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REGULAR ARTICLE

Uninterrupted Power Supply System for Network Equipment

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Today, Ukraine faces a few challenges, among which the use of an Internet connection is becoming a necessity in various spheres of life, especially in conditions of blackouts. At the time of war, especially at the front, communication is essential for the coordination of military operations and the exchange of information. Providing network equipment with uninterrupted power sources can play a key role in ensuring a reliable and fast Internet connection, becoming a critical reserve for ensuring communication. The issue of creating a device that can ensure the autonomous and uninterrupted operation of routers, modems, network terminals and other devices becomes urgent. The article proposes new constructive solutions for creating an uninterruptible power supply (UPS) system, which can protect devices from possible damage during power supply interruptions and ensure uninterrupted operation of the equipment.

Keywords: System, Power source, Energy, Power consumption, Network, Equipment, Parameters, Switching time, Inverter, Continuous operation, Characteristics, Battery.

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1. INTRODUCTION

In connection with the beginning of the full invasion of the Russian Federation in Ukraine and the constant shelling of our energy infrastructure, power outages began, which led to emergency blackouts. The lack of electricity supply and a reliable Internet connection paralyze not only enterprises and business work, but also leads to the inability to defend our country rapidly. In the absence of a power grid, a large load is taken over by mobile communication, but in this case, mobile towers cannot ensure reliable use of the mobile Internet.

The issue of developing new power supply systems becomes urgent, because complex technological and network equipment of modern industrial production cannot function normally if the power supply is not uninterrupted.

For many industrial enterprises and Internet providers, a power interruption for a few seconds or even for tenths of a second leads to a disruption of the continuous technological process, failures of Internet resources and can even lead to stop production.

So, today, electricity consumption plays an extremely important role in human life. It is an integral part of our daily existence, providing convenience, comfort and safety.

It is known that thanks to electricity, houses and streets of populated areas are lit up in the dark. At home, every person constantly uses household electrical appliances that help him in everyday life and create a comfortable living, including a computer, laptop, smartphone and many others that require uninterrupted power supply.

It is also needed for large buildings, shopping malls and office complexes that use elevators and escalators to move people, because all these buildings and private residences are often equipped with security systems such as video surveillance, alarms and access control. They are powered by electricity and provide security and protection against unauthorized access.

Vehicles that also depend on electricity have become problematic. Underground, electric buses, trams and trolleybuses are the main types of public transport for many countries. In addition, in the past few years, many leading automotive companies have successfully developed electric cars or electric bicycles for environmentally friendly transportation.

It is difficult to imagine industries that use modern machines to perform complex technological operations and are dependent on electricity. Such machines are used by industrial enterprises to increase their productivity while maintaining a low cost of production. This heavy machinery can only run-on electricity, otherwise it is difficult to run it to work.

It should be noted that electricity consumption is not limited with the earth, it has also reached space. Satellites sent to space must stay there if possible. Their operation requires electricity because transporting other types of fuel into space is dangerous and expensive.

The well-known global information network, the Internet, simply will not exist without electricity, as surely as any other type of communication.

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In modern realities, the Internet has become not only a global means of communication, but also an effective tool in almost all spheres of activity:
– education;
– industry;
– medicine;
– trade;
– transport and military industries;
– in mass media, etc. [1].

During the coronavirus pandemic, modern man's dependence on the Internet has increased even more, as many people have started working and studying remotely.

However, there are problems in power supply networks, which lead to failures in the operation of devices, appliances, entire enterprises, including network equipment.

2. DESCRIPTION OF THE OBJECT AND METHODS OF RESEARCH

Studies show that the main problems of power supply networks are:

– Disappearance of voltage (Power Failure) – absence of voltage in the power grid for more than two periods (40 ms). The consequences of a power failure can be: loss, damage of data and current information in electronic devices, disruption of the technological process, equipment failure.

– Brownout (Power Sag) – a sudden decrease in voltage in the electrical network below 90 % of the nominal value, which is followed by the restoration of the voltage to the initial level or close to it in a time interval from ten milliseconds to several tens of seconds.

– Overvoltage (Power Surge) – a sudden increase in the voltage in the electrical network above 110 % of the nominal value, which is followed by the restoration of the voltage to the initial level or close to it in a period from ten milliseconds to several tens of seconds.

– Voltage Deviation (Brownout) – deviation (decrease / increase) of voltage in the network from values allowed by the standard for a long time (more than tens of seconds).

