Autonomous Solar Power Plant for Individual use Simulation in LTspice Software Package Booster Voltage Converter

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Abstract: This work discusses the development of portable and inexpensive solar stations with low power, which are of great interest to farmers, summer residents, geologists, and travelers. The main focus is to ensure the reliability of the installations during transportation in various conditions, convenience and ease of operation, as well as ensuring the minimum size, weight, and reasonable price. The widespread use of alternative energy sources, particularly solar power plants, can save natural resources, improve the ecology of the habitat, reduce carbon dioxide emissions, and stimulate the training of specialists in the field of alternative energy sources. The purpose of this work is the development of portable solar stations that provide lighting for at least 8 hours, charging cell phones, and which are convenient for transportation. The work discusses the use of a DC voltage converter as an intermediate link between the solar battery and the autonomous voltage inverter, which provides high efficiency with a minimum of power elements and minimized weight and size.

1 INTRODUCTION

Our modern society is constantly moving somewhere, and this movement, otherwise called "permanent hypodynamia" - makes some sections of the population retire from society and its modern achievements. But in the modern world, probably, no one succeeds in completely retiring from all its features and achievements, and therefore, although some minimal connection with it is necessary for everyone, even the most inveterate modern “natives” [1].

In this article, we will consider mobile solar power plants based on solar batteries - through which, any of us, being away from home, is able to establish normal communication with relatives and friends, as well asprovide our other, minimal energy needs.

The sun is a source of inexhaustible energy reserves, andthe widespread use of this energy is one of the most urgent tasks for the Republic of Uzbekistan, which has significant solar energy resources. Other alternative energy sources (AES) are also significant. The main supplier of solar electrical energy is solar cells, the principle of which is based on the direct conversion of solar radiation energy directly into electrical energy. Solar cells generate energy at low operating costs and donot pollute the environment. In connection with the increase in the cost of petroleum products, a sharp increase in demand for alternative energy sources is predicted. It should also take into account the environmental and social impact of the use of solar power plants in remote and hard-to-reach areas. Widespread use of AES will save natural resources, improve the ecology of the habitat, reduce carbon dioxide emissions, improve the living conditions of the population and stimulate the training of specialists in the field of AES [2].

Calculations show that the use of RES in remote areas of the republic gives not only a social and environmental effect, but also a direct economic effect.

The purpose of this work was the development of portable solar stations that provide lighting for at least 8 hours, charging cell phones. At the same time, these stations should be convenient for transportation. At the same time, it was necessary to accurately calculate the power of the solar flux, which would not only have to provide the necessary energy to the system for lightingat night with a duration of 8-10 hours, but also recharge the battery. At the same time, the device had to have optimal dimensions for ease of transportation andplacement [3].

In accordance with the requirements of [4], we havedeveloped a universal portable autonomous solar power plant for individual use, designed for the electrification of farms and summer cottages, as well as for use in remote and hard-to-reach places where there is no traditional power supply.

To expand the operating range of the solar inverter, a DC voltage converter is used as an intermediate link between the solar battery (SB) and the autonomous voltage inverter (AVI).

Such a solar energy converter (PESB) can be a step-up converter or an inverting converter. Such schemes provide high efficiency due toa minimum of power elements, while the weight and size of the filter are minimized by high conversion frequencies [5, 7].

2 MATERIALS AND METHODS

Since consumers require a standard voltage of 220 V with a frequency of 50 Hz, a step-up stabilized voltage converter will be used between the battery and the consumer. At night, the converter (inverter) will be powered from the battery, which is charged during the day.

The choice of voltage of the SB and AB panels is made taking into account the following considerations:

1) Ensure the safety of the solar battery and the battery, which decreases with increasing voltage;
2) Achieving reliability battery and solar battery. In high voltage circuits with a voltage of 220 V, reliability is reduced;
3) The high voltage battery has a large voltage spreadbetween the battery cells and requires a complex balancing system to prevent failure;
4) Reducing the input voltage ripple of the converter when operating from a solar battery in the current section of its current-voltage characteristic.

2.1 Methods

The paper investigates the effectiveness of the application of the controller control of the software using the UC3845A microcircuit [6].

