Hybrid Alternative Power Supply for Communication Equipment Operating in Severe Conditions

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Abstract – **The paper describes one approach to satisfy power supply requirements of the wireless communication node located in the area with severe meteorological conditions and without access to an electrical power grid. Hybrid alternative electrical power sources are used as a solution. A practical example is presented as an illustration.**

Keywords – **Alternative power sources, photovoltaic (PV) solar cell, wind generator, hybrid power sources**

I. Introduction

In many practical cases a portion of communication equipment and systems is located at the places that are very hard to approach or in sparsely populated areas, so the electrical power distribution grid is too expensive or in some cases technically almost impossible to build. As a rule, in these cases the use of electrical power generators that use oil as a fuel is also rarely possible, due to problems with fuel transportation and regular supplies (for example in high mountain areas during the winter season at the southeastern part of Europe). On the other side, placing some communication equipment at these locations, especially for wireless transmission of signals, is often the best choice if only the pure communication aspect is considered.

In those or similar situations the use of alternative electrical power sources offers an acceptable solution. Solar power generation by solar photovoltaic panels – arrays of appropriately arranged photovoltaic semiconductor cells covered with glass and packed in waterproof cases is one of the now widely accepted solutions. The other eligible source of electrical energy is the wind generator that converts the mechanical energy of wind into electrical energy. Solar energy and wind energy by their nature are energy sources that generate energy ruled by aleatory processes. It is obvious that in these cases some reservoir for electrical energy accumulation is necessary, as well as a control device that synchronizes the performance of the power generation and obtains the requested uninterrupted continual electrical power delivery to the customer.

The application of hybrid power sources that combine two (or in some cases even more) independent power sources that are complementary by their nature also significantly upgrades the reliability and efficiency of the power generation. The overall investments are often lower as well.

The technology of solar cell production has been upgraded significantly in the recent years resulting in the improvement of their efficiency and reliability. The same case is with wind generators.

Comercially available solar panels are produced by the use of various technologies of semiconductor photovoltaic cells that transform the solar energy of light into electrical energy. Amorphous, monocrystal and polycrystal materials are used as well as various shapes of cells, so the cells' efficiency is enhanced with each new generation, reaching nowadays an efficiency of up to 41 % by Fraunhofer Institute for Solar Energy Systems, as declared recently in [1].

Solar photovoltaic panels and electrical power wind generators are often parts of a hybrid alternative power supply system, because of their complementary nature of generation, respectively to their daily or seasonal behavior. During the summer PV panels provide sufficient energy, while during the winter when the insolation (of the Northern hemisphere of the Earth) is poor winds are more intensive and can compensate lack of solar energy. A similar relationship is when the day and night behavior of PV and the wind generation of electrical energy is concerned. Also, when the air pressure is high it is usually clear sky with little or no clouds at all and without significant air mass movement, so PV panels can get the most of coming solar energy.

The advantages of solar PV panels also lie in the lack of moving parts. So lubrication is not necessary at all and all problems with moving parts are avoided. At the same time, the mounting and integration of the PV power system is an easy maintenance of PV panels and is reduced to periodical (once a year, before winter season) checks of accumulators and clarity of PV cell glass cover, and dust cleaning.

Simple construction and good quality material make the chosen wind generator reliable and with mimimum maintenance requests.

II. Concept of the Chosen Solution

Basic request is: to obtain uninterrupted electrical power supply with constant DC power at least 15W (i.e. 360Wh per 24h). It is intended to provide electrical energy necessary for the operation of the telecommunication system located in the southeastern part of Europe at an altitude of about 1750 m above sea level. The power supply has to be absolutely independent from the electrical power grid supply.

As the first choice for an alternative power source, the PV power supply is chosen. Its configuration is redundant due to

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the isolated position of the location. The redundancy consists of doubled independent sets of PV panels and appropriate electronic controller and accumulator sets. Each set (accumulator) can by itself generate the requested electrical energy to independently power the telecommunication equipment at the location.

The supply voltage of 24 V DC is chosen to minimise the DC currents, the power supply voltage drops along conductors and losses of electrical power in instalation.

