facilities and equipment that make up a large number of energy production systems that directly connected to the electrical network and work in parallel with the distribution system of energy [4]. Distributed generation can be considered those objects that are near the final consumption, regardless of who owns them.

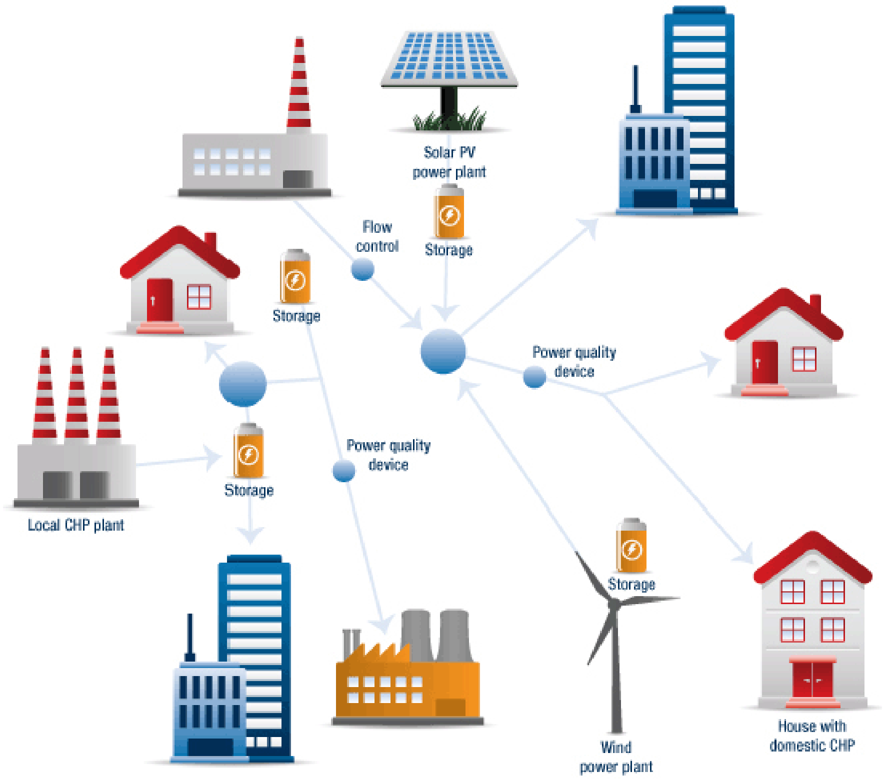

Fig. 2 - Distributed generation scheme [5]

It is necessary to notice that the global electricity consumption is rising and consequently there is a demand to increase the power generation capacity. A significant percentage of the required capacity increase can be based on RES. Liberalization of the electric power industry has given the possibility of choice for consumers. Leaving the Unified Energy System of Russia (Edinaya Energeticheskaya Systema Rossii) to their power supply can reduce their costs by 30–60% [6]. The need for a cleaner environment and the continuous increase in power demand makes renewable energy production, like solar and wind increasingly interesting approach for a new solution.

Nowadays trends in the development of a distributed PV system with battery storages show that countries, administrative and municipal governments are actively experimenting with policies aimed at encouraging a distributed PV system to compensate for peak demand for electricity and stabilize the local network regarding voltage levels. This paper gives a broad overview of the development of distributed PV energy not only in Russia but also in other countries.

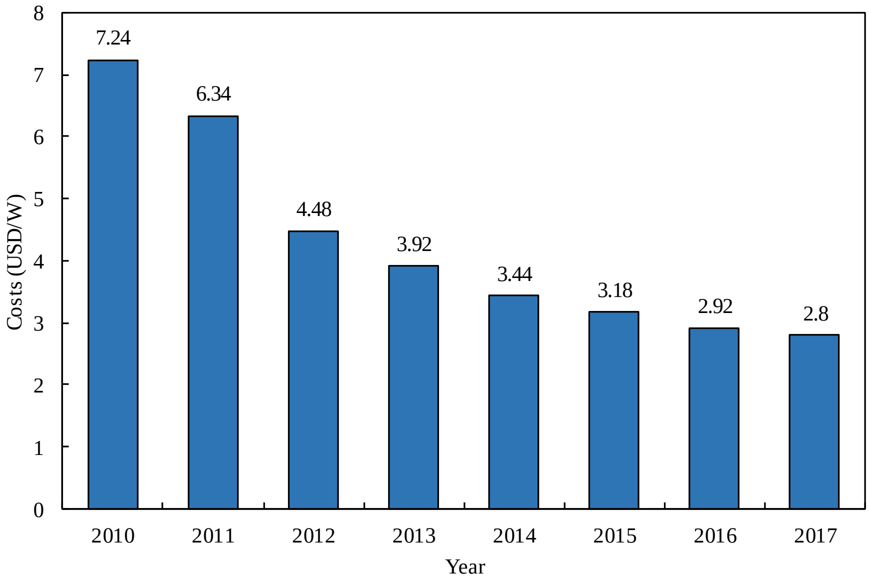

Fig. 3 - World's trend of the reduction in residential PV system cost between 2010 and 2017 [7]

As shown in Figure 3, from 2010 to 2017 there was a 61% reduction in the residential PV system cost. Approximately 61% of that reduction can be attributed to total hardware costs (module, inverter, and hardware of balance of system), as module prices dropped 86% over that period. An additional 18% can be attributed to labor, which dropped 73% over that period, with the final 21% attributable to other soft costs, including permitting, inspection, and interconnection, sales tax, overhead, and net profit. [7].