– Electromagnetic interference (Electrical Line Noise) – occurrence in the network of high-frequency pulses superimposed on the sinusoidal form of voltage.

– Voltage Impulse (High Voltage Spikes) is a short-term excess of voltage above 110% of the nominal value with a duration of 10-50 μs (with a pulse front time of 1-10 μs). At the same time, the amplitude of overvoltage pulses can reach values of 6000 V.

– Frequency Variations (Frequency Deviation) – frequency deviation of more than 0.2 Hz from the nominal value (50 Hz).

– Non-sinusoidal voltage (Harmonic Distortion).

It is known that short-term disruptions to normal operation in the electrical network are inevitable. Short circuits are the cause of most short-term power outages. It is almost impossible to completely protect the electrical network from them, or, in any case, it would be very expensive.

Short-term power outages are much more common than long-term ones. A long power interruption can be avoided, as an option, by using automatic reserve input (ARI). At the same time, there will be short-term power interruptions not only in the case of a short circuit on any of the lines feeding the ARI, but also on the lines feeding neighboring consumers.

It has been established that if the allowable power interruption time is less than 0.2 seconds, only uninterruptible power supplies can be used because short-circuit breaker protection to reduce the power interruption time is not possible or ineffective in this case.

If the allowable time is more than 0.2 seconds, it is possible to use power grid protections or use uninterruptible power supplies.

The authors proposed an uninterruptible power supply system for network equipment, which will allow electrical equipment to work without an electrical network. Its implementation will provide the main advantages compared to known power sources:
– lack of time to switch to battery power;
– sinusoidal form of the output voltage, i.e., the ability to power any loading;
– the ability to adjust both voltage and frequency (what's more, such a device is simultaneously the best possible voltage stabilizer);
– installation of overcurrent protection from 1 to 10 A;
– compact body and low weight due to forced cooling with the help of fans with thermoregulation of the air supply flow;
– convenience of operation, repair and regulation.

As you know, standard power supply networks cannot provide uninterrupted power supply and therefore measures are applied, one of which is the use of sources of uninterrupted power supply. However, the specificity of its operation is that this device creates a form of variable output voltage. In this case, a deviation from the sinusoidal form is possible. But for some electricity users, it is important to maintain a voltage form close to a sinusoid, which can be ensured by limiting the higher harmonic components of the supply voltage.

An uninterruptible power supply is a device that ensures the stable operation of electrical appliances during a sudden or planned power outage, which, unfortunately, is observed every day in Ukraine. Depending on the technical characteristics and capabilities, such devices provide long-term or short-term autonomous operation of the equipment.

Uninterrupted power supply differs from guaranteed one. In the case of guaranteed power supply, an interruption is allowed for the time of putting the backup source into operation. In the case of uninterrupted power supply, "instant" activation of a backup source is required. This important requirement limits the range of backup sources suitable for use in uninterruptible power supplies. In practice, usually only one such source can be used – a battery.

To meet the requirements of various devices, uninterruptible power supplies are used, which are divided into 3 categories, as shown in Fig. 1.

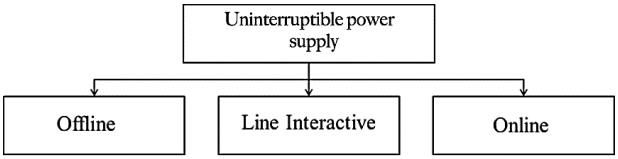

Fig. 1 – Classification of uninterruptible power supply sources

By topology, they are divided into offline type (hereinafter – Offline) and online type (hereinafter – Online).

The Offline UPS scheme includes an automatic switch. In the autonomous mode, the load is provided by rechargeable batteries (hereinafter referred to as the battery), and in the normal mode, the load is switched to the stationary network. Such UPSs are used to back up the source of the main power supply in case of an accident (opening or lowering/increasing voltage).

The advantages of the Offline UPS are its simplicity, small size and low cost, and the disadvantage is the non-zero switching time (~ 4-10 microseconds) to the batteries and more intensive use of the batteries, since the device goes into offline mode in case of any problems in the power grid.

Offline UPS, as a rule, have a small capacity and are used to ensure uninterrupted power supply of devices that have a low priority (working personal computers, printers, plotters, air conditioners).