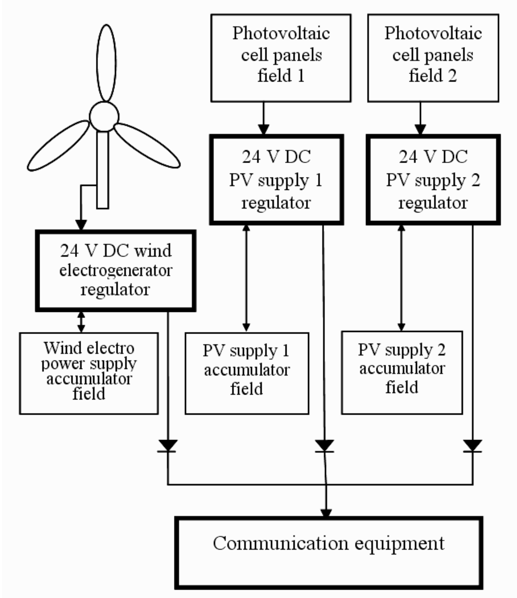

Figure. 1. Hybrid power system for comunication system

As an additional redundancy factor the hybrid alternative power system is chosen, realised by an additional wind generator with appropriate characteristics – capabilities for electrical power generation, an electronic power regulator and an independent acumulator set (Fig.1).

III. Solar Energy Based Power Source

The first input data necessary for the PV power system dimensioning is the insolation estimation for the location of interest. For every location of interest statistic data presenting insolation during the year can be found. Usually, such data is collected over the long term and regularly updated.

For the the chosen location in Southeast Serbia (42°49’26’’ North, 22°21’22’’ East, 1691 m above sea level) the insolation variation during the year according to [2] is presented in Fig.2.

As can be noticed from Fig.2, the minimum insolation at the location is in December (2.53 kWh/m2/day). Since the worst case design approach is applied, this value is used for the PV panels dimensioning.

To obtain required nominal 24V DC power supply voltage, a serial connection of two 12 V DC PV solar panels is applied, with 80Wp peak PV power delivery from each solar panel, giving 160Wp peak PV power per configuration.

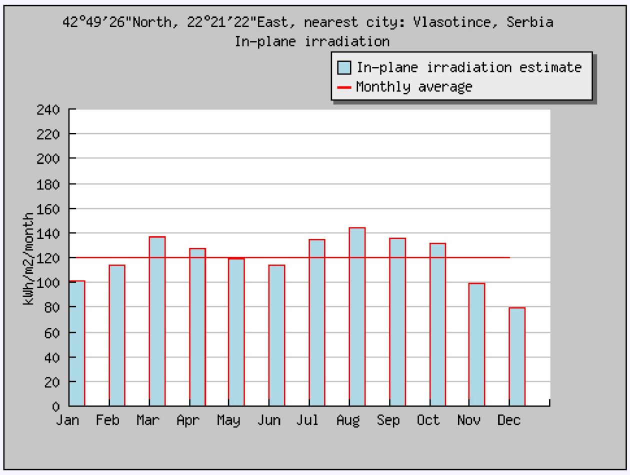

Figure. 2. Distribution of Insolation during the 1 year period at the chosen location

The parallel connection of two such PV panel serial configurations is used in each PV power source, giving a total of 320 Wp solar power from four panels. MPPT (maximum power point tracking) configuration of the accumulator charging controller is chosen instead of the usual PWM controller configuration. There are two groups of PV panels (formed by four 80Wp PV panels each) as was mentioned earlier. As 15 W is planned as the maximal (maximum?) useful power, the fixed position of PV panels is chosen instead of the Sun position tracking device.

Figure. 3. Photovoltaic 80 Wp solar panel

The supporting metal construction is designed in a manner that the longitidinal axe of PV panels is oriented towards the south to obtain maximum solar energy. The angle between the axe and the horizontal plane is defined by the use of a diagram presented in Fig 4, taken from [3]. In this particular case the angle is selected to be 65^0, according to the geografic position of the panel location.

The check of the satisfying basic request (360 Wh generated electrical energy per 24h) based on a month’s solar energy statistics according to [2] shows that it is satisfied in the worst conditions (December) when the least solar energy is available (670 Wh per day – presented at Fig.5).

