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A POSSIBILITY OF HYBRID SUPPLY OF AUTONOMOUS MILITARY UNITS WITH ELECTRIC POWER

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Abstract: *This paper presents one possible solution of hybrid electrical power supply for military units without electric connection to electric distribution network. The hybrid photovoltaic and diesel aggregates island's power supply with maximal power of 80 kW and daily energy of 400 kWh is shown in this paper. The advantages of this system are: reduced consumption of fossil fuels, efficient use of fossil fuels, reduced emissions, improved energy system reliability, ensuring continuous electric supply and increasing life of diesel engines. The working concept is such that hybrid system uses photovoltaic panels for prime power and diesel generators as a secondary source of energy. We expect creating such a system as a test installation, soon.*

Key words: *hybrid power supply, island power supply, diesel aggregate, photovoltaic*

1. INTRODUCTION

To enhance the power of the autonomous object without the possibility of connection to the electricity grid, it is necessary to make a new solution that can cover average daily energy consumption of 400 kWh and peak power of 80 kW. Power supply should be in operation throughout the year, in summer and winter conditions, so to be suitable for power supply of military units in isolated areas. In addition to building high-quality power supply voltage and constant frequency and voltage, power source should respect the following criteria:

- It is necessary that the system is autonomous, that is reliable, durable and maintenance is kept to a minimum;
- **Consumption of diesel fuel have to be minimal** (which is often the dominant factor for various reasons);
- Noise and vibration should be minimal;
- Source for electricity generation should be a fuel that pollutes the environment minimally and the various components of the combustion products
- Despite all that, investment and operating costs should be acceptable and system operation profitable.

2. POSSIBLE WAYS TO REDUCE OIL CONSUMPTION

The reduction of oil consumption, with respect to respond to daily electricity consumption and peak power can occur in several ways:

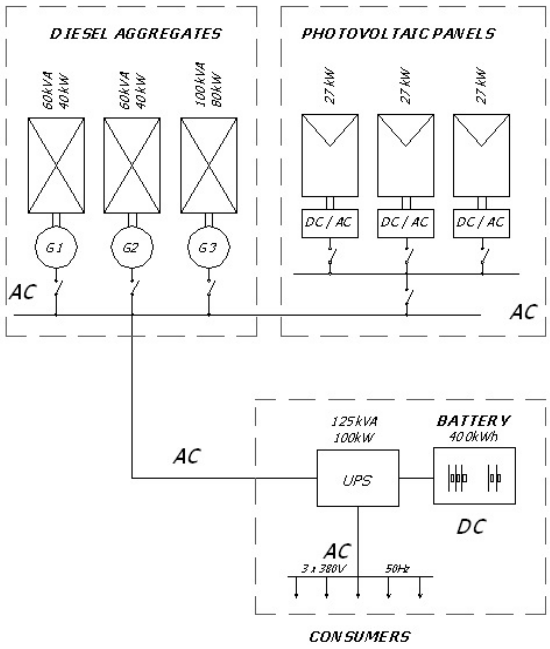
- Using the renewable energy. Although there are several types of renewable energy sources that can be efficiently and effectively implemented so far the most suitable are photovoltaic panels that convert sunlight directly into electricity.
- Efficient use of fuel in diesel engines. Operating at the optimum point of use, it is possible to make diesel fuel consumption about 0.3 *l* per produced kWh of electricity, which is often substantially less than when working alone diesel generators.
- Efficient use of electricity. The use of electrical appliances class "A" and especially "thrifty" consumer, it is possible to increase energy efficiency and to achieve significant energy savings. In addition, it is necessary to include large consumers per day when there is sunlight, and when electricity is the most cost-effective.
- Combination of the above methods (hybrid method).

Optimal results can be obtained using several methods at

the same time or all together.

3. HYBRID POWER SOLUTION

A hybrid power generation system consists of photovoltaic panels (PV) of the total power of 80 kW, as the primary source, the two diesel generators (D1 and D2) with 60 kVA (40 kW), a diesel generator (D3) 100 kVA (80 kW), three-phase inverter (INV) with about 27 kW each, with the AC Inverter (UPS) with 125 kVA (100 kW) and battery (AB) for storing 400 kWh of electrical energy. It is important to note that diesel engines (D1 and D2) work as sources of constant power at the optimum point of operation with minimum fuel consumption for kWh of electric energy production, with minimum emissions and maximum service life.



