INFLUENCE FACTORS ON COST IN DESIGNING OF THE HYBRID POWER SYSTEMS

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Abstract Renewable resources are considered to be a cost effective alternative for providing electricity to remote rural areas, still designing a hybrid power system (HPS) is not an easy task. A lot of factors influences on the initial and the total life cycle cost of a HPS. In this paper we analyze the following one: installed power of the bulbs for inside and outside lightning, c.c. bus voltage, fuel used by Diesel groups, the choose between individual and common HPS in rural insulated area electrification and cost distance dependence factor.

Keywords: hybrid systems, rural electrification, initial cost, total life cycle cost

1. INTRODUCTION

Recently statistics shows that about 33% of the world population does not have access to electricity [1]. There are entire areas that are situated far from national grid and most of them are in developing countries.

Electrifying these insulated regions can be done either by extension of an existing grid, or designing and operating hybrid power systems which used renewable resources. The abundant energy available in nature can be harnessed and converted to electricity in a sustainable way to supply the necessary power demand and thus to elevate the living standards of the people without access to the electricity grid. There is a huge potential for utilizing renewable energy sources, for example solar energy, wind energy, or micro-hydropower to provide a quality power supply to remote areas.

Nevertheless, using a standalone power system based on renewable resources rise some difficulties:

- availability of these resources has daily and seasonal patterns;
- regulating the output power to cope with the load demand;
- a very high initial capital investment cost is required.

This paper focused on this last disadvantage of the HPS, trying to identify aspects that influence that costs.

2. DESIGNING A COST EFFECTIVE HYBRID POWER SYSTEM

To find and underline the factors that have an important influence in HPS initial and final costs, we consider a calculus example.

It is needed to electrify a hamlet of five cottages in a remote insulated area of Bihor country, Borod –Auseu area. The renewable resource considered is solar and wind. Daily solar irradiance is took from [2] and annual average of the wind speed from [3], in both cases we used latitude and longitude of the site. Daily and seasonal profiles of the load are modeling with HOMER program as shown in Figure 1.

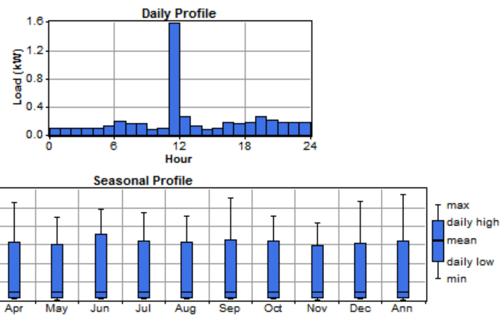


Fig. 1 - Daily and seasonal profile of the load

For system sizing we used [3] and we choose a configuration with c.c. bus for the HPS, the same with the system chosen in worksheet no.9, as shown in Figure 2.

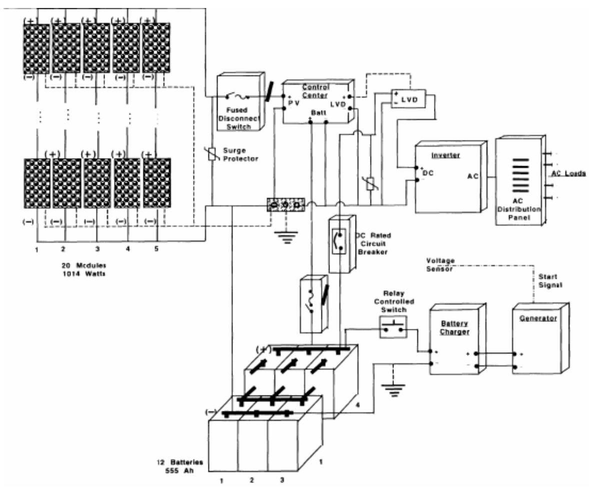
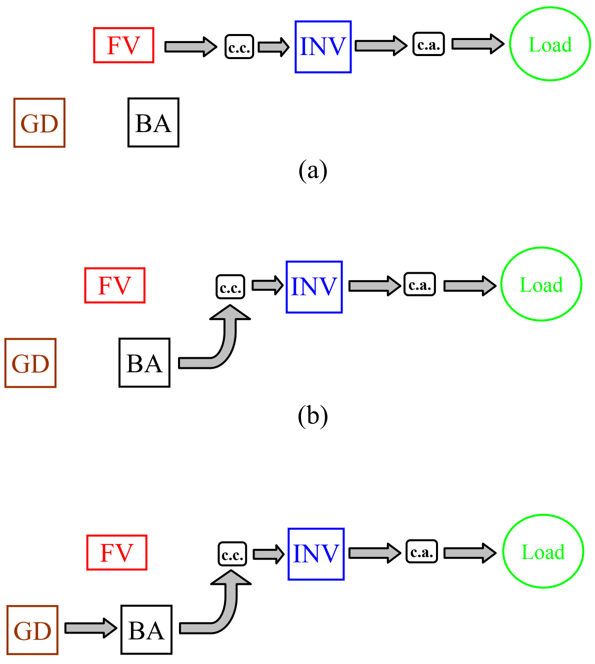