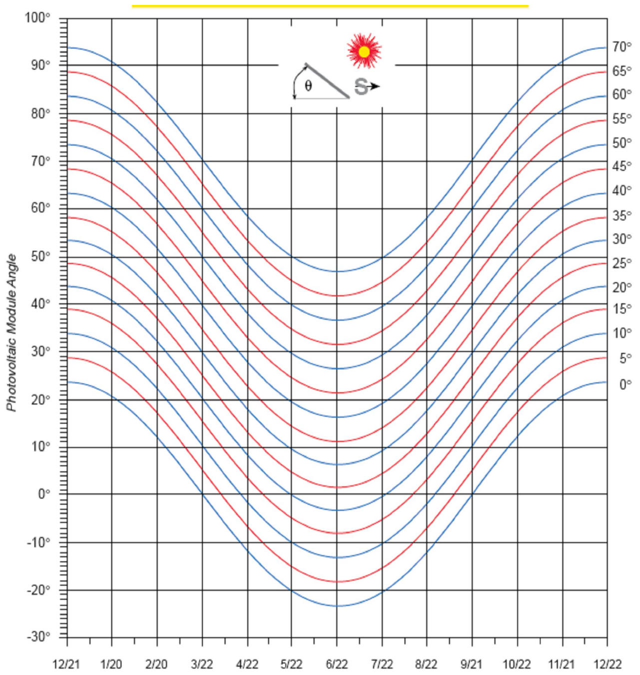

Figure 4. Angle of PV panel to horizontal plane depending of geographic Latitude of location and month in year

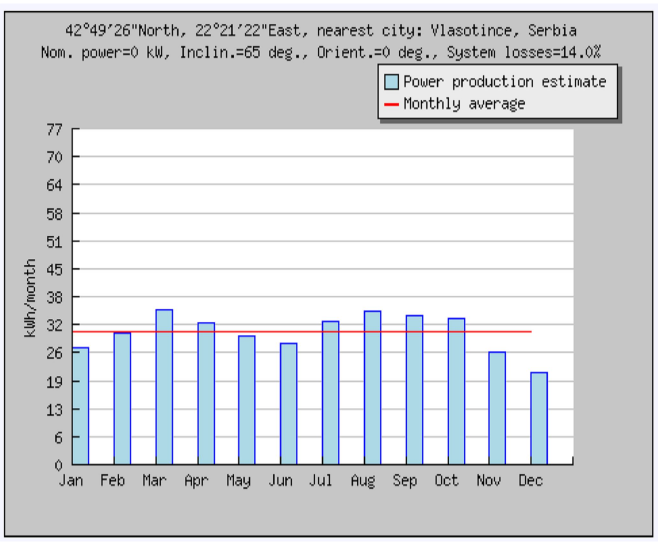

Figure 5. Electrical energy generated by PV solar panels of 320Wp

The other method for checking the generated energy per day, which is independent from the quoted software package [2], is as folows:

$$E= S \times \eta \times Ins \times n \qquad (1)$$

Where: PV panel area S=0.5m^2, PV cell eficiency η=14%, the worst case insolation Ins=2530Wh/m^2/day (December), number of panels in panel array n = 4

$$E = 0.5 \times .014 \times 2530 \times 4 = 708.4Wh \qquad (2)$$

This result is almost equal to the previously mentioned obtained result.

The acumulator capacity for the solar part of the electrical power supply is 300Ah, i.e. 7 200 Wh. At an ambient temperature of -25^{0}C, the accumulator capacity drops to 60% of its nominal value. Noting that the discharge of the acumulator is allowed at most 40% of its capacity, the available energy for the supplying of the communication equipment is:

$$E_A = 7\,200 \text{ Wh} \times 0,6 \times 0,6 = 2\,592 \text{ Wh} \qquad (3)$$

As the daily electrical energy consumption of communication equipment is at most 360 Wh, the autonomy of the operation based on the use of accumulators is only 7,2 days without any contribution from solar energy (i.e. days with the sky totally covered by clouds, rain, fog, snow).

IV. WIND ENERGY BASED POWER SOURCE

The wind generator chosen for this application is presented in Figure 6:

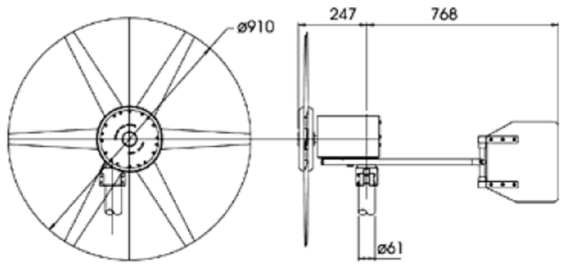

Fig. 6. Wind generator of electrical power (dimensions in mm)

The characteristics of the wind generator (the generated current intensity dependance from the wind velocity) are presented in Figure 7 [4]