The active economic support provided by leading countries such as the United States of America, Germany and China in the field of the DG will stimulate the growth of electricity production from alternative sources such as solar energy, wind and geothermal energy. However, the high cost of DG installations will become a critical factor that adversely affects growth. Therefore, this research should define DG's economically efficient criteria for customer, suppliers and government.

3.2. Benefits of distributed generation

The benefits of distributed generation compared to the traditional way of electrification are listed below

1. Essential participant of national power system operation

DG can be used to satisfied baseload power, peaking power, backup power, and remote power demand. DG has a significant impact on decreasing energy losses, increasing voltage level, reducing of flickers, terminate of high harmonics order existence as well. Distributed energy also has the potential to reduce the impact of electricity price fluctuations in the remote villages, strengthen energy security, and provide greater stability to the electricity grid [8].

2. Stand-alone applications

Also called Remote Access Power Systems (RAPS), which provide electricity to people that are not connected to the grid. Usually, PV systems or Wind-turbines combined with a battery or fuel-cell for storage or small engines powered by diesel or biogas are used to generate and provide electricity. On a stand-alone electricity basis, DG is also used as backup power for reliability purposes.

3. Size

Distributed power generators are small and provide unique benefits that are not available from centralized electricity generation such as repair and maintenance service, requirements about the necessary area of installation.

4. The possibility of cogeneration or heat energy generation

The use of combined cooling, heating, and power (CHP) applications lead to improved efficiency and lower energy costs.

5. Reduction of power losses

In DG systems electricity is produced and consumed locally. Thus, there are fewer transport distances of electricity, and so there are fewer power losses. Other problems with energy losses occur in the larger DG system with a lot of network branches. The losses in that branch are possible to resolve with some RES connected to a network branch. The RES can improve the reliability and quality of power supply, especially in areas at the end of DG network.

6. Supporting of central grid

Grid-connected distributed energy resources also support and strengthen the central power system which includes electricity generation, transmission, and distribution. While the central generating plant continues to provide most of the power to the grid, the distributed resources can be used to meet the peak demands of local distribution feeder lines or significant customers.

7. Security of electricity supply

Consumers in some regions are facing periodic blackouts and low-quality power problems. It can be caused by the insufficient generating capacity for meeting the peak demand or by the aging of the existing power transmission and distribution grid which cannot carry all of the electricity needed. Installing DG at or near the point of energy use reduces the demand for central power plants and can avoid the need to upgrade transmission and distribution lines to satisfy power quality requirements.

8. Cost and investment analysis

DG allows players in the electricity industry to react in a flexible way to changing market fluctuations. Liberalization of the electric power industry has given a possibility of choice for consumers. Leaving the Unified Energy System of Russia (Edinaya Energeticheskaya Systema Rossii) to their own power supply can reduce their costs by 30–60% [6]. The need for a cleaner environment and the continuous increase in power demand makes renewable energy production, like solar and wind increasingly exciting approach for a new solution.

9. Environmental benefits

Environmental issues are one of the primary drivers that force to use DG in Europe. DG can play a role in cleaner and cost-efficient energy generation, especially if heat and power are needed. Distributed resource usage with renewables provides a reduction of greenhouse gas emissions, mainly carbon dioxide from the burning of fossil fuels.

10. shared battery storages

One of the main benefits of DG with small distance among houses with PV is the ability to use a high power shared battery. This technical solution solves the problem of connecting photovoltaic cells and batteries in each house and moving it to the central battery. Combination of surplus energy from households into the central battery storage has a lot of benefits. Central battery storage solution allows a continuous check of the individual batteries status on one place, active cooling of all batteries in technically adapted "cargo box," quick response to the failure of the battery set with a possibility of rapid exchange of faulty cell. Last but not least the benefit of shared battery storage is better price/performance ratio than a ration of small battery kit for house solution.

11. cornerstone for the development of the smart village

DG can be divided into individual logical areas, which are always composed of power generators and consumers. The advantage of splitting into smaller sectors is the possibility of decentralized management of each area and possibility of management of cooperation. The logical control of each sector is responsible for the production of energy and accumulation of unused electricity only in its sector, but for ensuring the flexibility and stability of the system is necessary the regular mutual communication between the each of control systems. The mutual communication through messages with information about the current state of the sector, the amount of energy produced from RES, the amount of energy consumed, the accumulated energy in the battery energy storage and therefore information about the losses on the lines between the sectors. This solution should approximate DG to smart network and technical and economic optimization in energy management.

3.3. Main obstacles of distributed generation

There are a few technical, economic, and legal issues, which occur in the development of DG facilities. In this paper, we would like to consider the case of the decentralized power supply as it is the most common way of usage DG in our World.

For the first step, the probable development of a renewable source of energy and DG must be checked from technical and economic points of view. Climatic and territory conditions give technical hurdles for construction of new generating facilities. Also, they are limited by the number of suitable locations for instance biomass usage. There are some environmental constraints as well such as wind turbines facilities are not allowed to be installed in national parks and other protected natural areas due to the noise and animals. Some parts of the river are not allowed to be used for construction hydropower plant due to the threat of flood. For some cases, it is not possible to use distributed PV system in the area without the necessary level of solar insolation.