Fig. 2 - HPS chosen configuration

The dispatch strategy consists in:

- for daylight and renewable resource (rr) available the load will be cover from PV system (Figure 3a);
- for night or rr not available, battery system will cover the load (Figure 3b);
- for night or day without rr or battery (battery discharged) the load will be covered by genset(GD), simultaneously the battery will be recharged (Figure 3c).



(c)

Fig. 3 - Dispatch strategy of the HPS

If it is suitable to add or not a wind turbine the HOMER simulation program will pointed out, depending on the chosen system configuration, Figure 4.

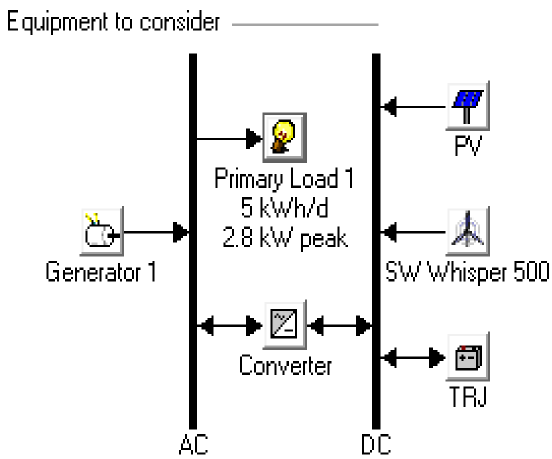


Fig. 4 - HPS configuration in HOMER

3. FACTORS OF INFLUENCE ON TOTAL COST OF A DESIGNED HYBRID POWER SYSTEM

Whatever the variant is chosen for a HPS, designing a cost effective system is not an easy task. Some factors have an important impact on the system initial investment cost and also on the total cost of the system during its lifetime.

a) the bulbs for inside and outside lighting: to a standalone HPS, installed power of the bulbs it is important because these it finally resume in amp hour loads that must be covered from PV or battery bank systems: a greater Ah-load must be covered from a greater PV panel or battery, hence the initial capital cost increase. The implication goes further in the size of the genset: a large diesel group is needed, hence the fuel consumption is rising.

Making a calculus for the same HPS configuration shown in Figure 2, but with different type of bulbs we obtained the results shown in Table 1.

Table 1 - Influence of the bulb types on costs

Type of bulbs	AC load power [W]	Daily loads [Ah/day]	Initial HPS investment [$]	Theoretic consumption [l/yr] GPL*
LED 9W	2314	90	11831	1397
Economic 24W	2429	106	12424	2224
Normal 100W	2769	176	15929	2870

* rounded up values

It is important to notice, when using 9W LED bulbs results a substantial economy from normal 100W bulbs, moreover the consumption of Diesel genset reduces more than twice. It results also a substantial economy from 24W economic bulbs.

In consequence, when it is design a hybrid power system it is necessarily to consider the lowest wattage for the lighting bulbs to obtain a cost-effective price of the HPS initial investments.

b) nominal voltage of .c.c bus: this is an important factor to consider, because it appears in early stages of the HPS design. Most of the common home appliances work on 220V tension and for our example we consider the following (Table 2):

Table 2 - Loads to consider for an insulated hamlet

Load description	QTY		Load Current [A]		Load Voltage [V]		AC Load Power [W]
Lightning – LED 9W	5	x	0,041	x	220	=	45
Refrigerator	1	x	0,8	x	220	=	176
Hydrophore	1	x	3	x	220	=	660
Washing machine	1	x	6	x	220	=	1320

Table 2 - (continuation)

Load description	QTY		Load Current [A]		Load Voltage [V]		AC Load Power [W]
Tv	1	x	0,4	x	220	=	88
Radio	1	x	0,113	x	220	=	25
Total AC power (W)							2314

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A calculus has been made for these ordinary a.c. loads of 220V taken into account the 24V, 48V, 60V and 120V bus. The results are shown in Table 3.