The Online UPS is built on a double conversion of the power grid: the input voltage is transformed into DC using a rectifier, and then back into AC using a reverse converter - an inverter. As a result, the built-in battery, connected at the switching point of the inverter with the rectifier, performs power supply in emergency mode. Moreover, charging can be performed both with the help of a rectifier and a monobloc adapter.

At the same time, the battery can be connected in different ways. Online UPS provides ideal output voltage in case of any problems in the power grid. It is characterized by zero switching time from the normal mode between the source (rectifier) and the load.

The disadvantages of Online UPS are their high complexity, cost, and low efficiency (electricity will be converted twice).

Online UPS are used to protect such devices that require high responsibility, that is, the need to have constant electricity, which must be supplied without possible interruptions. An example of such devices is medical equipment, in particular life support systems in intensive care units, data centers, file servers and other equipment with a similar purpose.

Since routers, modems, and other devices have an input voltage of 9...15 V, a power consumption of 5...20 W and a long reboot time (up to 1-2 minutes), it is necessary to develop a UPS that will have a similar design to an Offline UPS, as well as Online properties Double conversion UPS.

3. DESCRIPTION AND ANALYSIS OF RESULTS

It has been established that mainly UPSs are controlled by purely analog circuits, although in recent years there is a process of gradual transition to microprocessor control of even such simple devices as switching UPSs. The network analysis circuit measures the average rectified value of the network voltage and issues commands to switch from mode to mode depending on its value.

When the mains voltage drops or disappears altogether, the mains analysis circuit commands the UPS to switch to battery mode. If the voltage becomes higher, the UPS starts working from the mains again. For stable operation in the UPS mode, it should have a small (usually a few volts) hysteresis of the switching characteristic. So, if the switching from mains operation mode to battery operation mode is carried out, for example, at a voltage of 185 V, then the reverse switching should be occured at a voltage of 188-192 V.

An analysis of the characteristics, parameters and design features of known UPSs showed that most of them with switching react only to a decrease in voltage, that is, they switch to operate from the battery when the network voltage reaches a certain limit value in the range of 200-160 V. Only some also react to an increase voltage, i.e. switch to battery operation when the mains voltage reaches a certain threshold value in the range of 250-290 V.

This UPS function is useful. However, if you use a switching UPS to protect a personal computer with a switching power supply, then it is not always necessary. Well-designed switching power supplies can operate at very high voltage. The control circuit of the UPS monitors follows for the state of its battery. When it is completely discharged (the voltage on the lead-acid battery cell is 1.7–1.75 V), the control unit removes the voltage from the load. This is necessary to prevent deep battery discharge.

Unfortunately, most UPSs continue to use battery power to power supply a small part of their circuit even after the load is turned off. The discharge current of the battery in this case is very small, but if the discharge lasts for a long time, the battery reaches a state of deep discharge, after which it can only be thrown away. Therefore, if the UPS disconnects the load by itself because of battery discharge (and the network voltage has not appeared), it should be turned off immediately and turned on only after the network voltage appears.

Today, the uninterruptible power supply market is actively developing and offers potential buyers many options. Hundreds of models and modifications are presented by dozens of manufacturers. Their UPSs differ not only in operating time without charging and rated power, but also in other functions.

Currently, a wide range of companies are engaged in the production of various types of uninterruptible power supply units, among them such well-known companies as APS, Eaton and others. This equipment is usually characterized by either high value indicators or low consumer qualities, such as, for example, the absence of the possibility of connecting an additional battery, the impossibility of system operation at low voltage in the network, short battery life, and others.

APC manufactures UPS for personal computers and peripheral equipment, for desktop PCs in corporate environments, small businesses and as components of computer medical equipment; provide battery power supply with minimum size and ergonomic UPS design.

Eaton is one of the leading suppliers of Eaton 5P 850VA uninterruptible power supplies, which have a wide range of applications: from network cabinets and server rooms to enterprise data centers and cloud data centers. The design of this company's model, which is designed for servers, network equipment and systems, is used in demand and is made for 19 racks and has a height of 2U.

The PowerWalker VFI 10000 TGB uninterruptible power supply device provides power protection for servers, telephony and data networks, medical equipment and industrial systems. This UPS design allows you to place them both in the usual way - horizontally or vertically, and by mounting a server rack. It is also possible to connect external batteries.

An analysis of existing types of uninterruptible power supplies used for PCs, peripheral devices, server network equipment, medical and industrial systems showed that they have a few significant shortcomings and do not allow for stable uninterrupted operation during network failures.