DG connection to the electricity grid requires the use of more advanced facilities and devices with non-linear characteristics. These devices have a negative influence on distribution systems. Properly designed and optimized off-grid systems should be divided into smaller sectors with their own control logic. Individual segments are independent of each other. Each industry will have its own control system, which will be responsible for the accumulation of unused electricity from particular RES (mostly PV) and compensation for losses to the remote end users (areas). A necessary condition for ensuring the flexibility and ensuring the stability of the system is the mutual communication between the each of control systems. The communication will include information about the current state of the sector, the amount of energy produced from RES, the amount of energy consumed, the accumulated energy in the battery energy storage and therefore information about the losses on the lines between the sectors

The restrictions occur in a case of integration DG with power generation and transmission utilities. Specific hurdles are the following:

1. Lack of efficient energy storage systems.

   The split of the entire system into the individual sectors with its own logical control increases the stability and security of the whole system. In an optimized system, failure of the single industry should not compromise the functionality and durability of the entire system. In the event of an unexpected failure of one sector, the power supply will be replaced by PV or energy stored in energy storage facilities from the adjacent segment. The proposed system will contain the dual placement of battery energy storage. The first energy storage groups will be located together with the PV among the different sectors of the system and will compensate for losses on the connection. Another option is to place the energy storage close to consumers to avoid unnecessary transmissions of PV energy produced on the roofs over long distances and thus further losses.

2. Renewable sources of generation are intermittent sources.

   They may not meet the requirements for proposes of dispatching without backup generation (energy storage). To ensure 100% security of the system, the links between each sector should be duplicated. The cost of such an installation would disproportionately increase the value of the whole project. Therefore, only the primary connection in each segment of consumption will be doubled. For instance, will be created a duplicate relationship between residential area and local battery power storage.

3. Impact on the grid.

   Some RES connected to a power distribution network can improve the reliability and quality of power supply, especially in areas close to the national borders (Russia–Kazakhstan, Austria–Germany) which are at the end of power distribution networks [9]. The basic European requirements of technical standards for connection DG to the distribution grid include following subsections: size of connected power: rated asynchronous generator power should not exit 10% of distribution transformer rated power; voltage difference no more than 2% between distribution and low-voltage systems; long-time flicker perception rate should be less than 0.46 and long-term flicker factor – less than 0.1; allowable harmonic currents are calculated for each individual case [9].

4. CURRENT SITUATION IN RUSSIA AND AUSTRIA

4.1. Russia

Distributed generation can be considered as those objects that are near the final consumer, regardless of who owns them. For today in Russia, it is possible to allocate three categories of generating capacities which fall under this definition [10].

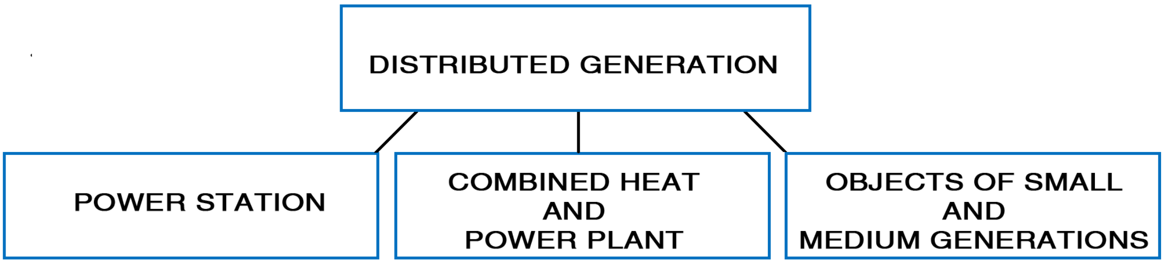

Fig. 4 - Block diagram of the structure of the DG in Russia

Power stations, a source of electrical (sometimes thermal) energy located in the territory or near of an industrial enterprise and owned by the owners of this enterprise on the basis of ownership or another legal basis. Power stations, as a rule, are beneficial to their owners, since they can function at the expense of by-products of the main production (associated gas or blast furnace gas, etc.);

Cogeneration plants. Combined heat and power plant (CHPP) and centralized heating of settlements was the pride of Soviet Union energy. Indeed, the combined production of electricity and heat increases the fuel utilization factor by an average of 30% [10]. According to the background of this effect, significant costs and inconveniences in the construction and exploitation of heating systems become acceptable. This is one of the reasons why cogeneration is widely promoted and encouraged now in the West;

Small and medium generation facilities, including a gas turbine and gas piston stations, as well as small power plants based on RES which still not used widely.

In Russia, despite the fact growing temps of construction of DG facilities, the process of focusing government's forces do not find a clear place in the long-term planning of the development of the system. There is still no understanding of the contribution that DG can make to improve the development of the system and its modernization, and there is no developed state policy on this case. When developing such a policy, the most important part should be the requirement to analyze and, if necessary, revise the philosophy and technology of long-term development planning of the system taking into account the spread of DG, the creation of micro-networks and the integration of smart grid technologies [10].

4.1.1. Main reasons of attractiveness by using DG

1. The DG removes the requirements to build and reconstruct a new network infrastructure.
2. The availability of voltage sources in locations close to the load increases the reliability of power supply, helps necessary voltage levels in the network and reduces transmission losses.
3. Reduction of losses in transmission lines and flows of reactive power.

4. Financial risks associated with small and medium generation facilities are much lower than for facilities with a large installed capacity.
5. Predictability of energy costs.
6. Improving the reliability of power supply for the owner of its source of electricity, because most of the interruptions in power supply are associated with unexpected situations in the network economy.

DG is often new equipment imported from abroad, with new dynamic characteristics and management capabilities. The influence of DG on the quality of electricity by voltage levels as well as on the generation of higher harmonics in the system is also unpredictable. The connection of sources of DG to the distribution network increases short-circuit currents, which may require replacement of switching devices, changes in protection settings, etc. The appearance of DG complicates operational dispatch control, as well as relay protection and automation system, emergency control.

