The alternative energy Technosphere safety problems

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Abstract. The work shows that the dangerous vulnerability of renewable energy sources is the imperfection of materials and design of energy storage devices. A study of the charge-discharge cycles’ effect on the batteries’ stability in a specially developed installation showed that if even the most promising lithium-ion devices are used, due to the microdamage accumulation, all electric energy storage devices will not be durable and will necessarily fail. In addition, it is shown that the materials used in the manufacture of solar panels and wind turbine blades can harm the environment. It is concluded that the Technosphere safety problems of alternative energy can be solved only if the technology for the efficient utilization of used solar batteries and blades of wind-powered generators is created.

Introduction

It is believed that the introduction of alternative energy based on renewable energy makes it possible to create the reliable as well as more environmentally friendly energy supply systems \cite{1–5}. The most dynamically developing renewable energy sources are the wind energy and solar energy use. Both of these methods are inexhaustible - this energy cannot be used up in the process of satisfying the needs of mankind in energy carriers, so that it will be enough in excess for the share of future generations. The production, transportation, installation and use of wind and solar installations is accompanied by the significantly less harmful emissions into the atmosphere than of the traditional power plants. Nevertheless, these methods have inherent disadvantages, and the aim of this work is to analyze the already known problems of their work and the impact on the Technosphere safety of this type, among which the following should be mentioned:

– power instability and battery problems;
– the need to alienate large territories due to the small unit capacity;
– environmental impact;
– problems with the solar panels and wind turbine blades’ disposal.

The existing energy storage systems’ problems

The energy generation instability in day and nighttime, as well as the dependence on weather conditions limit the use of alternative energy or require the use of energy storage. In the afternoon, the energy generated by solar panels can be used or stored. Similarly, for the wind power plants (wind turbines) - they produce electricity depending on the presence and speed of the wind. At night, the average wind speed decreases, and almost no electric energy is produced. This creates problems both for the wind turbines’ owners and for the power system as a whole. It is established that the country’s
energy system is safe if the share of cyclic alternative energy in the total balance does not exceed 20\%. Some countries have already reached such a border, and the further development of alternative energy requires large investments for them.

To ensure the stable power supply from alternative energy, the batteries have to be additionally installed and their use in practice has no alternative. The use of batteries of any modification is not an environmentally friendly technical solution, and not only during their operation, but also during disposal. Batteries, which are commonly used in alternative energy, are most often lead-acid due to their low cost [9]. A specific distinguishing feature of lead-acid batteries is their low energy efficiency - 60\% and low energy density of 30 Wh / kg [10]. These batteries have their own environmental disadvantages: the presence of lead and acid electrolyte. Electrolyte is a corrosive substance, while it has a high content of dissolved lead salts and can cause chemical damage to skin [11]. In turn, lead is very toxic: the maximum permissible concentration (MPC) of lead is very stringent - not more than 0.057 mg / m³. To date, only a smaller portion of sulfuric acid batteries, not more than a few percent of their number, are being utilized [13]. It should also be noted that the use of batteries with large storage capacity causes the additional problems with land acquisition, maintenance and large investments.

There are also installations with slightly more promising nickel-cadmium batteries, which have a longer service life, but they are much more expensive. The disadvantages of nickel-cadmium batteries [14] are also associated with their high environmental hazard, since they contain cadmium. Cadmium belongs to the group of heavy metals with high toxicity [15]. With a sufficiently long contact of the body with such metals, the main affected organs are the kidneys. For the safe kidneys’ functioning, it is necessary to maintain the concentration of cadmium in the room not higher than 0.01 mg / m³. In addition, although hydrometallurgical or purely chemical methods for the nickel-cadmium batteries’ disposal are known, but they are much less common and developed in comparison with the disposal of lead-acid batteries.

The main disadvantage of these renewable energy sources is that all the batteries, regardless of the type of material, origin or principle of operation, when charged, sooner or later, fail. The reason for the electrochemical energy storage aging is associated with chemical “defects” of reactions in the battery. The inevitability of aging is all batteries’ characteristic, but further work considers the most promising lithium-ion batteries. Many researchers have proved that a longer service life and specific energy density, the absence of the need for constant monitoring of the main parameters and the ability to maintain the original capacity at high discharge currents open up the possibility of using not nickel-cadmium, namely lithium-ion batteries as the current sources [5, 6].

**Methods of monitoring the operation of promising energy storage**

The service life (lifetime) of a battery is characterized by the number of charge-discharge cycles that it withstands during operation without significant deterioration of its parameters. The battery, as a rule, is considered to be out of order after reducing its capacity to 60 - 80\% of the nominal value. From the literature data it is known that even when using under the ideal conditions (charging current 0.5 A, temperature 220 C), the capacity of a Li-ion battery decreases to 80\% of the nominal value after 500 charge cycles [6].