The controller contains a high-frequency transistor SW, allowing for an efficiency of up to 86%. The circuit for switching on the microcircuit, modeled in the LTspice program, is shown in Figure 1.

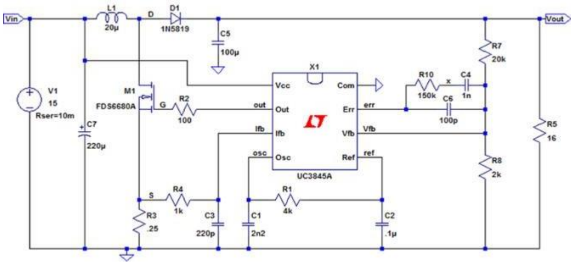

Figure 1: Schematic diagram of a boost converter [7].

The COMP pin is the output of the error amplifier. V_{fb} isthe inverting input of the error amplifier. It is usually connected to the output of the switching power supply through a resistor divider. I_{fb}, a voltage proportional to the current of the inductor is connected to this input.

The PWM uses this information to stop the output switch from working. O_{sc} adjusts the oscillator frequency and maximum duty cycle, programmed by connecting a resistor to V_{ref}. Operation up to 500 kHz is possible. The out pin directly drives the gate of the power MOSFET. V_{cc} - This pin is the positive power supply. V_{ref} provides charging current for capacitor C_2.

The switching circuit is intended for use in the converter as an inverting type, (manufacturer's recommendation) [7]. The output characteristics of voltage (U_{out}) and current (I_{out}) of the boost converter are shown in Figure 2.

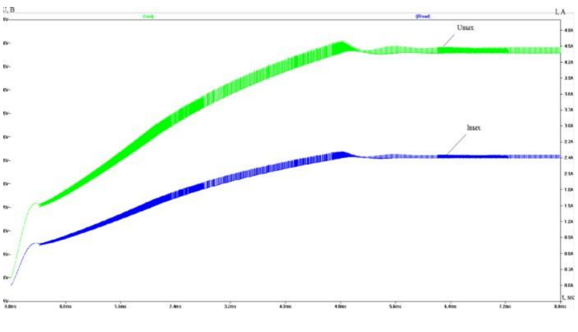

Figure 2: Boost converter voltage (U_{out}) and current (I_{out}) output characteristics.

On Figure 3 shows the transient process of the output voltage U_{out} and current I_{out}.

Based on the diagram of the transient process, we seethat the transient process lasts 5 m×s. And it takes 5.2 m×s to reach the first maximum, and the voltage value at this point is 51 V.

On Figure 4 shows the transient current on the inductive element IL.

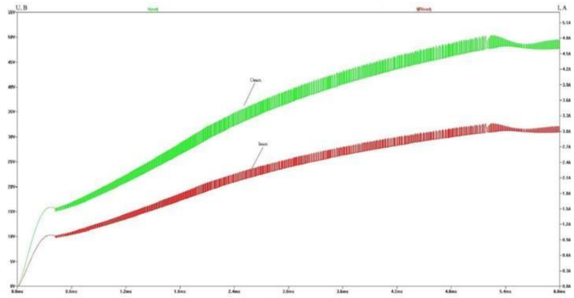

Figure 3: Transient process of output voltage U_{out} and current I_{out}.

Figure 4 shows the transient process of the output voltage (U_{out}) and current (I_{out}), which was obtained using the LTspice program.

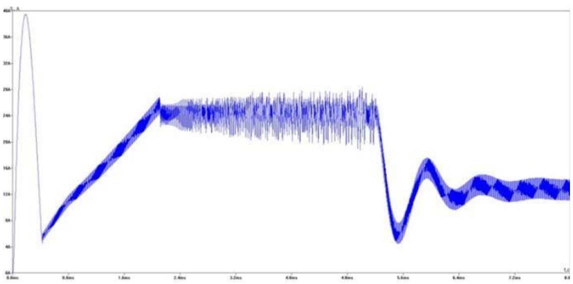

Figure 4: Transient current inductance in the program.

Study of the dependence of the output voltage on theload.

This dependence U_{out} ($R_н$) was studied on the model (Figure 4) and the results are shown in Table 1.

Table 1: Values of the dependence of U_{out} on $R_н$.

