The Environment Friendly Power Source for Power Supply of Mobile Communication Base Stations

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Abstract. The article describes the technical proposals to improve environmental and resource characteristics of the autonomous power supply systems of mobile communication base stations based on renewable energy sources, while ensuring the required reliability and security of power supply. These include: the replacement of diesel-generator with clean energy source - an electrochemical generator based on hydrogen fuel cells; the use of wind turbines with a vertical axis; use of specialized batteries. Based on the analysis of the know technical solutions, the structural circuit diagram of the hybrid solar-wind-hydrogen power plant and the basic principles of the algorithm of its work were proposed. The implementation of these proposals will improve the environmental and resource characteristics.

1. Introduction

The condition of the normal and smooth functioning of any communication object is to ensure high quality of its electricity supply. Therefore, when designing and constructing the special attention is paid to the power supply elements such as a cellular network base stations (BS), base station controllers (BSC), etc. According to regulatory documents [1], BSC refers to the first, and BS to the second categories of technological power consumers on power supply reliability. This includes the absence of interruptions in electricity supply, the presence of two independent mutually reserving power supplies, as well as presence of two power supplies from the electrical networks of the power system [1].

In practice, there are many situations when different subscriber groups are geographically distant from areas with established structure of the State power system. To date, over 65% of the territory of our country is a zone of decentralized power supply. More than 15 million people are residing in this zone. Of the 225 million kW of installed capacity of power plants in Russia - 17 million kilowatt is accounted to power plants working in the area of decentralized power supply. In the northern parts of our country there are more than 6,000 diesel power plants (DPP), which have a capacity of more than 3 million kW. About half of these DPPs do not work reliably due to interruptions in the supply of fuel and high prices on imported fuel. To the remote areas of the Far North and Far East, the fuel is delivered by rail or by road, and sometimes by helicopter, as well as by river and sea transport with limited navigation period. Such deliveries are unreliable and expensive. The considerable damage is caused to the ecology through inefficient burning of fossil fuels in boilers and diesel power plants

(DPPs) of low technical level. In the far north it is aggravated by the removal of the empty fuel barrels [2].

In addition, connection to the existing power networks is very costly. Thus, according to the existing rates, according to the indicative calculations, more than 1.5 million roubles will be required for the construction of overhead power lines in the Rostov region on the first level of voltage in the length of 5 km, for organizational and technical measures, as well as for the issue of the relevant project documentation.

Therefore, the construction of the national cellular communication networks with power supply from base stations based on renewable energy sources (RES), taking into account environmental requirements in the regions of Russia, where there is no centralized power supply, is an actual scientific and technical task.

2. Results and discussion

The problem is formulated as follows. Develop technical proposals to improve the environmental and resource characteristics of autonomous power supply systems of base stations (APSS BS) of mobile communication based on renewable energy sources, while ensuring the required reliability and security of power supply.

To solve this problem, the preliminary study of the following issues is required:
- the choice of renewable energy sources for the construction of APSS BS;
- development of proposals to improve the environmental and resource characteristics;
- analysis of the known technical solutions;
- development of technical recommendations to the designed installation.

A. Selection of the renewable energy sources

This selection is expedient to carry out in view of the particular geographic region. Analysis of the renewable energy resources of Russia leads to the following conclusions:

- areas of effective application of wind turbines (WPP) are regions on the subjects of the Russian Federation: Arkhangelsk, Astrakhan, Volgograd, Kaliningrad, Kamchatka, Leningrad, Magadan, Murmansk, Novosibirsk, Rostov, Tyumen; krais: Krasnodar, Perm, Primorye, Khabarov, republics: Dagestan, Kalmykia, Khakassia, Sakha (Yakutia); autonomous regions: Nenets, Chukotka, Yamalo-Nenets [3,4];
- the most promising regions in the use of solar batteries (SB): Kalmykia, Stavropol region, Rostov region, Krasnodar krai, Volgograd region, Astrakhan region and other regions in the south-west, Altai, Primorsky region, Chita region, Buryatia and other regions of the West, East Siberia, and the Far East [3, 4];
- today, hybrid solar-wind turbines are the most popular, they are a combination of solar panels and wind generators, and often supplemented by a diesel generator. They successfully replace the gas turbines of small power, oil boilers and diesel generators, especially located in the area of decentralized energy. By 2020, the world market of such installations could reach 65 billion dollars. Their use will allow increasing the share of renewable sources in electricity production from 5% to 15% by 2035 [5].

Thus, to ensure the required reliability and security of electricity supply it is advisable to consider the possibility of designing APSS BS on the basis of a hybrid solar-wind-diesel power plant (HSWDPP), because it uses all the advantages, and disadvantages of individual sources are compensated.