The most commonly used graphite anode in lithium-ion batteries is “easy-to-discharge”, i.e. it easily “releases” electrons to the electrolyte. Graphite is a material widely used for the manufacture of anodes, but it is thermodynamically unstable in organic electrolytes. It is a known fact [6], that during intercalation of lithium ion into the crystal lattice of graphite, the graphite layers are expanded. During deintercalation of lithium ion, the reverse process occurs and stresses arise in the lattice structure. The implementation of such micro stresses is accompanied by the high-frequency voltage waves generation (frequency above 10 MHz). The multiplicity of this process, in turn, due to the phenomenon of “beating,” leads to the relatively low-frequency waves’ generation (up to 1 MHz). Therefore, these changes can already be registered with the available ultrasonic equipment [7, 8].
In order to study the changes occurring in Li-ion batteries during charging / discharging cycles, the authors developed a facility that allows controlling the AE signals of a Li-ion battery. The Li-ion battery was rigidly connected to a piezoelectric sensor that generated an electrical signal. This signal passed through the amplifier and entered the A-Line 32D complex, where it was recorded and processed. At the same time, the current-voltage characteristics of the electric network were monitored on the battery connection line. Both the load and the charging device could be connected to the battery.

Since it is known that a serious problem of Li-ion batteries is the drop in their capacity during the charge-discharge process, special attention was paid to the AE parameters’ study precisely during cyclic charge-discharge processes. As it can be seen from the obtained AE activity data (Figure 1), the cyclic process of charging / discharging Li-ion batteries is quite reliably recorded by AE parameters. Moreover, as the acoustic parameters show the dynamics of the discharge of Li-ion batteries under the same external conditions’ changes.

As it can be seen from Table 1, with each cycle of charging / discharging, the number of AE signals increased. At each charge / discharge cycle, the structure of Li-ion batteries changes and microstresses, which manifest themselves in dislocation shifts of the graphite anode crystal lattice, are accumulated. A distinctive feature of AE is the fact that it accompanies the entire process of the material’s mechanical properties degradation. The experiments have confirmed that for the lithium-ion batteries with microdamage accumulation, all electric energy storage devices will certainly fail sooner or later.

Thus, even the most promising Li-ion batteries have the same disadvantages that are characteristic of all chemical energy storage devices. Over time, lithium-ion batteries gradually lose their ability to hold a charge. To this drawback is added the problem of safe recycling and disposal of Li-ion batteries, since currently there are no relevant proven technologies.

![Figure 1. Acoustic emission (AE) activity during charge-discharge cycles](image)

**Table 1.** Change in the number of pulses and AE activity from the cycle number when charging / discharging Li-ion batteries.

| cycle no. | The total number of beats per cycle (NΣ), [imp] | Maximum value activity (Ñ), [imp / s] |
|-----------|-----------------------------------------------|-------------------------------------|
| 1         | 40014                                         | 201                                 |
| 2         | 42400                                         | 239                                 |
Thus, it can be stated that even the most promising lithium-ion batteries have the same disadvantages that are inherent in all chemical energy storage devices: over time, they gradually lose their ability to hold a charge. The problem of safe recycling and disposal of Li-ion batteries is added to this drawback, since currently there are no relevant proven technologies.

The impact of alternative energy on the environment

The second significant problem in introducing alternative energy is the issues of choosing the wind location and solar installations. Obviously, in those places where a developed infrastructure already exists, replacing the existing energy supply with alternative energy or in addition to it is practically impossible. As for wind energy, according to the information [9–12], the metal consumption of a modern wind-powered generator with a capacity of 3 MW reaches 350 tons. If a thermal power plant (TPP) of 1 GW requires an area of several hectares, then thousands of hectares have to be allocated to a wind farm of the same capacity. There is a potential possibility of using alternative wind and sun energy in the conditions of new designed private houses and villages in the absence of connection to a centralized power supply or as an addition to the latter. However, this requires special projects, qualified installation and maintenance.

The procedure for selecting the sites for the construction of wind farms should be noted. It is believed that for energy production it is enough to build wind turbines in those places where the wind blows during the year at the speed of 3 m/s. The cost of building a wind farm is about $1,500–2,000 per 1 kW of installed capacity, which is several times higher than the investment cost of building a thermal power plant.

For solar energy, this problem (location choice) is often amplified many times. The instability of the photons receipt from the sun forces us to use much more space for the solar power system, whether it is an industrial station or a home electrical installation that needs to be equipped with the appropriate solar panels, connect a deep-discharge battery, voltage converter (inverter), charge controller, etc., conduct professional installation and provide maintenance. In the middle zone of the European part of our country, the solar radiation intensity is 150 W/m², which is 1000 times less than heat fluxes in the boilers of thermal power plants. Therefore, for the location of a solar power plant with an electric capacity of 1 GW, taking into account an efficiency of 10%, a minimum area of 67 km² is required. Consequently, this area will be “taken” by alternative energy from the natural environment.

Chemical and physical problems of the alternative energy negative impact

The third issue of alternative energy is environmental impact. In the past few years, many people living near wind-powered generators have claimed that the rotating blades cause them various diseases. People complain of many unpleasant symptoms, ranging from headache and depression to conjunctivitis and nosebleeds. There is a problem of the inner ear vestibular system violation due to low-frequency noise from wind turbines.