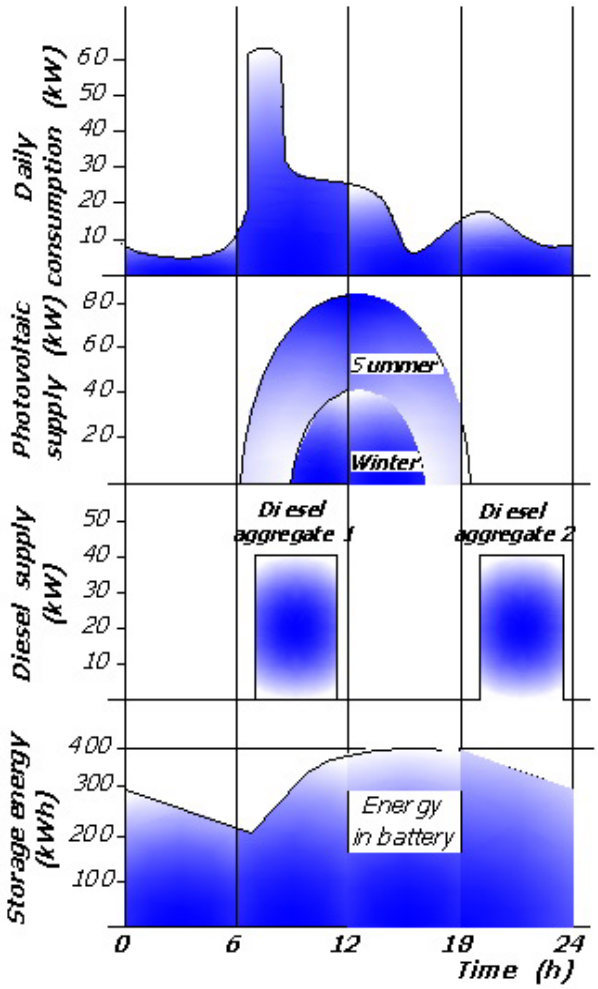
Picture 1. Single line diagram of the hybrid system Photovoltaic panels (PV) are the main source of electricity that will be used primarily, two diesel generators (D1 and D2) are additional sources of electricity that will be used when there is not enough solar power, and diesel generator (D3) is a backup source of electricity to be used when there is a large need for energy or when the regular system is out of service.

4. PRINCIPLE OPERATION OF HYBRID SUPPLY

This solution is made so that the average daily consumption of the military unit and associated facilities should be 400 kWh. With the early morning hours daily activities begin, kitchen starts to work and peak load occurs. Since the batteries will always be at least 50 % of energy from 400 kWh to limit the peak consumption is only with the AC inverter (UPS) power over 125 kVA (100 kW).

The advent of the sun begins to recharge batteries with PV over the three-phase inverter (INV) with about 27 kW each or a total of 80 kW. In the event that there is no consumption in the military unit, this power responds to five hour currant of supplementing batteries. In the winter time, recharge from PV is lower.

Diesel engines (D1 and D2) are included when needed and when the level of stored energy drops to 50 % of nominal power and 200 kWh. Its turns off when the energy level in the battery reaches 80 % of nominal power or 320 kWh of electric energy stored. It is not anticipated that diesel engines operate in parallel.



Picture 2. Daily consumption of a diagram of the military unit and the participation of individual units in production

If the level of stored energy, for some reason, decline to 35% of nominal power or 140 kWh, the engine turns off and spare drive is placed to operate (D3) the maximum power that forced complements the battery pack and power consumers. The diesel engine can be put into operation to charge consumers directly at the military unit, if they drop from the normal power supply operation.

5. BENEFITS OF HYBRID SYSTEMS

Diesel engines use non-renewable fuels, but there is less and less of diesel fuel in the world, becoming more and more expensive. In addition, diesel engines have higher specific fuel consumption and emissions of gases when the loads are smaller. Renewable sources are not constant in electricity generation so that they are largely dependent

on the unpredictable weather. Given these facts, hybrid systems have certain advantages [1-2], which largely compensate disadvantages of both systems, by:

a. Improved reliability of systems

Supply reliability and reduced downtime can be achieved by combining multiple sources of power to provide electricity. Photovoltaic panels require less maintenance than diesel generators, thus reducing delays in operation and maintenance.

