Autonomic energy supply of distributed/isolated villages in Russia by using combination of LNG/CNG/LPG/diesel and renewable energy

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Abstract. This article is dedicated to search of right balance for heat and power supply of distributed villages in different conditions in Russia. Russia has a huge territory that is not connected to power grids, many villages aren’t connected to natural gas network and don’t have district heating systems. Approach consists of several steps. On the first step we choose isolated areas and villages that have no chances to get connection to natural gas grid. Even if they are connected to power grids, they still have a room for autonomic solutions in producing heat/hot water. In many cases quality of power is not very good. Then on the second step we compare different combinations of traditional (LNG/CNG/LPG/diesel) and renewable (PV panels, solar collectors, wind turbines + heat/power storage units) power sources in order to find the best way of power/heat supply for the village. In the article the approach is shown on two different examples – Dagestan (south of Russia) and Yakutia (north of Russia). Article also covers some ways and proposals of renewable energy supporting considering current situation in this industry.

1. Introduction

Russia is one of the biggest energy consumers in the world (after US), it is also the second biggest natural gas market (comparable with whole EU market). Traditional fuel (coal, hydrocarbons, nuclear and hydro power) forms almost 100% of country energy market. At same time the use of combined systems for the generation of electric energy through the use of fossil fuels and renewable energy resources is relevant worldwide [1 – 13]. Despite the huge potential renewable energy (we are not count hydro power plants with capacity more than 25 MW) plays a minor role in Russian energy balance (less than 1%). Potential of renewable energy in Russia can’t be got only by development big or medium scaled projects (mostly in power sector for wholesale power market or for compensating grids loses), it is necessary to develop small scaled projects for autonomic and distributed locations [14 – 17]. More than 50 % of Russia are not connected to electricity and natural gas grids (population of them reaches 20 million people), in Artic zone live more than 2 million people. Figure 1 shows the current situation with energy supply in different Russian regions.

For finding the best solution for energy (heat/cold and electricity) supply of autonomic or isolated location in Russian conditions the approach was proposed. It helps to find the combined energy
solution for small (generally up to 1000 people) villages (objects). This approach put together heat/cold/power supply by using both traditional and renewable energy sources and may be used for any village (autonomic objects) in Russia.

Figure 1. Current situation in energy supply of Russia.

2. Approach of choosing the right fuel balance

Proposed approach consists of three basic steps:

- Checking possibility of natural gas grid connection;
- Choosing the best combinations of traditional and renewable energy sources (both for heat and electricity production);
- Choosing the best solution based on economic evaluation.

On the first step we can go in two directions – to check village (object) that has already been chosen or to find a right village (object) for autonomic (partly autonomic – power grid + local energy sources) energy supply. If the region is not connected to the gas grid or have a low level of gasification, we can go to the step 2. However even if the level of gasification reaches 90% or even higher, we still can find a good village (or objects) that meets our criteria. For example, in Moscow region there are plenty of locations that are in grid zone but objects (cottage villages) can’t be connected to the grid because there is no technical possibility (grid is overloaded). In this situation we can consider village (object) as located autonomic. In some regions such as Kostroma or Dagestan (shown later) part of the region (several district) stay beyond natural gas grid, therefore we can also consider them as autonomic (or partly autonomic) locations.

On the second step we consider all possible combinations of traditional and renewable energy sources for the village (the object) heat/cold and power supply. Possible traditional and renewable heat supply variants are shown in Table 1.

Table 1. Possible sources of heat and power supply

| Variants | Heat/cold supply       | Power supply                                |
|----------|------------------------|---------------------------------------------|
| A        | Natural gas (LNG or CNG) | Power grid                                 |
| B        | LPG                    | Diesel power units                          |
| C        | Heat pumps             | Natural gas small-scaled power units        |
| D        | Solar collectors        | PV panels                                   |
| E        | Electric tents/electric coolers | Small-scaled wind turbines               |
| F        | Geothermal wells        | Hydro energy                                |
| G        | Biofuel (wood, biogas from manures, sewage etc.) | Biofuel (wood, biogas from manures, sewage etc.) |
Depending on where village is located (South or North of Russia), possibility of LNG/CNG supply, wind, hydro and solar energy potential, different combinations of energy sources are possible. For example, for isolated villages in Artic conditions the most popular combination is wind/diesel or solar/wind/diesel. In case of distributed locations in south of Russia solar energy may play an important role. In some cases, power from PV panels may be stored in power storage units (the most popular choice is lithium storage units), in some cases power produced not in pick demand time may be used to produce heat (electric tents), heat may be stored in special heat storage units. For cooling (in south regions) electric cooling may be a good solution (both ambient temperature and PV panels power production correlated with solar activity), however other ways of cooling may also be considered. New microgeneration law will give a right to domestic producers or small commercial to send to the power grid up to 15 kW of power capacity (about 3-5 MW for 1000 people village).

However, in many cases power grid can't meet this energy in off-peak period, so it is better for the grid if most of power is consumed locally. To peaks in some cases power storage units may be used (there are still expensive but getting cheaper every year).

After we make a matrix with all possible fuels (combinations of fuel) many of them may be exclude as irrelevant. For example, if locations are more than 600 km far from natural gas grid there is no way to consider it as a fuel; if we don’t have rivers nearby the location or have a bad wind conditions (week wind) there is no way for hydro or wind power etc. The third step is to choose the best variant among the variant from step 2. In isolated zones basic fuel for heat and energy production is expensive diesel (in 2019 wholesale price may reach 70 RUR and even more), solar (PV panels and collectors) and wind energy can partly substitute diesel. In autonomic (partly autonomic) locations in case of LNG/LPG availability this fuel may be considered as part of fuel balance; in this case renewable energy has good chances to compete. For example, heat and electricity from wood and from sewage plant biogas may have the same price as heat and electricity from grid natural gas and even lower. PV panels, solar collectors and even some of heat pumps are also competitive with traditional fuel (CNG, LPG). In case of diesel even wind or small hydro energy may be competitive.