Russia is one of the countries in the world with the largest areas not covered by main grid power lines. The most common small-scale generation utilities in Russia are DPP. There are certain advantages of producing energy from diesel fuel, but the disadvantages are considerable, too: high consumption of fossil fuels in the production of one kWh of electricity, pollution.

There is no doubt that the centralized electricity grid correlates with the areas of density of Russian population. South regions of Russia more attractive to life and it has historical backgrounds: better possibilities for agriculture, proximity to other countries, better environmental conditions, etc.

It is clear that now in Russia there are specific areas – the Far East, the Arctic zone, the regions of the Far North, where distributed generation facilities have already been introduced, and they can be points of growth in the sphere of small energy.

The development of the Far East is one of the state's top priorities today. To solve this problem, a federal target program for the development of the region has been developed, and the Ministry for the Development of the Far East has been established.

In the northern part of the Far Eastern Federal District and the coastal areas of the Northern Sea Route, a large number of small DPP operate in the SAPS. As a consequence, the cost of electricity is extremely high, due to the large distance of these areas from the suppliers of diesel fuel [3]. In order to reduce the fuel dependence for local energy companies, alternative energy projects are developing in the region, including distributed PV and wind generation.

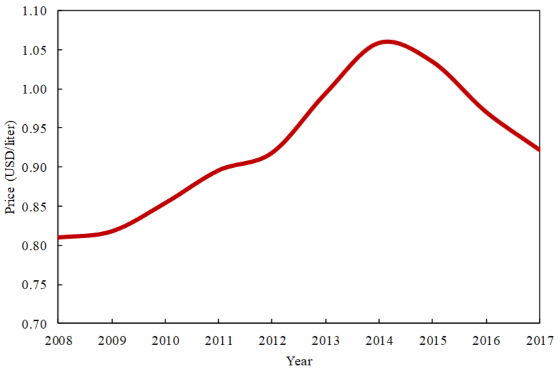

Fig. 5 - Dynamic of monthly prices of diesel fuel in Russia [11, 12]

The growth from October 2010 to November 2014 described in Figure 5 is explained by monopolistically high prices of diesel fuel. The leaders in the field of oil industry such as Rosneft, LUKOIL, GAZPROM Neft withdrew diesel fuel from the market, causing an artificial deficit, established and maintained higher prices, and created discriminatory conditions for deliveries of goods to the market [11, 12].

The Northern Sea Route is the shortest sea route between the European part of Russia and the Far East, the historically established national unified transport communications of the Russian Federation in the Arctic. Passes through the seas of the Arctic Ocean (Barents, Kara, Laptev, East Siberian, Chukchi) and partly the Pacific (Beringovo). The distance from St. Petersburg to Vladivostok along the Northern Sea Route is over 14 thousand km (in contrast to 23 thousand km through the Suez Canal). The Northern Sea Route serves the ports of the Arctic and large rivers of Siberia (import of fuel, equipment, food, removal of timber, minerals). The overall route on Russia's side of the Arctic between North Cape and the Bering Strait has been called the Northeast Passage, analogous to the Northwest Passage on the Canada side.

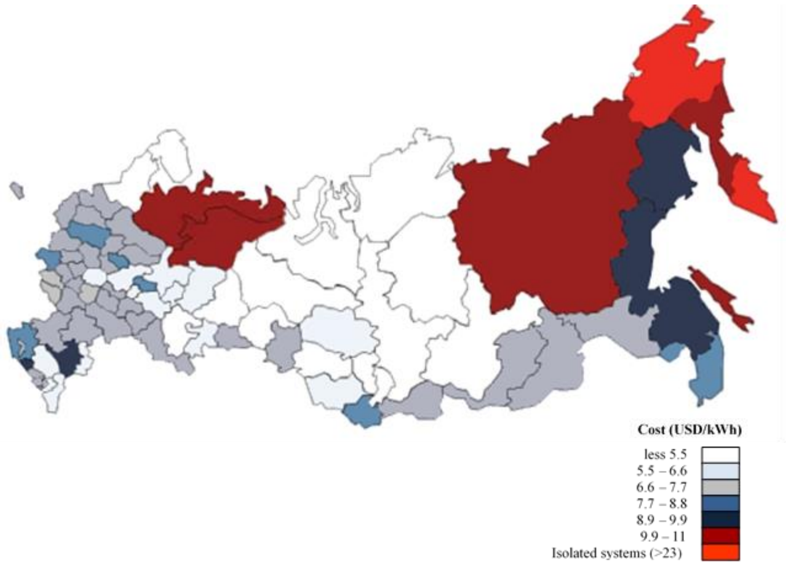

Fig. 6 - Price of electricity production in diesel generation in stand-alone areas during 2011 [13]

The Arctic attracts many countries with rich gas and oil reserves. The melting of ice and general warming could make the Arctic Ocean a busy transport route between Europe, Asia and America [14]. Also, the possibilities of pirate attacks on ships following the southern routes, increase the interest of ship-owners to the Arctic routes. However, the North Sea Route will be able to compete with the southern routes only if it is economically advantageous and its infrastructure will ensure the maximum reduction of additional costs when navigating in Arctic ice.

4.1.2. Main problems related to the energy infrastructure of the Northern Sea Route and the Far East.

1. Adaptation of the work of wind and PV plants in the Arctic climate.

   The main obstacle to development, in particular, wind energy, is the difficulty of working in the Arctic climate [15]. And, as a consequence, damage to the generating equipment.