U_{out},V	15,5	36	44	48,5	48,5	48,5	48,5
$R_н$, Om	1	5	10	15	20	25	30

A graph of this dependence was also built (Figure 5).

As seen in Figure 5, the output voltage increases as the load increases to 15 Om. With an increase in load above 15 Om, voltage stabilization is realized, this indicates that the operating range of this 48 V circuit is achieved at 15-16 Om [8].

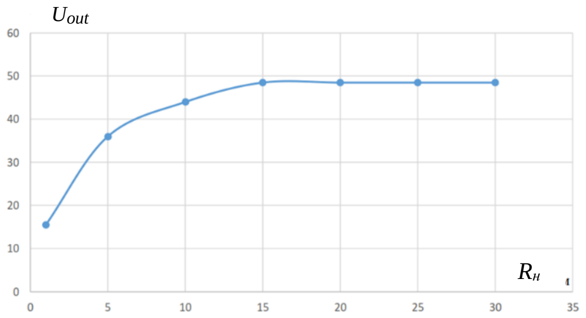

Figure 5: Graph of dependence of output voltage U_{out} on $R_н$.

2.2 Investigation of the Dependence of the Output Voltage on the Supply Voltage

This dependence U_{out} (E_{pit}) was studied on the model (Figure 5) and the results are shown in Table 2.

Table 2: Values of the dependence of U_{out} on E_{pit}.

U_{out},V	0,5	3,5	7,5	48	48,5	48,5	48,5
E_{pit},V	1	4	8	12	16	20	24

A graph of this dependence was also built (Figure 6).

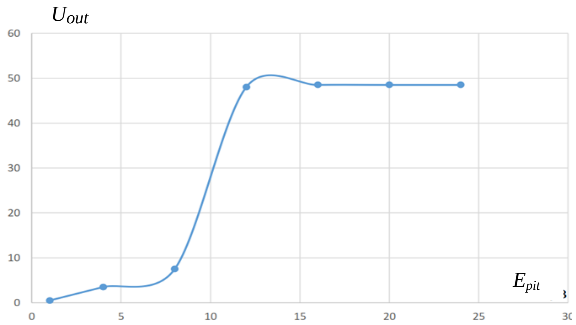

Figure 6: Graph of dependence of output voltage U_{out} on E_{pit}.

As seen in Figure 6, the change in the output voltage U_{out} is not linear and depends on the change in the input voltage U_{out}. Namely, the required 48 V is achieved at a supply voltage of 12 V, which indicates the correctness of the calculations of the power circuit and the possibility of alternative power supply from the battery [9].

2.3 Study of the Dependence of the Ripple Factor on the Load and Output Voltage

Coefficient of voltage (current) ripple according to the average value - A value equal to the ratio of the average value of the variable component of the pulsating voltage (current) to its constant component [10].

When calculating this indicator, information was collected on the minimum, average and maximum valuesof the output voltage, at various values of the supply voltage and load. The received data is substituted into a special formula. The ripple factor is calculated as the difference between the maximum and minimum values, divided by the average, after which the resulting amount is multiplied by 100%:

$$k_n = U_{\text{out}(max)} - U_{\text{out}}(min) \times 100\%.$$

The dependence k_n (E_{pit}) was studied on the model (Figure 6) and the results are shown in Table 3.

Table 3: Dependence values of k_n on $R_н$.

k_n, %	14,5	6,8	4	3	2	2	2	1,2
$R_н$,Om	1	5	10	15	20	25	30	40

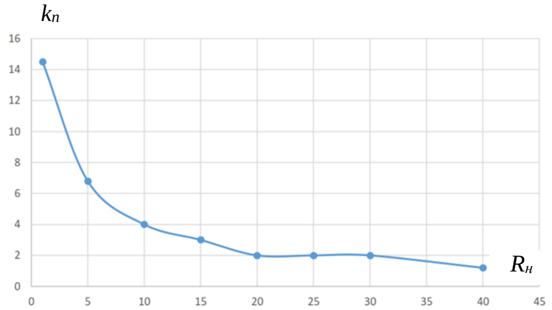

Figure 7: A graph of this dependence was also built.