B. Development of proposals to improve the environmental and resource characteristics.

For the formation of these proposals it is advisable to perform the analysis of the environmental properties of the elements of HSWDPP: diesel power plant (DPP), wind power plant (WPP), solar power plant (SPP).

DPP has the following disadvantages [2]:
- the risk of fire;
- the presence of exhaust gases;

- the generation of noise and vibration;
- accumulation of empty fuel barrels.

WPP has the following disadvantages [2]:

-presence of noise and vibration;
- generation of infrasonic vibrations by wind turbines with rotor diameter more than 10 m These vibrations have adverse effects on humans and animals;
- the occurrence of electromagnetic interferences in the reception of TV and radio transmitting stations.

Using SPP necessarily implies the presence of sufficient storage capacity of electricity. As a rule, these are ordinary batteries, which pollute the environment.

In order to develop proposals for improving the environmental characteristics, consider the available possibilities. Disadvantages of DPP can be compensated in the following ways:

- fire hazard is reduced by correct installation of diesel generator and the use of fire-prevention automatics;
- exhaust emissions can be reduced by using high-quality motor oil and fuel, regular replacement of fuel and oil filters, the use of the ventilation system, as well as the use of filters in the exhaust system;
- noise and vibration can be reduced by placing a diesel generator in the block container, or in a room with special sound and vibration dampening walls;
- removal of empty fuel barrels can be arranged using the transport that delivers fuel.

All these measures lead to a significant increase in capital and operating costs, which ultimately can not solve the environmental problems associated with the use of DPPs. The improvement of the environmental characteristics of the power plant can be radically achieved only as a result of replacing the diesel generator with the ecological clean energy source - hydrogen fuel cells (FC), in which only hydrogen and oxygen contained in the air are involved in the reaction, and the reaction product is water vapor [6].

Ecological characteristics of WPP can be improved by the use of wind turbines with a vertical axis. It has the following advantages [7, 8]:

- reduced initial speed (1-3 m/s);
- it does not create a vibration on the ground;
- it does not require the installation on high masts;
- harmless (noise level does not exceed 35 dB);
- it does not require orientation to the wind;
- it uses energy not only of horizontal wing, but also updraft wind.

Environmental issues associated with the use of SPPs are currently successfully being addressed as follows:

- the environmentally friendly technologies of production and utilization of solar panels containing cadmium telluride were developed [9];
- the market offers a wide range of specialized batteries for operation in the composition of SPP. These are gel and AGM batteries having the following properties [9]:

a) use in any position (there is no leakage of electrolyte);
b) does not require topping up of water and electrolyte replacement;
c) sufficiently resistant to deep discharges;
d) doubled the cycle life: over 600 cycles of discharge in 100% depth;
e) do not emit hazardous noxious gases into the atmosphere;
f) resistant to strong frosts;
g) the quick commissioning: 105-107% capacity in the first cycle;
h) the service life - 16 years.

Thus, summarizing all the above steps, on can identify the main proposals for improving the environmental and resource characteristics of hybrid power systems for designing and operating organizations. These include the following:

- replacement of diesel generators with the clean energy source - electrochemical generator (ECG) based on hydrogen fuel cells;
- the use of wind turbines with a vertical axis;
- use of specialized batteries for operation in the composition of SPP.

Taking into account the recommendations made to improve environmental and resource characteristics, provision of the required reliability and security of electricity supply, APSS BS is expedient to design based on hybrid solar-wind-hydrogen power plants (HSWHPPs).

C. Analysis of the known technical solutions

One of the examples of the use of hydrogen fuel cells is the base station of the St. Petersburg branch of OJSC "VympelCom" [6]. Tests of a power plant (PP) on hydrogen fuel cells, natural cooling system and special software for remote monitoring of the equipment complex were conducted. For the conduction of tests, the 48 V power system was installed based on the Dantherm Power hydrogen power fuel cells. Two hydrogen fuel cells with a capacity of 1.6 kW, and rectifier unit with the supercapacitors block are placed in a 19” rack. The rack also houses the control and safety unit of the power plant. An important feature of FC Dantherm Power is the air cooling system of the fuel cell. In general, we received a very compact and reliable solution that is not afraid of lower temperatures, as the cooling is provided only by the fan. The hydrogen PP can operate simultaneously as an uninterruptible power supply and backup power supply for all the BS consumers. Supercapacitors (electric double layer capacitors) are intended to compensate for the short-term voltage dips. In the course of tests, they ensure reliable operation of the base station mode of frequent switching on and off of power supply from the city network for 10 minutes at intervals of 30 seconds.