2. Formation of infrastructure for the operation of hybrid complexes of three types of substitution [15].

   For each category of hybrid power plant substitution schemes, there are some problems associated with the organization of automated complexes and control systems with the growth of installed capacity of installations.

3. Formation of own production of generators for wind turbines and PV in the territory of the Russian Federation.

   Prospective is the large-scale use of RES power stations for electricity supply, oil and gas complex, railway and motor transport, and agriculture [15]. The need for the development of production and service infrastructure for wind energy and PV systems is one of the important vectors. Currently, the enterprises of local production of energy based on RES are not enough in Russia.

4. The problem of using oil and gas production equipment by traditional technologies along the Northern Sea Route area.

   Because the Arctic Ocean is a specially protected object, the use of components containing radioactive elements is prohibited. It is about equipping virtually all oil producing wells with multi-phase VX-based flowmeters technology (radioactive measurement) [16].

4.1.3. The characteristic features of using RES in the northern and remote areas for wind power and PV power are the following [16]

1. Reliable operation at extremely low temperatures (-40/-50°C);
2. Installation without construction machinery;
3. Simple and reliable design;
4. Availability of independent examination of the test results.

Distributed PV generation can provide support to the system in emergency situations and there prevent their occurrence or reduce the amount of damage. As a result, the tariff load on consumers served by the energy system is reduced because of portion substitution of diesel fuel by solar energy. In addition, thanks to diversification into DPP and PV system, the financial risks associated with the objects of small and medium generation are much lower.

4.2. Austria

Historically seen, Austria had an energy supply system principally based on micro-grids. But the grids became connected more and more even with other countries, and it is now part of the UCTE - Union for the Co-ordination of Transmission of Electricity, like the Czech Republic too. Usually, the central European power grid is meant by the term UCTE. In this power grid, it is possible to transfer huge amounts of electrical energy between the different power grid operators - even if there are losses for the transportation of the electrical energy. For the transfer, high-voltage power lines of 220kV and 400kV are needed - these high-voltages power-lines minimize the losses, but they do still exist. But the advantage of large connected grids, such as the central European power grid is a more stable one, in which fluctuations of production and consumption can be balanced better.

The term smart-grid is very popular in this context. The idea behind the smart-grid is to connect consumer, producer and energy storage to one system that communicates together so that the future requirements to the power-grid, caused, e.g., by a lot of small-generation-systems, are fulfilled. "The introduction of generating sources into the distribution network called distributed generation (DG) can produce a significant impact on power flow through the network, voltage condition at various utility consumer, equipment and switchgear fault ratings," says Balamurugan et al., 2011.

Micro-grids can be understood as smart-grids just with the advantage of an autonomous operation mode. If the superior power-grid is in maintenance or even collapses then the micro-grid switches to an autonomous mode and the consumers can still be supplied adequately. The main difference is the grid-load. Micro grid loads are from 50kW to a few MW.

- The power-grid-levels:
  1. Maximum voltage level

     In western Europe it is 230kV or 400kV; used for feeding high-power transformer; connected to the international power-grid.
  2. High voltage:

     110kV, regional distribution grid, covers power demand from 10 to 100MW, wires are connected to energy-intensive corporations, city-regions, and different distribution stations
  3. Middle voltage:

     1kV to 30kV, especially used in rural regions, distributed the electricity to regionally distributed transformer-stations, hospitals or factories; also used to feed in the electricity of smaller power plants; suitable for micro-grids.
  4. Low voltage:

     230V or 400V, used for private households or smaller industry companies, also used for the feeding of electricity produced, e.g., from photovoltaic systems, suitable for very small micro-grids

4.2.1. Micro-Grids and the ADRES-Concept:

The regenerative power generation systems are usually smaller generation systems and not huge power plants as the conventional nuclear, coal, gas or oil power plant. So the idea is obvious to create autonomous micro or mini-grids, in which production and consumption are predominantly in the same area. Hence, DG and micro-grids are highly linked. In Austria is an attempt with the aim to develop an Autonomous Decentral Regenerative Energy-System [17].

- Developing micro or mini-grids seems on the first sight like a step back, but the motivation behind the decentralized or distributed generation is mostly the following:
  1. Integration of regenerative generation systems to get a high share of regenerative electrical energy

2. A higher safety in case of a blackout through the possibility of an autonomous operation mode.
3. Minimization of the transport losses of electricity

The aims are to minimize the electricity production costs ensuring that the load is served reliably. One of the main challenges for Micro-Grids is production control of electricity or adaptation of production and consumption. The consumption is not always the same. Usually, there are peaks in the morning and evening. Figure 1 shows the consumption of a two people household during one average day:

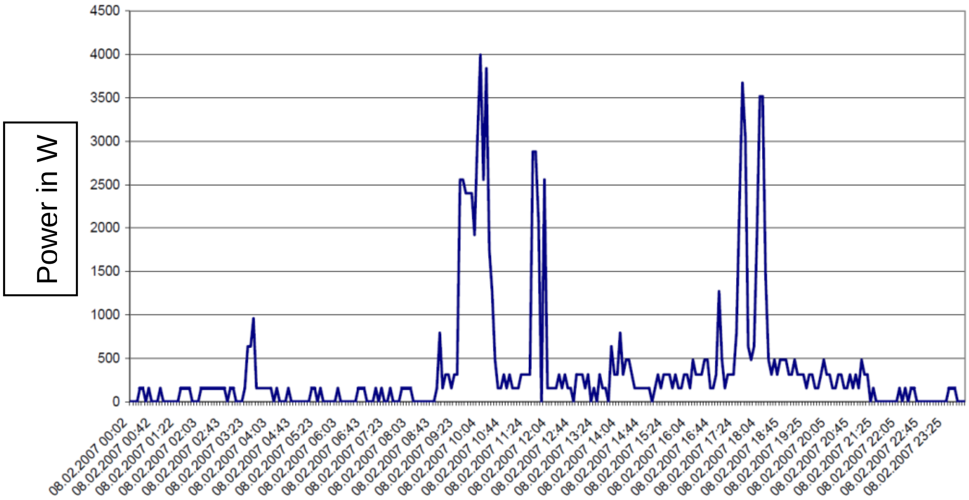

Fig. 7 - consumption of a two people household (Einfalt A. et al., ADRES, 2008)

