# OPTIMIZATION OF SOLAR POWER SUPPLY SYSTEMS

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**Abstract**

My work focuses on the development of approaches to designing solar power systems for the needs of decentralized power supply. It develops an algorithm for determining an optimal structure of power supply system taking into account technical, economic, environmental and social aspects. The case study for the algorithm is the solar power supply system located in decentralized area of the settlement Stepanovka.

**Introduction**

Solar power system play a crucial role in regions without central power supply (Decentralized energy supply). Decentralized energy supply is one of the most important problems of modern power engineering. More than 65% [1] of the territory of Russia fall into the category of decentralized energy supply – that is a consumer supply of electricity from a source unconnected to a power system. Power supplementation of such regions would help in at least two ways: formation of quality of life of the population and also creation of suitable conditions for business, as the question of ensuring access and quality is very important. One of the solutions to this problem is the supply by a solar power system. [1]

This work is devoted to research in the area of optimal design of a solar power system. The goal of the thesis is the assessment of efficiency of the use of solar panels by domestic household consumer.

For achieving this goal it was required to solve the following problems:

- The problem of decentralized electricity supplies and possible ways to solve it;
- Governmental or regional support for renewable sector of energy;
- To develop methods for assessment of effectiveness of the use of solar panels and choosing equipment for solar power systems;
- Implementation of proposed methods for given location.

**The problem of energy supply in decentralized zones**

The problem of electrification will always exist due to the constant growth of world's population and development of society in general. Nearly one fifth of the world's population – over 1.3 billion people – still has no access to electricity nowadays. Energy poverty mainly affects developing countries of Sub-Saharan Africa and Asia. Across developing countries, the average electrification rate is 76%, increasing to around 92% in urban areas but only around 64% in rural areas. However, there are gaps in the public electricity grid, not only in developing countries and emerging markets but also in industrialized countries, such as remote mountain regions, large forests or expanses of water. [2]

Only one third of Russian territory is covered by central power network. The electrification of the rest of Russian territory – about 20 millions of people – is performed by local power stations with transported fuel or by local fuels (coal, peat, etc.). As usually, non-electrified regions of Russia face serious social problems: a high poverty rate and poor living conditions, unemployment, a potential demographic crisis, unfavorable migration patterns, etc. [2]

The construction of efficient central or off-grid power systems would solve these problems and cause the development of rural not electrified areas.

**Techno-economic evaluation method**

This method allows to determine the efficiency of solar panels. As a result of my own work, the following scheme for evaluating the effectiveness was proposed. The main factors of evaluation of the efficiency of power systems can be combined into four main steps as the most influential in the design of these kinds of systems.

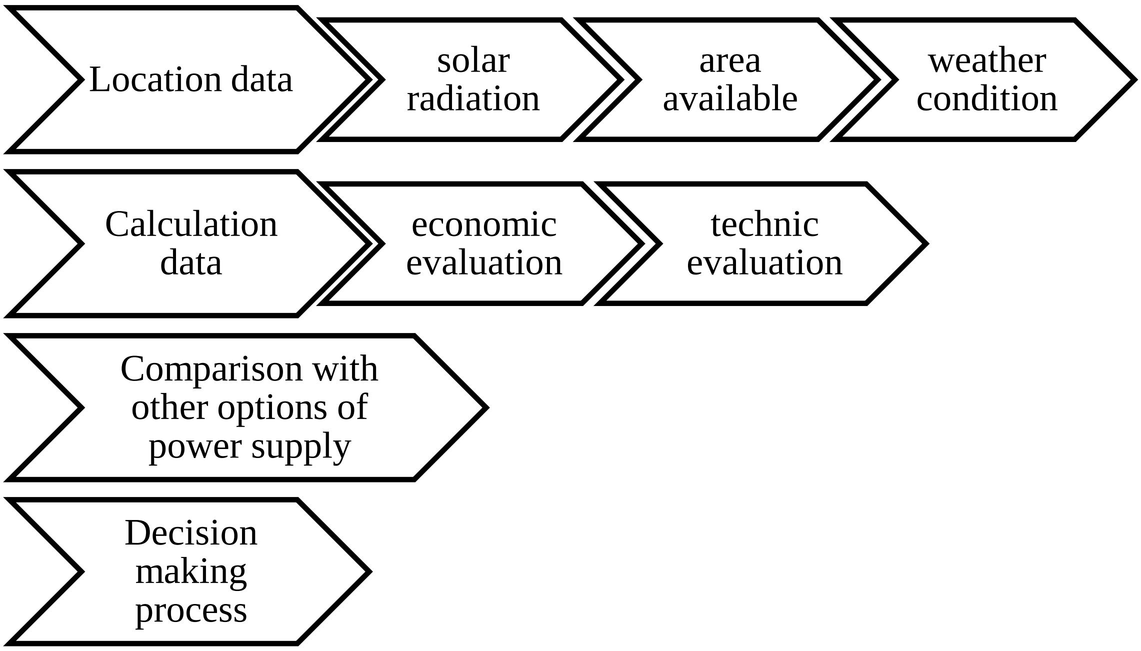


Fig. 1. Method for evaluation the efficiency of power system.