b. Reduced noise and emissions of harmful gases

Diesel engines emit particulate pollutants into the air, and noise during operation, which indicates a significant difference from renewable energy sources that use environmental sustainable technologies.

c. Uninterruptible supply

By connecting the parallel operation of diesel generators and photovoltaic panels with battery pack, the possibility of accepting the initial impact, or current is increased, and thus, the system is less susceptible to interruption of electric energy supplies.

d. Increased duration

Units D1 and D2 in the optimal and alternating operation mode provide their maximum duration. In addition, the optimum discharge of batteries contributes to their increased duration.

e. Cost reduction

Renewable energy sources or hybrid power system behaves as a very effective way of generating electricity, considering the savings in the current fossil fuel consumption and lower maintenance costs. For a conventional diesel generator system in a remote area, the cost of fuel and transport costs are usually quite high, as well as service costs. The costs of renewable energy sources are displayed only as an investment or capital, so that the operational costs are very low.

f. Efficient use of energy

The hybrid system promotes efficient use of electricity from renewable energy sources.

6. ENERGY SAVINGS IN HYBRID POWER

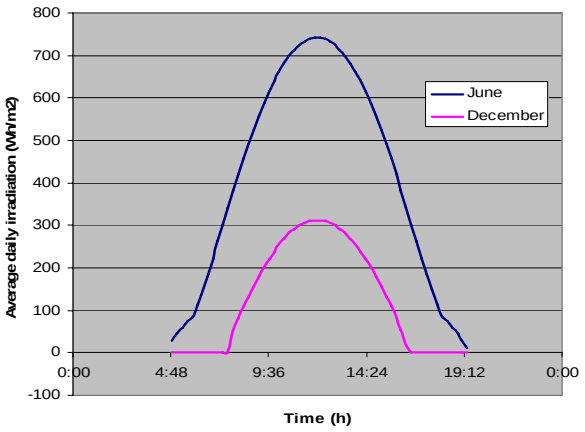
As mentioned above, reducing diesel fuel consumption, and thus the funds allocated annually for the exploitation costs, hybrid power stations allows in two ways: by using renewable energy, using more efficient use of fuel in diesel engines as well as using energy efficient consumers.

- Use of renewable energy

As a source of electricity, photovoltaic cells still have major advantages: reliable in operation, there is little need for maintenance, do not adversely affect the natural, the energy source is free, there are standard sizes that can be increased and easily transported.

The main limitations stem from the fact that there is a strong dependence on solar radiation and the still relatively high investment cost.

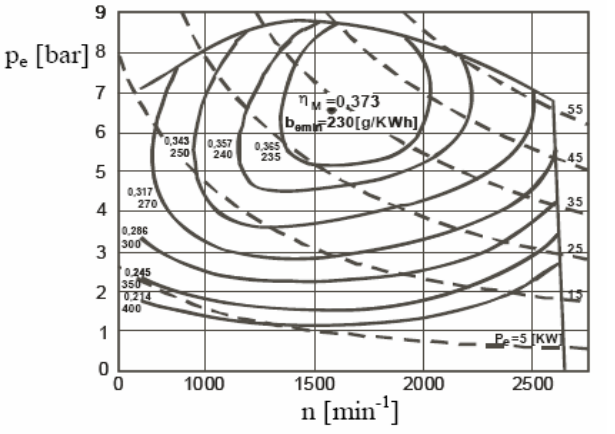
Measurements in Serbia [3-4], shown that the average daily irradiations obtained from photovoltaic cells could be up to 983 Wh/m^2 in June and 253 Wh/m^2 in December. It is assumed that the slope of photovoltaic cells is 35 degrees to the horizontal axe and that the cells are facing the south.



Picture 3. Diagram of the average daily irradiations vs. time during summer and winter season

To verify these data the database of the European Community Photovoltaic Geographical Information System was used [5] and the diagrams are shown in picture 3 for two typical months.

Photovoltaic panels of 80 kW rated power, during the summer period could provide up to 415 kWh electric energy, but during the winter period could provide up to 134 kWh electric energy per day. But it may happen that in several consecutive days, the system could be out of use. Inverter power 125 kVA (100 kW) ensures smooth start without any major consumer issues.