Therefore, the development of new constructive solutions for the creation of competitive UPS with a high coefficient of useful activity has become an urgent problem.

The main function of the UPS, proposed by the authors, is to ensure the continuity of power supply by using an alternative energy source. In addition, it improves the quality of the power supply, stabilizing its parameters within the established limits. In systems such as energy storage, usually chemical current sources were used. In addition, other drives can be used.

The double-conversion mode of the UPS will be used to power loaded servers (for example, file servers), high-performance workstations of local computer networks, as well as any other equipment that makes high demands on the quality of network power supply.

The principle of operation consists in the double transformation of the type of current. First, the incoming alternating current is converted to direct current, then back to alternating current with the help of a reverse converter (inverter). Control of the inverter will be carried out in the pulse-width modulation mode based on signals from the microcontroller.

Stabilization of the output voltage and current values will be achieved by a negative feedback circuit consisting of signal generators proportional to the output parameters, which enter the input of the microcontroller, where it is compared with the reference value and change the fill factor of the pulses in the direction of restoring the value of the deviated parameter.

If the input voltage disappears, switching the load to the battery power supply is not necessary, since the batteries are connected to the circuit constantly (the so-called buffer mode of operation of the battery) and the "switching time" parameter does not make sense for these UPS.

The authors note that the phrase "switching time is 0" can be used for marketing purposes. This mode reflects the main advantages of this type of device: there is no time gap between the disappearance of external voltage and the start of battery power, the predicted efficiency will be (96.5 %) in online mode, the use of various intelligent modes is provided, which will allow you to automatically adjust the operating mode to increase efficiency up to 99 %.

The following constructive solutions should include the uninterrupted direct current power supply system developed by the authors, which will allow the inverter module (DC/AC converter) and AC/DC adapter of the router to be excluded from the circuit, while the UPS will have an online structure with all its advantages [2].

4. CONCLUSIONS

The proposed direct current inverter consists of a rectifier (one or several) and batteries (one to several). Alternating current from the external network enters the input of the rectifier, then direct current goes to the consumer, and part of it recharges the battery. As soon as the power supply disappears, the rectifier immediately turns off. The load is provided by the battery.

The DC UPS is equipped with a battery management system. This is a board that is installed on the battery to control the process of its charge/discharge, monitor the state of the battery and its elements, control the temperature, the number of charge/discharge cycles, and protect against short circuits.

The advantage of a direct-current inverter with direct power supply to the router is the absence of an extra stage of conversion (inverter). This is an important criterion, because this stage is the most complex in the UPS, since it implements the generation of the sinusoidal form of the output voltage. Implementation of this generation is impossible without the use of special microcontrollers.

An important decision of the authors was the production of the UPS model and the approbation of its operability at "Impuls" LLC.

It has been proven that all the investigated parameters and characteristics of the proposed UPS meet the specified requirements. It is necessary to note their high efficiency (98.5 %), which confirms its advantages as the most reliable option of an uninterrupted power source when operating network equipment.

The combination of experience and knowledge of the authors and leading designers of the enterprise with the energy of young specialists, extensive cooperation with foreign developers allow to carry out projects of any complexity from the selection of the elemental base of the UPS to its commissioning, to develop devices at a high technical level using modern nanotechnologies.

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Система безперебійного живлення мережевого обладнання

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Сьогодні Україна стикається з кількома викликами, серед яких використання Інтернету стає необхідністю в різних сферах життя, особливо в умовах відключень. Під час війни, особливо на фронті, комунікація необхідна для координації військових дій та обміну інформацією. Забезпечення мережевого обладнання джерелами безперебійного живлення може відігравати ключову роль у забезпеченні надійного та швидкого підключення до Інтернету, стаючи критичним резервом для забезпечення зв'язку. Актуальним стає питання створення пристрою, здатного забезпечити автономну та безперебійну роботу роутерів, модемів, мережевих терміналів та інших пристроїв. У статті запропоновано нові конструктивні рішення для створення системи безперебійного живлення (ДБЖ), яка здатна захистити пристрої від можливих пошкоджень під час перебоїв електропостачання та забезпечити безперебійну роботу обладнання.

Ключові слова: Система, Джерело живлення, Енергія, Споживана потужність, Мережа, Обладнання, Параметри, Час перемикання, Інвертор, Безперервна робота, Характеристики, Батарея.