Of course, there is a difference between a single-household and the overall-consumption, but the main statement is, that there are fluctuations in consumption and so they have to be in production, except the produced power can be stored.

Photovoltaic cells, e.g., cannot provide the amount of electricity that is needed or especially to cover the peak-consumption. So the supply security is very dependent on the sources that are used and how they are connected with each other. The conclusion therefore is: There is no panacea for decentralized power generation.

Hence, different kinds of generation systems have to be combined, that match the local or regional situation**.** But the connection or especially the communication of different types of power generation systems, such as biomass, wind, photovoltaic, etc. is cost-intensive to realize. They have to communicate so that a stable and coordinated production of power is the result. Technically the problems can be solved, but it´s still too expensive and not commercially market-ready.

One possibility is to store produced electricity in times when consumption is lower than production. There are some possibilities: "A review of existing storage technologies found that Lithium-Ion (Li-ion) battery and flywheel systems are currently two of the most suitable and promising storage systems" [18].

4.2.2. Decentral power generation (DPG):

Connected to the grid, but produced in smaller powerplants, the decentral power generation covers about 16% of the total amount of Austria´s electricity-demand or 11TWh. Figure 2 shows the production quantity of Austria´s DPG from 2002 to 2010.

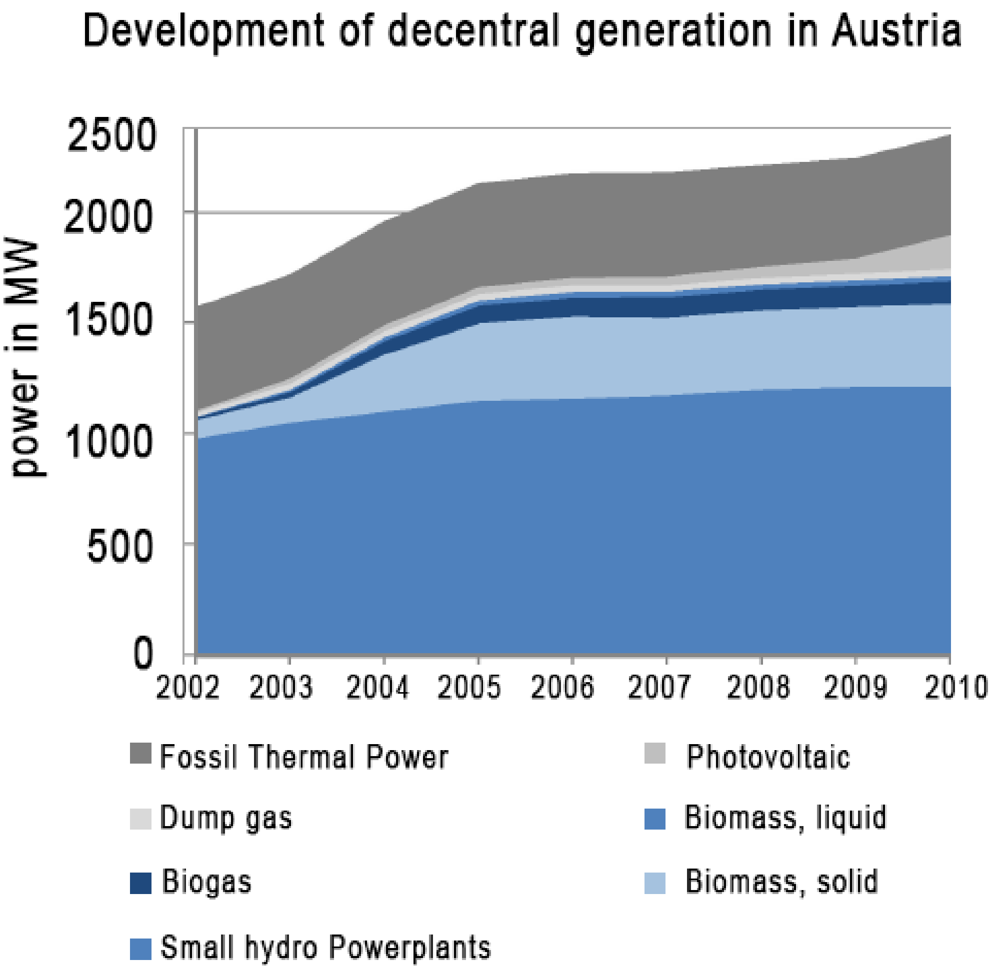

Fig. 8 - Decentral electricity Production in Austria from 2002-2010 [19]

The biggest part is small hydro powerplants, followed by solid biomass and fossil thermal power. Remarkable, that photovoltaic installations are increasing fast since 2008/2009. This trend can be described with the implementation of the amendment of the "Ökostromgesetz" in 2008, which promotes photovoltaic installations from 5kWp+. Large Wind parks are not considered in this figure.