During the tests, the equipment RBS900 / 1800, 3G, PPC transport hub, obstruction lights and air conditioner were connected to the plant. When the air conditioning compressor was turned on, the overload protection of the plant Dantherm Power was tripped. It was decided to disable split-system and connection of free cooling plant Nordic Blue. At repeated starts, the system of alternative uninterruptible power supply and monitoring system equipment were operated normally. During the tests, the compliance with the standards on assurance the smooth operation of the telecommunication equipment RBS 900/1800 - 4 hours, PPC - 24 hours, protecting fires - 48 hours was conducted.

Another example of the use of hydrogen fuel cells is the base station of PJSC "Mobile TeleSystems" in the Noginsk district of Moscow region [10]. This is Russia's first base station in the LTE network, which runs on hydrogen-air fuel. In the hybrid power supply system: an ordinary electrochemical battery and the backup power supply system is used with the use of the hydrogen-air fuel cells, which power is 10 kW. In case of a power failure or voltage drop, the hydrogen unit is started up in a few seconds automatically. It converts the energy released by the chemical reaction of hydrogen with oxygen compound into electricity. The equipment, components and fuel for the hydrogen supply system are made in Russia. The costs of installation of the hydrogen supply system are by 10-30% higher than the conventional power supply systems, but such systems are generally advantageous. Their lifetime is 15 years, which is five times longer than conventional batteries, and maintenance costs are less. Platform "Astra", in contrast to the "traditional" emergency and backup power systems based on batteries and diesel generators, combines high environmental friendliness due to the lack of exhaust, odour, vibration and noise, safety and reliability, simplicity and modularity, and allows easy scalability and low operating costs. Unlike traditional systems, an important feature of the platform "Astra" is the lack of moving-rubbing parts, the ability to provide "long reserve" and exclude fuel logistics and remote monitoring. The obvious advantage is the high energy efficiency - efficiency of power generation is 60%, as well as the lowest operating costs of all types of backup power systems. The ASTRA platform is almost not serviced (replacement of air filters - every 2 years).

D. Development of technical advice to the projected installation

In development of the technical advice the given above proposals should be considered to improve the environmental and resource specifications, as well as the following requirements and assumptions [2, 5, 7, 8].

1. Selection of the installed capacity of wind WPP, SPP and electrochemical generator (ECG) based on hydrogen fuel cells should be made taking into account the fact that ECG should generate all the energy flow in the absence of wind and sun, and the installed capacity of WPP and SPP can share nominal one according to specific climatic conditions. This arises from the need to ensure the required reliability and security of electricity supply to BS power consumers. Given that the work of ECG is supposed to be separated from joint work of WPP and SPP, the total nominal installed capacity is assumed equal, i.e.

$$P_{N.ECG} = P_{N.WPP} + P_{N.SPP}. \quad (1)$$

Thus, the nominal capacity of WPP and SPP is understood as power developed by WPP at the estimated wind speed and power of SPP with the estimated flow of solar energy.

2. HSWHPP consisting of WPP, SPP and ECG, should provide uninterrupted electricity supply of cellular base station during the warranty life of at least 5 years with the required quality parameters. The generated total capacity must be at least 5 kW, voltage should be a single-phase/three-phase 220/380 V of nominal value and have a frequency of 50 Hz. Converting AC into current with the characteristics and parameters required for operation of the telecommunication equipment (usually a direct current voltage of 48 V). The power supply not only converts, but also stabilizes parameters within a rather rigid levels - up to 1-2%.

3. There are also consumers of AC and DC. The telecommunication equipment system are provided with DC, consumers of own needs with AC.

4. HSWHPP control should be based on a balance between consumed and generated energy.

On the basis of these technical requirements, as well as the known technical solutiontion [11, 12] a block diagram of ASPP BS is developed and based on HSWHPP shown in Figure 1.

