A METHOD FOR CHOOSING THE OPTIMAL POWER SUPPLY FOR A REMOTE HOUSE

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Abstract: *The electrical power required by a house can be obtained either by producing it locally from various sources but also by connecting to the main grid. This article wants to provide a method to calculate the cost in the two situations, in order to choose the best option.*

1. INTRODUCTION

It is difficult to imagine the existence of a house without electricity. Usually, this is obtained at a reasonable price from the main grid. But if a house is built at some distance from this grid, the cost to connect it can significantly increase. In such cases there is a viable alternative, that of producing electricity locally from renewable primary sources and/or internal combustion generators.

Knowing the value of initial investment, operating costs for certain periods (eg 20 or 40 years) and the energy price in the main grid, we can calculate and compare the total cost per KWh of electricity produced in both situations. Thus, it can be estimated depending on the distance to the main grid which of these options would be more economical.

2. THE CONDITIONS UNDER WHICH THE COSTS WERE COMPARED

- Date on which the calculations were made: 6.01.2013
- Exchange Rates : 4,4251Ron = 1Euro

- The price of electricity from the main grid: 0,627Ron/KWh = 0,14 Euro/KWh, at 6.01.2013
- The calculations were made taking into account the costs of the two variants, on two periods, one of 20 years and another of 40 years and introducing them in the final price of the energy.
- The results of the calculations and the conclusions obtained can be affected by how it will come true or not the estimates of the following:
- The evolution of electricity prices provided by the main grid
- Fuel price evolution (for internal combustion generator)
- Lifetime of equipments, especially batteries

3. ESTIMATION OF ELECTRICITY NECESSARY FOR THE LOCATION

Is taken into consideration a household with the following consumers (*table 1.*):

Table 1. Electrical consumers from the household

Electrical appliance	Electrical power [W]	Operation hours per day [h/day]	Daily energy consumption [KWh]	Monthly energy consumption [KWh]
Energy saving bulbs	5x20=100	5	0.5	15
TV	100	5	0.5	15
Computer	300	5	1.5	45
Refrigerator	200	5	1	30
Washing machine	300-800-3,000	a cycle	1	30
Iron	1,000	0.2	0.2	6
Central heating	100	12	1.2	36
Vacuum cleaner	1,000	0.2	0.2	6
Other appliances			0.9	27
The total energy consumed			7	210

It requires an amount of energy of 7KWh/day, 210KWh/month, 2,520KWh/year

4. OBTAINING ELECTRICITY FROM THE SOLAR ENERGY USING PHOTOVOLTAIC PANELS

The system is made up of:

- The production of energy: photovoltaic cells (PV)
- The electric power conditioning
    - Charging regulator with MPPT tracking
    - 3KVA Inverter
    - Electrical panel, protections switches
    - Scheduling and monitoring system
- The electrical energy storage: batteries
- 3KVA Diesel generator and automation
- Electrical appliances with low power consumption

A. System sizing:

1. The photovoltaic cells

According to the data provided by suppliers, a photovoltaic panel with 100W rated power has a daily electricity production of approx. 400Wh , ie 0.4 KWh [1] [2].

The number of panels needed to produce the required daily energy of 7KWh daily is Np,

$$Np=7KWh/0.4KWh=17.5 \quad (1)$$

If we denote by Pp the total power of these photovoltaic panels, then

$$Pp=100W \times Np=1.75KW \quad (2)$$

Therefore to produce the 7KWh every day, we need panels with a total power of Pp=1.75KW;

If we need a reserve of energy from photovoltaic sources for bad days, we need to increase the PV power. Considering one unfavorable day for every three favorable days, in each of these three favorable days the energy produced shall be 33% higher than the daily consumption. The recalculated PV panels power Ppr becomes:

$$Ppr=1,75KW \times 1,33=2,327KW \quad (3)$$

We choose 13 photovoltaic panels of 185W each, which will have a total power Ppv of:

$$Ppv = 0,185KW \times 13=2,4KW \quad (4)$$

2. The chosen electric power conditioning system (controller, inverter, electrical panel) will provide a power of 3KVA.

3. 3KVA Diesel generator [3][4] and automation [5].