4.2.3. Support mechanisms in Austria - the Ökostromgesetz:

The central support instrument in Austria for environmental-friendly produced electricity is the so-called "Ökostromgesetz" (ÖSG) which provides law regulated compensation for electricity that is fed into the grid especially from small producers. These compensations are guaranteed for at least 13 or 15 years depending on the production, whether it is resource-dependent (e.g., Biomass) or -independent (e.g., Photovoltaics). The grid feeding-compensations increased from 202 mln. Euros in 2003 to 657 mln.euros in 2012.

Beside the grid-feeding-compensations, there are investment incentives from the federal-states and the federal republic. The ÖSG exists since 2002 with important novels in 2006, 2009 and 2012.

- Some improvements of the novel of 2012:
  1. 10 million € for the reduction of project waiting-lists including wind, photovoltaic and small hydro power plants.
  2. Increasing the subsidies from 21 million € to 50 million € per year.
  3. New, binding development goals for the year 2020 (Table 4.2.)
  4. Subsidies for particular technologies
  5. Rearrangement of the support mechanism: more transparency in connection with significant reliefs for low-income households and energy-intensive corporations.

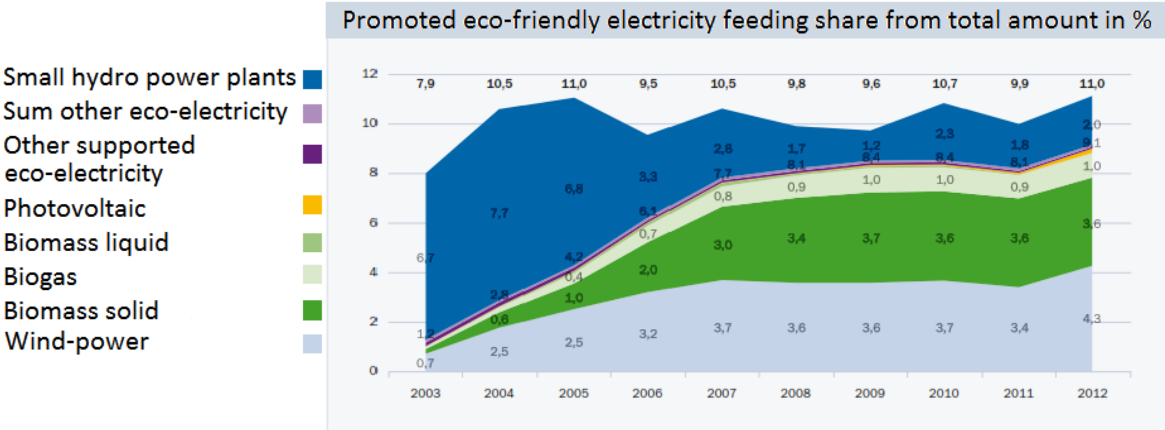

Fig. 9 - Promoted share of electricity covered by the Ökostromgesetz [19]

As figure 3 shows, the amount of promoted produced power is quite stable since 2004. Only the different shares are varying. Wind power and especially solid biomass and biogas are increasing their shares, whereas the amount of subsidies for smaller hydro power plants is constantly decreasing. Hard to see in this figure, but the increase in photovoltaic was 157% from 2011 to 2012, the number of facilities nearly doubled in one year. Altogether, there were 13512 contract-partners who received subsidies, generated through the Ökostromgesetz, whereas 11056 were photovoltaic-facilities. All in all 6152 GWh where fed into the grid in 2012 from promoted facilities - mentionable: 2386 GWh wind, 1983 GWh solid biomass, 554 GWh biogas, 101 GWh photovoltaic [19].

4.2.4. Developments goals in Austria:

Developing Goal Ökostromgesetz 2012				
	2015		2020	
	MW	GWh	MW	GWh
Hydro - power	700	3500	1000	4000
Wind - power	700	1500	2000	4000
Biomass and Biogas	100	600	200	1300
Photovoltaic	500	500	1200	1200

Table 1 - Developing Goals for promoted RES for 2015 and 2020 in Austria [19]

Wind power should nearly be tripled from 2015 to 2020, Biomass and Biogas subsidies should be doubled in this five years, and Photovoltaic should generate more than twice the amount of power in 2020 than it did in 2015. Only hydro-power, which was promoted in the past with absolutely the highest rates, should be promoted nearly at the same level, or only a slight increase.

Another goal from the ÖSG novel 2012 is the independency of nuclear power until 2015, and a share of 15% promoted production from the total electricity demand of Austria.

The EU´s energy target - to cover 20% of the whole energy consumption by RES - is a driver and will foster DG deployments." The potential for a further increase of DG is sufficiently available, but deployment strongly depends on financial and political framework conditions. The Austrian energy strategy identified decentralized electricity and heat production as one major column to obtain the national energy targets. DG shall contribute to increased energy efficiency as well as a growing amount of renewables. Implicitly DG shall strengthen the security of supply due to decreasing dependence on energy imports. Hence, the recently issued new version of the green energy law (Ökostromgesetz) provides improved incentives, and rising numbers of new DG applications can be expected." [20].

5. CONCLUSIONS

Now the distributed generation is economically useful only in the areas, which are so far from the distribution network. The typical area for (Off-grid) implementation is Russia an especially the Far East and the Arctic zone. In countries such as Germany, Czech Republic and Austria with a good quality of the energy system, the off-grid system contributes to the development of a smart village with production and energy management. And that is the basic difference between the perception of the off-grid system in Russia and Austria. Because in Russia there is a large number of oil reserves, so the diesel generators are the preferred sources in their off-grid systems. We can expect, that production of electrical energy in remote areas In Russia will have higher priority than limitation to the amount of CO_x produce. The other way, a lot of European countries want to reduce the amount of CO_x, so they support production from renewable sources. In the EU, the off-grid system is primarily considered energy self-sufficiency system composed of renewable energy sources (RES). This system should be the basis for the concept of the smart village.