3. Examples of projects – Kutlab, Dagestan, Yakutia

In south regions of Russia many small (up to 1000 people) villages don’t have stable centralized energy supply. Power grids are very old therefore the quality of power is quite low. Even though the level of connection to natural gas grids may exceed 90%, there are still big number of villages that stays outside natural gas grids. For example, in Dagestan there are no any plans to connect to the natural gas grids 10 districts of 37 because there is no economic efficiency of such projects. Heat supply of households is often local (household boilers on LPG, electricity ore diesel).

Kutlab (population is about 1000 people, app. 300 houses) is a village in one of 8 districts in Dagestan that will stay outside natural gas grid supply, so it matches to positive conditions of the 1st step of proposed approach. Currently Kutlab takes electricity from the grid, but the quality of the grid and therefore the quality of electricity supply is not very good. Depending on power consumption household use from 8 to 30 kW. Heat supply is not centralized and is mostly on diesel and LPG. To improve electricity supply in Kutlab after the step 2 of the approach we chose combination of PV panels and diesel/LNG (in case of small scaled LNG plant construction in region) power plants. Taking in to account new microgeneration law (15 kW for each household) it is possible to install up to 4.5 MW of PV panels but in fact real consumption is 1.5 – 2.5 MW. Combination of PV panels and diesel seems to be a best choice for Kutlab (more detail calculation is in work now), for heat the best solution seems to be combination of solar collectors (for hot water we need 500 collectors 2 m² each) and LNG/LPG boilers.

Another example where the approach was used is one of the isolated villages in Niznekolymsky district, Yakutia (Figure 2). The main fuel for heat and power production is diesel. For power generation diesel can be partly replaced by wind or solar power. So far we made estimations for wind-
diesel complexes. Estimations for PV panels and for solar collectors have to be made. Figure 3 shows that average annual capacity consumed by the village is 168 kWh, maximal is 206 kWh in November. Estimations were made by using equipment that is in Table 2.

Table 2. Project equipment for wind-diesel complex.

| Equipment |
|-----------|
| Wind unit Condon Air – 50 kW | 4 |
| Accumulator Delta DTM 12200 – 200 A·h | 160 |
| Diesel power unit Iveco (FPT) GE F3250 (40 kW) | 3 |
| Diesel power unit Iveco Iveco (FPT) GE NEF125M (100 kW) | 1 |
| Invertor PI 50000 W (380V) | 1 |

Estimations show that if wholesale diesel price is 40 RUR/liter wind power plants can decrease cost of power in more than 1.5 times (from estimated 18 to 10.5 RUR per kWh). We are also currently try to use the approach to Hatanga (Krasnoyarsk region, 2600 people) that is in Arctic conditions.
Figure 3. Power production for the village.

Village uses modern oil power plants for electricity supply (3 units 1.5 MW each) and 2 boiler houses that use local brown coal. To improve environmental conditions, we consider using solar collectors for summer time. Similar solar collectors’ plant is installed in Yakutia by Novy Polus (Figure 4). For electricity production we plan to consider PV panels and Komai wind units. Similar units are installed in Tiksi village, Yakutia (Figure 4).

Figure 4. Wind unit Komai and solar collector plant (source – Novy Polus) in Yakutia.

4. Conclusion
In recent time the conditions for renewable energy in Russia will improve. In 2019 we also expect long-term electricity tariffs for isolated zones that also can boost renewable energy development in that zones. In 2019 we expect that State Duma approve microgeneration law (passed firs reading) that allow households and small commercial to send into the grid up to 15 kW. This can stimulate “exchange” of green certificates (virtual certificates can be emitted for produced but not consumed energy) that can support renewable energy projects.

To give an additional support to small-scaled and individual renewable energy projects the mechanism that is like car disposal system. Customer that get local equipment can get a benefit (it can be as a buy-out of part or all “green certificates” for lifecycle (not more than 15 years) of equipment, any type of voucher or something else). This will stimulate development of domestic small-scaled equipment production (solar panels and collectors, wind turbines, heat pumps, heat and power storage...
In 2019 it is expected to get new environmental legislation (is developing by Ministry of economic developments of Russia). Environmental fees will rise CO2 pollutions start to be a subject of penalties. It will also boost renewable energy projects and make them more economically viable.

5. Conclusion
Even though most populated regions of Russia have relatively high level of grid gas supplying more than 50% of country and almost 20 million people are not connected to natural gas grids. Traditionally natural gas plays significant role for Russian energy balance, renewable power generation doesn’t have the same level of support that it has in EU, on microgeneration level it still has no any support. Renewable heat is a relatively new direction for Russia and doesn’t have any support even on individual households’ level (like it is, for example, in Australia).

To evaluate possible ways of autonomic energy supply and to find the best solutions for hybrid (traditional and renewable) energy systems the approach was proposed. First step is to choose territories that are not connected to natural gas grid. Then we start to make a matrix that contains all possible combinations of village heat and electricity supply. On this stage we also eliminate irrelevant combinations (for example big part of Yakutia stays beyond natural gas therefor all combinations with LNG and CNG are not relevant). The last step helps to find the best solutions for heat/cold/power supply. This approach can be used for any village (object) in Russia. This approach is tested on several projects in Dagestan, Yakutia and Krasnoyarsk regions (some tests are in progress now).

Currently Russian government is changing legislation that is related to renewable energy. It should give positive impact to renewable part of autonomic energy supply projects.

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