**Case study**

The aim of this work is the exploration of the influence of available options for the development of the energy system, managing possible scenarios, measures of achievement of agreed objectives and developing economic models for each scenario. To achieve the present goals there can be formed a number of alternative scenarios with different characteristics and indicators. This work uses one scenario to assess the impact of PV panels. This is scenario are based on use diesel generators and PV panels.

For the purpose of power supply by means of combination of solar and diesel power sources it was decided to install the 1600 PV panels with nominal power 0,3 kW each, and total nominal power 480 kW, and three types of diesel generator with nominal power 1000 kW and two types diesel generator with nominal power 800kW. The total nominal power of diesel generators is 2600 kW.

In this scenario, maximized number of solar panels that could be installed and the total energy generated of the solar panels didn't exceed the daily load in the season when solar panels produce the maximum amount of energy.

The greatest advantage of this system is large power output. A 480kW system is capable of producing more than one-fourth the settlement electricity, and, at various times, almost one third the total power consumption. Based on current costs, the maximum system size also has a lifetime of 20 years. The greatest disadvantage to this system is the cost of implementation. Constructing a system of this size takes a large initial (134 611 024 rubles) capital investment, operational and maintenance costs (44 831 818 rubles) for each year. The capital investment consists of 1600 (HSE300-72M Helios SolarWorks, 24B) solar panels (36 864 000 rubles), sixteen (SolarLake 30000-TL-PM) inverters (7 427 840 rubles) and installation costs. To fit 1600 panels it is needed to deliver solar panels to the settlement. The price of installation and transportation is taken as equal amounts (12 199 184 rubles) which is 10% of the total price all equipment. Also installation of a fuel tank for the storage of fuel of volume of 40 000 liter (420 000 rubles) should be taken into account. The Operational and maintenance costs consist of maintenance of PV panels (80 000 rubles) and maintenance of diesel generator (176 000 rubles). A yearly maintenance the solar panels and diesel generator includes the prophylactic and emergency examinations. Fuel for diesel generator (42 907 578 rubles) and transportation of diesel fuel (870 000 rubles) by a rental truck would also cost. The wages for this branch of industry for the personnel of 2 people (798 240 rubles) are also included. This system does not require a storage. [3]

This scenario has high power efficiency value and quite low value of the minimum electricity price due to the significant saving of fuel by PV panels.

Tab. 1. Total minimum price of electricity for first scenario.

| | Without subsidy | Diesel subsidy | PV subsidy | PV+Diesel subsidy |
|---|---|---|---|---|
| Business | 16,66 rub. | 16,62 rub. | 15,76 rub. | 15,72 rub. |
| + Value added tax | 19,66 rub. | 19,62 rub. | 18,60 rub. | 18,55 rub. |
| | With tax | Without tax | With +subsidy | Without + subsidy |
| Municipality | 15,53 rub. | 14,87 rub. | 14,72 rub. | 14,17 rub. |
| + Value added tax | 18,32 rub. | 17,54 rub. | 17,37 rub. | 16,72 rub. |
| Current price | 16,6 rub. | | | |

**Conclusion**

In this paper, methods for the economic evaluation of PV plants are presented. This method takes into account all the installation phases of every PV plant type. The economic evaluation is based on the individual technical parameters of every PV plant. In the evaluation process, the initial costs of the PV plant and the annual cash flows resulted by the operation of the PV plant, play a significant role. The economic evaluation is implemented with the use of financial criteria.

The proposed method is applied for the economic evaluation of an off-grid photovoltaic station located in decentralized area of the settlement Stepanovka at the prefecture of Russia and the main conclusions from this application are the following:

- The results of the investment evaluation prove the general profitability of the project with the specified parameters. The project could be profitable for business investor but not much. The project could be even more profitable for municipality investors, if it is possible to find a good possibility to take a low interest loan. This is a possible scenario, as the project is interesting not only for the business investors, but also to municipality. The project has also the nonmonetary value, as it creates 2 new working places;

- The project allows decreasing of the governmental subsidies by 18%. This proves that the project would be particularly interesting for government that may support it by different means: cheaper loans, tax remissions and other;
- PV plant can help reduce the use of diesel generators, leading to less maintenance and decreasing of the emissions and noise of the diesel generator, it will help with preservation of nature and increase quality of life in the area.

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## КОНЦЕПЦИЯ ПОСТРОЕНИЯ КОМБИНИРОВАННЫХ СИСТЕМ АВТОНОМНОГО ЭЛЕКТРОСНАБЖЕНИЯ


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В данной работе рассматривается проблема электроснабжения маломощных (до 100кВт) отдаленных изолированных потребителей. Чаще всего для этого применяются дизель-генераторы, но такой способ достаточно затратный.

Задача состоит в эффективном использовании возобновляемых источников энергии (ВИЭ) в совокупности с дизель-генератором. Так как у ВИЭ непостоянные характеристики, невозможно использовать их обособленно. Для сопряжения ВИЭ и дизель-генератора необходимо ввести общую шину. Последняя может работать либо на постоянном токе, либо на переменном, либо на переменном с высокой частотой. У каждого способа свои достоинства и недостатки, как наиболее выгодная рассматривается шина постоянного тока (ШПТ).

Предлагается концепция маломощной гибридной электростанции с использованием возобновляемых ресурсов (рис.1). Установка включает в себя ветрогенератор, солнечную панель, буферный накопитель энергии (аккумуля-