4. Sizing the storage battery:

The batteries need to store up energy required for at least one day of operation without input of energy from panels (7KWh); if there are consecutive days without input of energy from the PV panels we use the diesel generator.

We choose 12V 200Ah batteries each with energy storage capacity W of:

$$W= 200Ah \times 12V = 2,400 \ Wh = 2.4KWh \quad (5)$$

In order to store the amount of 7KWh energy, we need 3 batteries.

Considering a maximum depth of discharge (DOD) of 50% in order to protect the battery, we need 6 batteries.

Batteries have a limited useful life, both in time and in number of full charge/discharge equivalent; according to the manufacturer, the life of the batteries will be 3-8 years, depending on operating conditions[6].

Consider a battery service life of 5 years, after that they will be replaced

B. Finding the annual cost and the specific price per KWh:

The system components can be found in *Table 2*:

Table 2. The system components

The component	Quantity	Unitary price 2013 [Euro]	Initial value 2013 [Euro]	Lifetime [years]	Annual cost (for 20 years) [Euro]	Annual cost (for 40 years) [Euro]
[1]	[2]	[3]	[4]	[5]	[6]	[7]
			[2]x[3]		[4]/20	[4]/40
180W Photovoltaic panels	13	332	4,316	20	216	216
3KVA Electric power conditioning system	1	4,397	4,397	40	220	110
3KVA Diesel generator and automation	1+1	843+505	1,348	20	67	67
Fuel for internal combustion generator (liters per year) (20 days per year x 7kwh/day x 0,33liters/KWh)	46	1,4	64	1	72	80
12V 200Ah batteries, 5 years lifetime	6	280	1,681	5	336	336
Total initial investment / annual investment			11,806		911	809
Price from photovoltaic sources if the consumption is 2,520 KWh/year (Euro/KWh)					Pret_f20 = 0.36	Pret_f40 = 0.32

For the first 20 years, the conditioning system value is divided by 20, although it can last 40 years.

We estimate an increase of the fuel price in the next 20 years of 25% and in the next 40 years of 50%; the fuel cost from columns 6 and 7 is calculated at an average price of diesel in the 20 and 40 years, reflecting the estimated price increases; the specified amount of fuel will be purchased annually.

The annual costs of the battery pack were calculated by dividing their value to 5 years (the estimated service life)

5. OBTAINING ELECTRICITY FROM THE MAIN GRID (NATIONAL POWER SYSTEM, SEN)

In the following we will calculate the energy costs in the version that we decide to connect to the main grid.

We take into consideration the following data :

The cost of connection to the main grid:

- Between 1,500Ron and 2,500Ron, depending on the distance to the first pillar, if the grid is in proximity; we consider an average cost of 2,000Ron = 452Euro;
- If the main grid is at a certain distance from our location, the connection cost increases with the cost of the power line as follows:

For an overhead power line (LEA) 0.4KV the cost is 90,000 Ron/Km (6)

and

For underground power lines (LES) 1KV the cost is 120,000 Ron/Km (7)

We consider a connection with LEA 0.4KV with a cost of 90,000 Ron/Km = 20,338Euro/Km.

The current price of a KWh of electricity from SEN, Pret_a, is :

$$Pret\_a = 0.627 \text{ Ron/KWh} = 0.14 \text{Euro/KWh} \quad (8)$$

Annual amount of electricity purchased, Cant_an, is:

$$Cant\_an = 210 \text{ KWh/month} \times 12 \text{ month} = 2{,}520 \text{ kWh} \quad (9)$$

The cost of annual purchased electricity will be calculated based on the current price, making an estimation of its future price trends.

We estimate a 50% increase in electricity prices in the first 20 years, and 100% in the first 40 years, from the current level due to the increase in price of primary resources, to the support granted to producers of electricity from renewable sources, retrofitting power plants in order to decrease pollution, building nuclear power plants and environmental taxes paid by polluting plants.