References (Literature)

1. Total energy consumption: Enerdata. Global Energy Statistical Yearbook 2017. Available at: https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html
2. Europe 2020. A European strategy for smart, sustainable and inclusive growth. Brussels, 2010. Available at: http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf
3. LUKUTIN, B.V., SHANDAROVA, E.B., MAKAROVA, A.F, SHARTSMAN, I.B. Effect of Distributed Photovoltaic Generation on the Voltage Magnitude in a Self-Contained Power Supply System. IOP Conf. Series: Materials Science and Engineering. Tomsk, 2016. Available at: http://earchive.tpu.ru/bitstream/11683/34882/1/dx.doi.org-10.1088-1757-899X-127-1-012005.pdf
4. State Standard R 54531–2011. Alternative technologies. Renewable and alternative energy sources. Terms and definitions. Moscow, Standartinform Publishing, 2013. Available at: http://gostexpert.ru/data/files/54531-2011/70239.pdf
5. Localized power generation: S&P Global Platts. Available at: https://www.platts.com/news-feature/2013/electricpower/powergen/local
6. KOZHUHOVSKIY, I.S. O problemakh razvitiya maloy raspredelyonnoy energetiki v Rossii. [The problems of development of small distributed energy in Russia]. Moscow: ENES forum, 2014. Available at: https://enes-expo.ru/docs/Kozhuhovskii-I.S.FGBU-Rossiiskoe-energeticheskoe-agentstvo.Problemy-razvitiia-maloi-raspredelennoi-energetiki-v-Rossii.pdf
7. RAN FU, FELDMAN, D., MARGOLIS, R., WOODHOUSE, M., ARDANI, K. *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017*. National Renewable Energy Laboratory (NREL) Prepared under Task No SETP.10308.03.01.10, 2017. Technical report. Available at: https://www.nrel.gov/docs/fy17osti/68925.pdf
8. LUKUTIN, B.V., MURAVLEV, I.O., PLOTNIKOV, I.A. *Sistemi elektrosnabzheniya s vetrovimi i solnechnimi elektrostanciyami* [Power supply systems with wind and solar power plants]. Tomsk: Tomsk Polytechnic University, 2015.
9. E.Mgaya , Z.Muller, Impact of Connecting Distributed Generation to the Distribution System, 2007.
10. Energosberezheniye, 2012. Tendentsii razvitiya raspredelyonnoy generatsii. [Energy saving, 2012. Trends in the development of distributed generation]. Available at: https://www.abok.ru/for_spec/articles.php?nid=5371
11. Avtonovosti, 2011. Ceny na soljarku: polniy absurd i naglost'. [Automobile news, 2011. Prices of diesel fuel: complete absurdity and impudence]. Available at: https://auto.mail.ru/article/34055-ceny_na_solyarku_polnyi_absurd_i_naglost/
12. Gazeta Kommersant, 2017. Dizel' razogrevayet ceni: toplivo dorozhayet iz-za remontov NPZ. [The newspaper Kommersant, 2017. Diesel heats up prices: the cost of fuel is higher due to refinery repairs]. Available at: https://www.kommersant.ru/doc/3408522
13. *Solnechnaya energetika. Analitika, 2011. Solnechnaya energetika: persperktivy v mire i sostoyaniye v Rossii.* [Solar energy. Analytics, 2011. Solar energy: prospects in the world and the state in Russia]. Available at: http://www.energy-fresh.ru/solarenergy/analitics/?id=1931
14. Voprosik, 2016. Perspektivy Severnogo Morskogo Puti. [The Question, 2016. Prospects of the Northern Sea Route]. Available at: http://voprosik.net/perspektivy-severnogo-morskogo-puti/
15. NIKOLAEV, N.G. Resursnoe i tekhniko-ekonomicheskoe obosnovaniye shirokomashtabnogo razvitiya vetroenergetiki v Rossii. Dokt, Diss. [Resource and feasibility study of large-scale development of wind power in Russia. Doct. Diss.]. Moscow, 2011. Available at: http://old.rgo.ru/wp-content/uploads/2011/12/VEU-methodology.pdf
16. RYMARENKO, K.V. Mnogofaznaya rashodometriya. [Multiphase Metering]. Schlumberger, 2011. Available at: https://elibrary.ru/item.asp?id=16330251
17. *TUESEA: ADRES-Concept* [online]. [cit. 2018-06-17]. Available at: https://www.ea.tuwien.ac.at/projekte/adres_concept/
18. DE BOER, Petra. Grow-ders: Grid reliability and operability with distributed generation using flexible storage. In: *CIRED Workshop* [online]. 8. June 2010, s. 4 [cit. 2018-06-17]. Available at: www.cired.net/publications/workshop2010/pdfs/0040.pdf
19. *E-CONTROL: Öko-Energie* [online]. [cit. 2018-06-17]. Available at: https://www.e-control.at/marktteilnehmer/oeko-energie

20. MATERAZZI-WAGNER, Christine. DISTRIBUTED GENERATION IN AUSTRIA. In: *CIRED Workshop* [online]. 29. May 2012, s. 4 [cit. 2018-06-17]. Available at: https://ieeexplore.ieee.org/document/6302535/