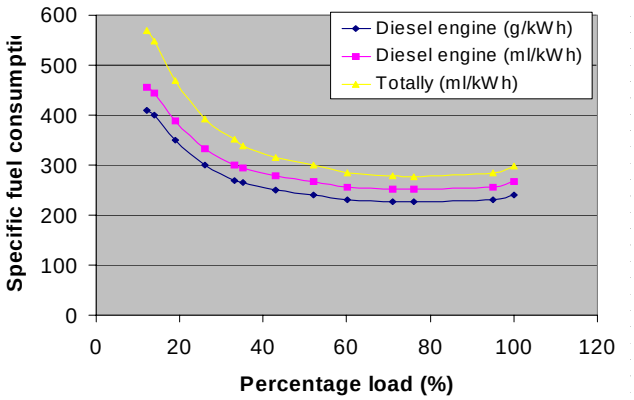
Picture 4. Diagram of the specific consumption of diesel fuel in the function of the load generator

- Efficient use of fuel in diesel engines

A typical diagram of the specific consumption of diesel engine, maximum power of 55 kW, shown in picture 4 [6], shows that the optimal range of the engine in generator mode, means that at the constant speed of rotation 1500 min^{-1}, is in the area from 60 to 90% of the nominal or rated power. Power over this area is not

recommended because the engine would be overload and starts to burn less and the black smoke appears. Small loads are also bad for the engine because it significantly increases the specific fuel consumption; engine burns poor and duration of engine become lower.

When an engine is connected to a generator and when the genset is made, overall efficiency is further reduced and the total specific consumption of diesel fuel increases. Picture 5 shows the typical consumption of diesel generator sets in a function of percentage load.



Picture 5. Specific consumption of diesel fuel loads as a function of maximum continuous rating

One possible solution is to use a diesel engine equal or slightly greater than the power required by peak period. But such a solution causes the diesel engine to generally work weakly loaded all day and thus the specific consumption would be high. Sometimes the solution used with a diesel engine is less powerful but consumers are divided on the priority that have to have constant power supply and on the general where in the case of overload they could switch on and off again when the diesel engine less is burdened. The following solution takes into account the parallel operation of several smaller diesel generators that are activated automatically in accordance with the needs of consumers.

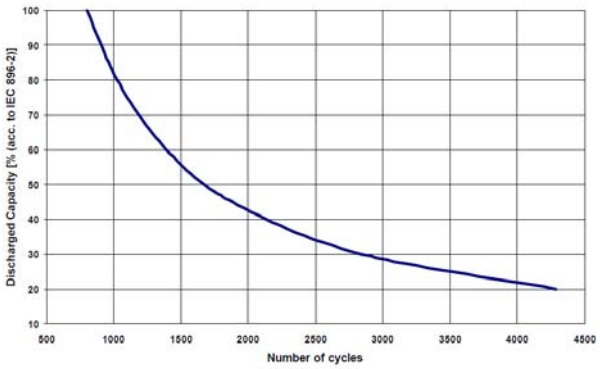
It is an optimal solution with a small diesel engine that operates in the optimal mode of usage, similar to hybrid cars [7]. The solution involves the use of low power diesel aggregates which operates in generator mode, in point where is the minimal specific fuel consumption per kWh and particulate emissions in the exhaust gas and diesel engines have a maximal duration.

- Efficient use of batteries

The plan is to use rechargeable gel batteries with total five-hour energy around the 400 kWh. The battery should be charged by a photovoltaic panels in summer season. In winter season, diesel engine will charged batteries only when the rated capacity fall on 50% of rated capacity. If it is assumed that during the day that would be one cycle of charging and discharging, the battery set could submit about 3,400 cycles per year and thus the battery duration would be over 9 years.

- Energy efficiency of consumers

Whenever possible, it is necessary to save power consumption and reduce oil consumption by certain types of energy transferred to another type of energy source. It is known that the greatest amount of energy is consumed for heating and domestic hot water, so that there is a need to rationalize the consumption of electricity and replace other forms of energy for heating. For illumination of living and working space a significant amount of electricity is consumed so that there is a relatively high potential of its savings. For this, a variety of options are available as the modern technical solutions energy saving lamps and light intensity control, which significantly reduce the losses. In the end it is necessary to use electrical devices with increased energy efficiency.