So the average price of electricity from the main grid will be:

For the first 20 years we have Pret_ret_20:

$$Pret\_ret\_20 = \{[0.627 + (150/100) x 0.627]/2\} Ron/KWh = $$
$$= 0.784 Ron/KWh = 0.177 Euro/KWh \quad (10)$$

And for the first 40 years we have Pret_ret_40:

$$Pret\_ret\_40 = \{[0.627 + (200/100) x 0.627]/2\} Ron/KWh = $$
$$= 0.94 Ron/KWh = 0.212 Euro/KWh \quad (11)$$

By measuring the distance in Km, we specify the cost of the connection to the main grid, in Euro, Cost_racord by:

$$Cost\_racord = 452Euro + (20{,}338Euro/Km) x distance \quad (12)$$

We denote by distance20 the distance to the power line if the calculation is made for the first 20 years.

We denote by distance40 the distance to the power line if the calculation is made for the first 40 years.

By introducing this cost in electricity prices, we get a recalculated price per KWh.

For the first 20 years we have Pret_ret_rec_20 :

$$Pret\_ret\_rec\_20 = Pret\_ret\_20 + [Cost\_racord / (20years x Cant\_an)] \quad (13)$$

$$Pret\_ret\_rec\_20 =$$
$$= 0.177 Euro + [452Euro + (20{,}338Euro/km) x distance20]/(20years x 2{,}520kWh/year) \quad (14)$$

And for the first 40 years we have Pret_ret_rec_40:

$$Pret\_ret\_rec\_40 = Pret\_ret\_40 + [Cost\_racord/ (40years x Cant\_an) \quad (15)$$

$$Pret\_ret\_rec\_40 =$$
$$= 0.212 Euro + [452Euro + (20{,}338Euro/Km) x distance40]/(40years x 2.520kWh/year) \quad (16)$$

6. CALCULATION OF THE DISTANCE TO THE MAIN GRID AT WHICH THE TWO PRICES ARE EQUAL

In each of the two versions, 20 or 40 years, we have an estimated price of energy from the photovoltaic (Pret_f20 and Pret_f40) and from the network energy prices, Pret_ret_rec_20 respectively Pret_ret_rec_40.

Since the recalculated price of electricity taken from the SEN depends on the distance between the location and the network, we calculate the distance at which the two prices are equal.

For the first 20 years we have:

$$Pret\_f20 = Pret\_ret\_rec\_20 \quad (17)$$

therefore

$$0.36 Euro/KWh =$$
$$= 0.177 Euro + [452Euro + (20{,}338Euro/Km) x distance20]/(20years x 2.520kWh/eyar) \quad (18)$$

Hence, the distance at which the two prices are equal:

$$distance20 = 0.431Km = 431m \quad (19)$$

For the first 40 years we have :

$$Pret\_f40 = Pret\_ret\_rec\_40 \quad (20)$$

therefore

$$0.32 \text{ Euro/kWh} =$$
$$=0{,}212 \text{ Euro} + [452\text{Euro} + (20{,}338\text{Euro/Km}) \times distance40]/(40years \times 2{,}520KWh/year) \quad (21)$$

Hence, the distance at which the two prices are equal:

$$distance40 = 0.513Km = 513m \quad (22)$$

7. RESULTS AND CONCLUSIONS

From the above results analysis, we find that on an average consumption of 7KWh/day:

- For the first 20 years, if the main grid is at a distance of less than 431m the connection to the main grid is advantageous and for a longer distance photovoltaics version becomes more advantageous.
- For the first 40 years, the distance where the photovoltaic variant becomes advantageous is of 513m. If we take into consideration that low voltage lines are designed with a length of less than 500m and beyond this distance a transformer is required (cost about 20.000 Euro) it is obvious that for more than 500m, the photovoltaic solution becomes more advantageous.

In addition to these comparisons, the price of energy obtained in the two variants, the national network and its own plant, each of them has some advantages and disadvantages to each other:

Connecting to the main grid has the advantage of increased security of supply, the malfunctions are solved by the supplier, no further expenses other than the payment of energy, lack of constraints on appliances use. The disadvantage is the high price of the connection, the fact that all the money should be given at the beginning and the risk of unfavorable evolution in electricity prices

Own photovoltaic installation comes with the advantage of much lower initial cost, of being clean, of providing energy even under critical circumstances, and also with the disadvantages caused by operational limitations, the risk of failure that will bring additional costs.

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