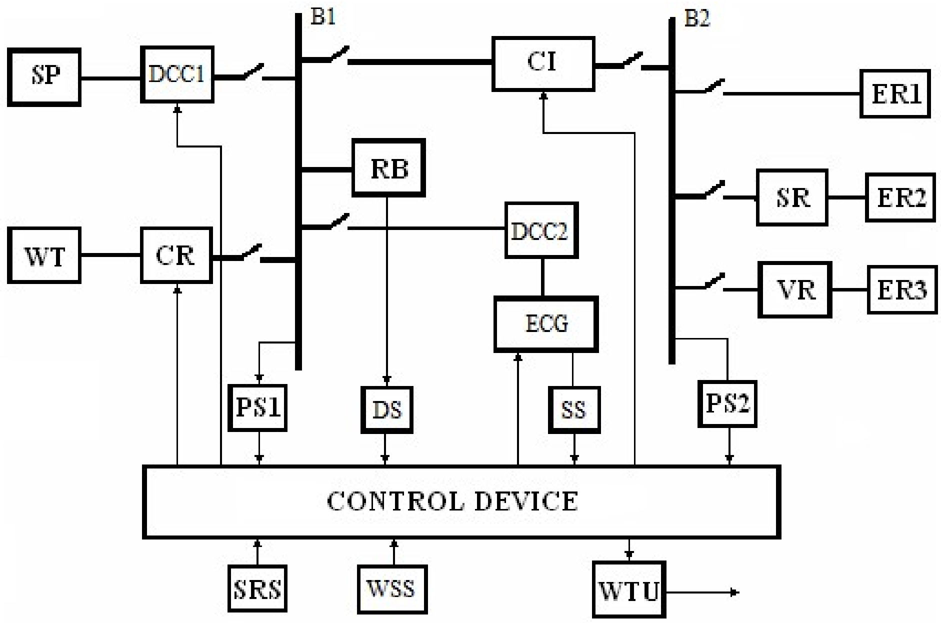

Figure 1 - Block electric diagram of a hybrid solar-wind-hydrogen power plant: SP - solar panels; WT - wind turbine; DCC1 and DCC2 - DC converters; CR - controllable rectifier; PS1 and PS2 - power sensors; SRS- solar radiation sensor; RB- rechargeable battery; DS - discharge sensor; WSS - wind speed sensor; CI- controllable inverter; ECG - electrochemical generator; SS - ECG status sensor; WTU - wireless transmission unit; SR- stabilizing rectifier; VR - voltage regulator; B1 - DC bus; B2 - AC bus; ER1, ER2, ER3 - electricity receivers

The algorithm of control over electric power sources work of HSWHPP should involve implementation of the principle of adaptability, according to which power supply of receivers with variable load schedule is provided by renewable energy sources, current values of the output parameters of which correspond with the required values, taking into account current environmental conditions.

Wind energy is expedient to estimate by the current value of electrical power generated by WPP (P_{WPP}). Energy of the sun by the current value of electrical power generated by SPP (P_{SPP}). The total consumed one by load of electric power in each time can be estimated by required current value ($P_{\Sigma.R}$).

Proceeding from the above, the HSWHPP control algorithm can be generally described as follows. If the current value of electrical power of WPP (P_{WPP}), greater than the current required value $P_{\Sigma.R}$, AC and DC receivers can be provided by WPP. Similarly - if the current value of electric power of SPP (P_{SPP}), greater than the current required value $P_{\Sigma.R}$, all the receivers can be provided by SP.

In general, if the total current value P_{WPP} and P_{SPP} exceed the current value of power $P_{\Sigma.R}$, the level of power generated by each of these sources is provided by respectively regulators to ensure the balance of generated and consumed powers, that is

$$P_{WPP} + P_{SPP} = P_{\Sigma R}. \quad (2)$$

With the low total current value P_{WPP} and P_{SPP} puts into operation and provides ECG station receivers. Thus, ECG as a backup source is activated only in case of impossibility to cover the required current power $P_{\Sigma.R}$ from WPP and SP. It also runs the balance of generated and consumed powers, i.e.

$$P_{WPP} + P_{SPP} + P_{ECG} = P_{\Sigma R}. \quad (3)$$

The installation in contrast to known circuits is introduced with additional sensors of current capacity of renewable power sources PS1 and current load power sensor PS2. To calculate the balance of power conditions and control energy conversion channels, the control device is used.

To ensure the required quality of electric power on DC buses (B1) and AC (B2) in the circuit, there are DC converters (DCC1 and DCC2), controllable rectifier (CR) and controllable inverter (CI).

Receivers of electric power ER2 and ER3 that require high quality electricity (electronic communication equipment) are connected to the power supply line B2 through stabilizing rectifier (SR) and through voltage regulator (VR).

In order to transmit signals to the dispatcher about launch of ECG, end of stock of fuel for ECG, discharge of battery RB etc., wireless transmission unit WTU is introduced.

3. Conclusions

1. The following recommendations for improving the environmental and resource specifications of hybrid power plants are proposed: replacement of diesel generator for clean energy source - electrochemical generator based on hydrogen fuel cells; use of wind turbines with a vertical axis; use of specialized batteries.

2. The cost of installation of hydrogen supply system is higher by 10-30% than normal ones, but in general such systems are profitable. Their lifetime is 15 years, which is five times longer than conventional batteries and maintenance costs are lower.

3. The proposed block electric diagram of environment friendly power sources of energy and basic principles of the algorithm of its work allow realizing adaptive control over operating modes with a view to ensuring the balance of power between sources and receivers at the current weather conditions. This control makes it possible to increase the energy conversion efficiency, power reliability, and efficient use of resources throughout the installation.

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