Picture 6. Number of cycles as a function of depth of discharge of batteries (MCR) for gel solar batteries [8]

7. GENERAL CHARACTERISTICS OF HYBRID POWER SOLUTIONS

This solution is made with the optimal assumption that the average daily electricity consumption of military unit and associated facilities would be up to 400 kWh. The system is designed so that during the summer months provide an almost total consumption of electricity from photovoltaic panels. During the winter months to generate electricity will be used diesel generators D1 and D2 when the consumption of diesel fuel will be considerably higher.

Given that very uneven loads occur during the year, the system should be flexible and to allow greater consumption of electricity in the days when necessary. A hybrid solution can be during the summer months to ensure the normal working conditions, about 960 kWh of the diesel engine and 415 kWh electricity from photovoltaic panels so that it is about 1.375 kWh per day maximum. During the winter months, this solution can provide in the normal operation of about 960 kWh diesel engines and 135 kWh electricity from photovoltaic panels so that it is about 1.095 kWh per day of electricity.

In emergency situations, the diesel engine (D3) with 100 kVA (80 kW) can provide a daily electricity of 1.920 Wh. The only limiting factor is the peak of the AC inverter (UPS) with 125 VA (100 kW). Until we get to the field of photovoltaic panels this system can operate effectively with a diesel engine but will be spending less than 150 l diesel fuel per day for energy needs of the military unit of the 400 kWh.

A hybrid solution has one important feature of the system reliability, that if due to some reason the UPS fails or normal supply of the military unit, it is possible to put in a spare drive unit D3 and directly supply the military unit with 100 kVA (80 kW).

8. ANNUAL SAVINGS OF DIESEL FUEL

Assuming that the average daily consumption of electricity is about 400 kWh, the annual energy consumption would be about 164.250 kWh.

If it is assumed that the annual insolation is about 1.440 hours, photovoltaic panels rated power 80 kW can generate useful energy from this system of about 87.000 kWh per year, taking the total losses in the system by 24,5% according to the EU interactive maps for Photovoltaic Geographical Information System [5].

The remaining 77.250 kWh should be obtained from the diesel generators. Taking into account the specific energy consumption of diesel fuel of 0,3 *l*/kWh it is possible to determine the annual diesel fuel consumption of about 23.175 *l* for the purpose of generating electricity. On the other hand, if it would work only in the regime of diesel engines as in use today, with an average specific fuel consumption of 0,45 *l*/kWh, to produce 164.250 kWh, its is needed to spend about 73.900 *l* diesel fuel. The annual diesel fuel savings would be approximately 50.700 *l* diesel fuel.

9. DURATION OF THE HYBRID POWER PLANT

It is necessary to bear in mind that it has any power in the military unit had a duration of about 15 years. It is believed that the diesel generators will work less than 2.000 hours per year or 1.000 hours each. Under the optimal conditions and with normal maintenance duration of diesel generators would be 25 years in operation. Photovoltaic panels have a normal duration of 25 years, but decreased conversion of sunlight into electricity will by 15 %.

Under the foregoing conditions, the duration of batteries would be about 9 years. It can be concluded that the total duration of the hybrid plant will be about 25 years with the need for every 9 years to change a battery.

Flexible solution enables some improvements and corrections solutions of the hybrid power plant. The addition of photovoltaic panels increase the production of electricity from renewable sources, and thus further reduce annually fuel oil consumption.

Higher batteries capacitz also reduce annualy fuel oil consumption. Peak load can be increased by replacing the rectifier inverter (UPS) power greater than indicated. It is believed that the military unit would not reach the daily consumption of 1000 kWh of electricity, so that it does not recommend increasing the substitution of larger aggregates.

10. CONCLUSION

It can be concluded that the proposed solution and discussed hybrid sources for electric power generation is optimal, because in this way it would provide the following:

– The average consumption of electric energy is 400 kWh. In addition to the annual consumption of oil would be around 23.175 *l* in normal conditions.

– Power plant is able to under the most adverse operating conditions to create in normal conditions of 1.095 kWh electric energy per day.

– The maximum daily peak power is 80 kW.

– Duration of the hybrid power plant is 25 years.

In addition.

– The achieved annual savings of more than 50.000 *l* of oil compared with the solution that applies only to diesel engines.

– There is a minimum of environmental pollution.

– Maintenance is minimal.

– There is the minimum specific fuel consumption per produced kWh of electric energy, minimum emissions and the aggregates have the longest duration.

ACKNOWLEDGEMENTS

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