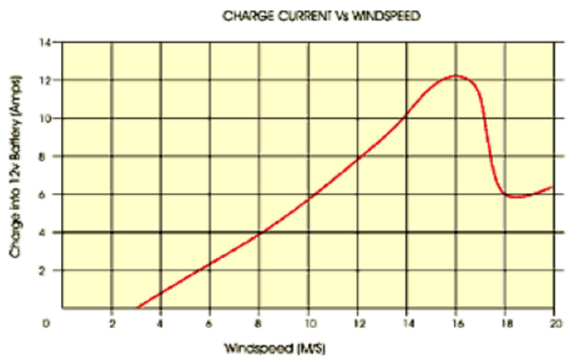

Fig. 7. Wind generator characteristic

The chosen wind generator does not generate the current for wind speeds lower than 3 m/s. For wind speeds above 16 m/s the generated power is abruptly lowered for the sake of the system integrity protection. For the chosen location, the average wind speed in December is 3,5m/s (at the height 10 m above ground).

It is important to stress that the actual height of the wind generator is 16 m above ground (due to the communication equipment requests fulfillment), so the corrected average wind speed for the actual height is

$$V = v_w \times (H/10)^{0.14} = 3.5 \times (16/10)^{0.14} = 3.74 m/s \qquad (4)$$

We shall use the Weibull distribution of wind speed during the day with an assuming factor shape K=2 (location inside continent) to calculate the average wind power during the day, i.e. energy generated by the wind generator during the day.

In Table 1, in the first column (speed) wind speed (m/s) is presented. The second column presents the actual power generated by the wind generator at an appropriate wind speed (column 1) – obtained by the use of the diagram presented at Fig 7. The third column (probability) presents the probabilities of appropriate wind speeds (column 1) during the day.

TABLE 1.
CALCULATION OF THE AVERAGE POWER OF THE WIND GENERATOR DURING THE DAY

Wind speed (m/s)	Actual power (W)	Probability (%)	Average power (W)
1	0	10.68	0.0
2	0	18.04	0.0
3	0	20.39	0.0
4	11	18.30	2.0
5	19	13.76	2.6
6	33	8.86	2.9
7	45	4.96	2.2
8	53	2.43	1.3
9	70	1.04	0.7
10	78	0.40	0.3
11	98	0.13	0.1
12	109	0.04	0.0
13	126	0.01	0.0
14	140	0	0.0
15	162	0	0.0
16	173	0	0.0
17		0	0.0
18		0	0.0
SUM		99.05	12.3

For each wind speed, by multiplying the actual power and probability we obtain the average power that contributes to the total daily average power during the same time percentage. The result is that 99.05% of the time during the day the average power of 12.3 W is generated i.e. total energy of 295,2 Wh during the 24h period of the whole day. It is not enough to provide total electrical energy for communication equipment (360 Wh daily) independently, but as a reserve it is excellent.

To raise the average power of electrical energy obtained by a wind generator to 15 W, the height of the wind generator has to be raised from 16 m to 28 m above ground. At that height the average wind speed would be 4,06 m/s, but this tower is too expensive.

The accumulators for the wind generator part of the alternative power supply have a capacity of 150Ah. This capacity gives an autonomy of 3.6 days in total without wind, so the total autonomy of the hybrid power supply is at least 10 consecutive days without the sun and wind stronger than 3 m/s. Though this model is a mathematical idealization of the probabilities of given wind speeds, the precision is as better as the data concerning the average wind speeds that are given for a longer time period of time (in this case for the whole month).

V. CONCLUSION

The hybrid electropower generator system with an uninterrupted supply of 15 W DC power in an ambient temperature range of -25^{0}C to 55^{0}C intended for providing the necessary electrical power for a small communication node located in a severe and hard to access environment is described [6].

The power generating system is based on the use of alternative sources of energy: solar and wind energy. Due to the very hard access to the location and severe meteorological conditions at the location, the redundant configuration of the power supply system for the communication node is chosen. It consists of three completely independent electrical power generators: two PV solar systems with identical characteristics and one independent wind generator based electrical energy generating system. The total obtained guaranted autonomy (in the worst case) is 10 days: without any Sun energy available and without any wind stronger than 3m/s available. In the paper it is shown that a single PV solar system fulfills the daily request for electrical power supply, so part of the system based on the wind generator is added in purpose to upgrade the reliability of the electrical power generation 365 days a year. The accumulators are chosen to provide a 10 day total autonomy of the requested power supply for the communication node. The described hybrid alternative power system is for a microwave digital radio relay active repeater station power supply and similar equipment located in heavy conditions that are at high mountain hard to access locations.

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