In the immediate vicinity of the wind-powered generator near the wind wheel axis, the noise level of a sufficiently large wind turbine can exceed 100 dB. However, with increasing distance, the noise level decreases and the noise at a distance of 100 m from the installation site is 34–45 dB. The calculations of the sound level total value for 10 wind power plants are presented in Table 2.

Table 2. Calculation of the total noise level depending on changes in the power of the wind-powered generator.

| Number of wind- | The total noise level of wind- | The total power of wind turbines |
|-----------------|-----------------------------|-------------------------------|
| 3               | 46035                       | 276                           |
| 4               | 52111                       | 306                           |
| 5               | 55043                       | 330                           |
| 6               | 60234                       | 340                           |
As it can be seen from the formula and calculated data, the noise level dependence on the wind turbine power has a logarithmic character and the shutdown of one or several wind turbines will not affect the noise level created by the entire wind farm. On the other hand, the above-made calculations show that acoustic pollution, in the case of the wind farms development, can be very noticeable. Moreover, it should be borne in mind that the calculation was related to the sound spectrum of the signals, and the area of infrasound was not affected. Infrasound, due to the long wavelength, freely avoids the obstacles and can spread over long distances without significant energy loss. Solar power plants also cause real environmental problems, including habitat degradation and harm to wildlife. The impact that solar power plants have on individual species can ultimately affect all ecosystems.

**Energy sources utilization**

The fourth significant problem of alternative energy is the problem with the disposal of its elements. Wind turbine blades are usually made of fiberglass reinforced polymer and are the most expensive turbine component. The generator, tower and their other elements are made of metals, and their disposal is not a problem. The researchers calculated that up to 9.6 tons of composite materials per megawatt of installed capacity [2].

Blade disposal remains a problem for the environment. The problem of blade recycling is associated with the composite material used in the blades, which are made of a thermosetting matrix and fiberglass. The thermoset matrix basically uses phenolic resins, but phenolates are very toxic to human health even if they are in small quantities. So, in particular, the maximum permissible concentration of phenol in the air of the working area should not exceed 0.3 mg / m³. Therefore, the process of grinding thermosetting resins is a significant danger to humans and the environment.

Two possible options for the blades’ disposal are known. One option involves the use of a pyrolysis furnace with a heat treatment temperature above 4500°C. Indeed, in this case, the thermosetting resin will turn completely into condensed carbon. However, the disadvantages of this method include the issues of maintaining the mechanical strength of fiberglass. In addition, it is unrealistic to build a furnace of such a size that produces significantly large fragments of fiberglass.

Another option for processing composite material is to grind it. This solution, however, represents a significant change in the properties of the composite. For this reason, the resulting crushed composite can only be used as a filler in the building materials production.

The problem with the solar panels’ disposal is no less acute. It is estimated that around the world there are already 250,000 tons of solar cell waste and that this number can grow to 78 million tons by 2050. Currently, in most countries there is no infrastructure for processing solar panels. Unfortunately, the modules that are available at the processing plants are designed for processing laminated glass, metals or electronic waste. As a result, only basic materials (glass, aluminum and copper) are released.
there, while solar cells and other materials such as plastics are burned or sent to landfills (for waste). That is, currently processing does not provide the restoration of environmentally hazardous (e.g., Pb, Cd, Se) or valuable (e.g., Ag, In, Te,) materials.

The substances that make up the solar panels are presented below.

1. Technical tellurium is extremely hazardous. When ingested through the respiratory tract or skin, tellurium causes chronic joint inflammation, bone disease, liver disease, and tooth enamel alteration.

2. Cadmium and arsenic belong to the 6th class of hazardous substances and products. These substances and all their compounds are toxic.

3. Technical selenium is a moderately hazardous substance. Inhalation of selenium leads to diseases of chronic bronchitis, gallbladder dyskinesia, an enlarged thyroid gland, gastrointestinal disturbances and nervous disorders.

4. Silicon itself is not considered to be harmful, but in the production of silicon, enterprises release more than 20 types of pollutants into the atmosphere, including chlorine-containing inorganic compounds (trichlorosilane, dichlorosilane, chlorine).

Summary
It has been established that the dangerous vulnerability of renewable energy sources is the need to use energy storage. A study of the charge-discharge cycles’ influence on the stability of batteries in a specially developed installation showed that in the case of using even the most promising lithium-ion devices, all electric energy storage devices have short service life. Moreover, all currently known batteries do not have safe technologies for their processing and disposal, i.e. become a big problem of Technosphere security.

It is shown that a significant problem of alternative energy is also the need to alienate large areas due to the small unit capacity of wind and solar installations. The withdrawal of large areas in the natural environment, in turn, leads to a violation of local natural ecological systems. It is shown that there are big problems in the disposal of solar panels and blades of wind-powered generators. It becomes one of the most important areas of Technosphere safety, since currently there are no effective ways of disposing of the renewable energy sources’ used elements.

The calculations found that the acoustic pollution created by the wind farm on the basis of single wind turbines of high power can be very significant, especially if their infrasound factor is taken into account. At the same time, stopping one or several wind turbines will practically not reduce the noise level created by the whole wind farm.

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