A graph of this dependence was also built (Figure 7) k_n,%. From this graph it can be seen that with increasing load, the ripple coefficient decreases significantly in the area from 0 Om to 16 Om. With further increase in load, the degree of fall decreases. The system is designed for loads above 15 Om.

The dependence k_n (E_{pit}) was studied on the model (Figure 7) and the results are shown in Table 4.

Table 4: Dependence values of k_n on E_{pit}.

k_n, %	3	2	1,8	1,6
E_{pit}, V	12	16	20	24

A graph of this dependence was also built (Figure 8).

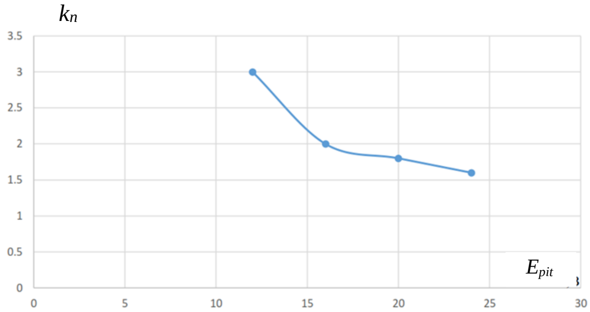

Figure 8: Graph of dependence of output voltage k_n on $R_н$.

Also, with an increase in the input voltage, it can be seenthat the ripple coefficient decreases. In the used range of supply voltages, the ripple factor does not exceed 3%.

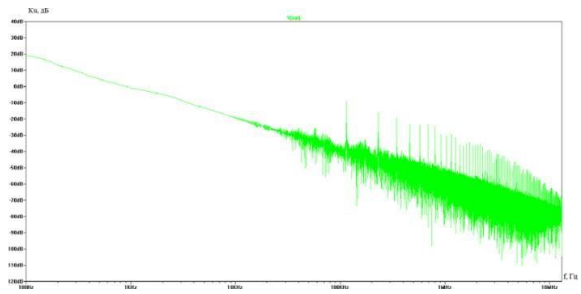

Figure 9: Frequency response of the boost converter.

The spectrum characterizes the type of the PPN harmonic (Figure 9). A sloping view indicates that this characteristic is rigid.

Such a solar station provides continuous operation of one TV and room illumination for 4 hours, and without a TV it illuminates the room and provides cell phone charging for 20 hours. To ensure the operation of such stations, it is necessary to place the solar panel in the sun from 6 to 10 hours, depending on weather conditions.

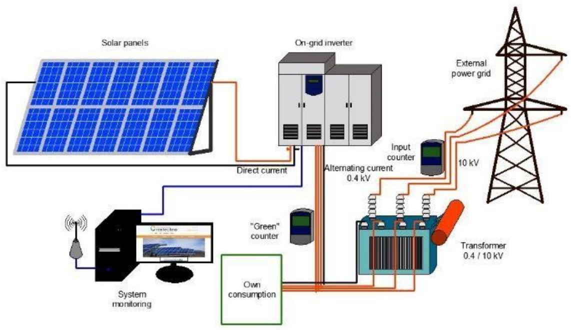

Figure 10: General and appearance of the solar panel device.

Our experiments have shown that the service life of such solar stations is at least 20 years, from time to time there is a need only to replace the batteries. In Figure 10 is the appearance and arrangement of such solar stations.

3 CONCLUSIONS

The study analyzed the coefficient of voltage (current) ripple of a solar-powered station designed for individual use and in remote locations where there is no traditional power supply. The ripple factor was calculated using data collected on the minimum, average, and maximum values of the output voltage at various supply voltage and load values. The results showed that with an increase in load and input voltage, the ripple coefficient decreases significantly. The system is designed for loads above 15 Ohms, and the ripple factor does not exceed 3% in the range of supply voltages used.

The solar station was found to provide continuous operation of one TV and room illumination for 4 hours and room illumination with cell phone charging for 20 hours. The station's service life was found to be at least 20 years, with only occasional battery replacements. This solar station is designed for individual use, as well as for use in remote and hard-to-reach places where there is no traditional power supply. Possible consumers of products can be budgetary organizations or individuals whose specific activity is carrying out work in remote and hard-to-reach places where there is no traditional power supply.

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