Table 3 - c.c. bus nominal voltage influence

c.c. / [$]	24V	48V	60V	120V
FV	2982	2982	4473	4970
BA	3300	1600	2000	3720
GD	4500	3900	4500	4500
INV	3905*	2700	3905*	7623*
CTRL	378	378	378	420
BAB	-	271	-	-
CHRG				
Initial investment [$]	15065	11831	12256	21263

* INV+CHRG included

Table 3 shows that the 48V c.c. bus is the best option for 220V appliances in terms of initial investment costs. Any other value leads in increasing genset and inverter size, number of batteries and in case of 60 and 120V c.c. bus the increase number of PV panel.

c) Influence of single or common design: it is obvious that a HPS for a single hamlet needs a certain amount of capital but when it has to consider more hamlets the cost multiplies. In this case we consider five 5 hamlets needed to be electrify, all of them on a radius of no more then couple of hundred meters. The question is which design is more cost effective: electrifying with one HPS for each hamlet or making a single common HPS to supply all 5 hamlets?

In Table 4 and 5 we present the results on two designs, individual and common HPS. Net Present Cost represent the total cost of the system to entire life duration (in this case 25 years) and it is are simulated and calculated with HOMER from the same loads and the same renewable resources on site.

Table 4 - Cost for individual HPS for 5 hamlets

Value [$] / System	GD on Diesel		GD on GPL	
	Initial investment	NPC	Initial investment	NPC
SHSD 50%FV 50%GD 9W bulb	11,182 (55,910)*	41,896 (209,480)	9,532 (47,660)	30,182 (150,910)

*Between parentheses we calculate the cost for all five hamlets.

Table 5 - Cost for common HPS supplying 5 hamlets

Value [$] / System	GD on Diesel		GD on GPL	
	Initial investment	NPC	Initial investment	NPC
SHSD 50%FV 50%GD 9W bulb	47,180 (90,491)	181,056 (224,367)	47,180 (90,491)	154,816 (198,127)

The components of the HPS are the same: solar, Diesel and batteries (SHSD).

In Table 5 we have to ad the value of 1 Km low voltage cable and the value of the connectors needed, which is: 26069$+17242$=43311$ So the total value are presented between parentheses.

We can see that the initial investment capital for common system on GPL of 47,180$ is smaller than individual system of 47,660$, but when we ad 43,311$ became grater.

Summarizing, it is cheaper to design five individual HPS to supply the five hamlets (150,910$) than to make a single common HPS for the same five consumers (198,127$).

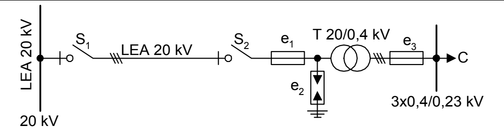
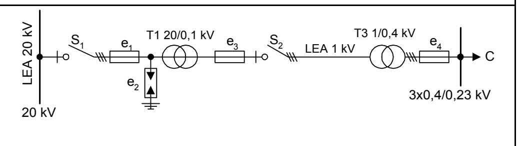
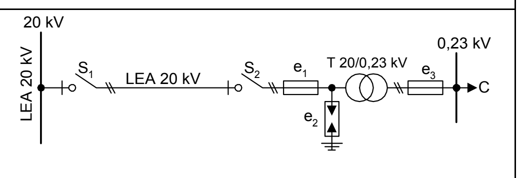
From these two table above we observe another influence factor, which is:

d) fuel used for Diesel group: Because the GPS is cheaper than Diesel, it is obvious that the cost of HPS running on GPL will be cheaper, considering the same operating hours of the GD. As a thumb rule it is better to choose the genset GD running on cheapest fuel.

e) the distance-cost dependence factor: The insulated region can be electrified either by extending the grids of the existing power system or by constructing new remote power systems based on renewable resources. In general it is preferred to go on the variant of extending the power grid, but it is not always affordable due to some factors: rough terrain, poor transport infrastructure, etc. Further more, power grid extension is primary distant depended: the investment cost increases whenever the site is further away. On the other hand, the investment cost of hybrid power systems does not depend on distance but only on generation capacity of the source: for a small demand, a small investment is needed, and for a large demand, a large investment is needed.

Having the calculus for the classical solution to electrify a consumer of 15KW from national grid [4] it can be taken into consideration three variants represented in Table 6. Cost distance depencence of the three variants are pictured in Figure 4.

Table 6 - Variant of connection the 15KW from national grid

Nr. crt.	Var iant	Connection to the National Power Grid
1.	I.1.	
2.	I.2.	
4.	I.4.	

From Table 4 we have the net present cost of individual HPS to supply 5 hamlet of 2,3KW (5X2314=11570W), in total 11,57KW, the results are represented also in Figure 4.

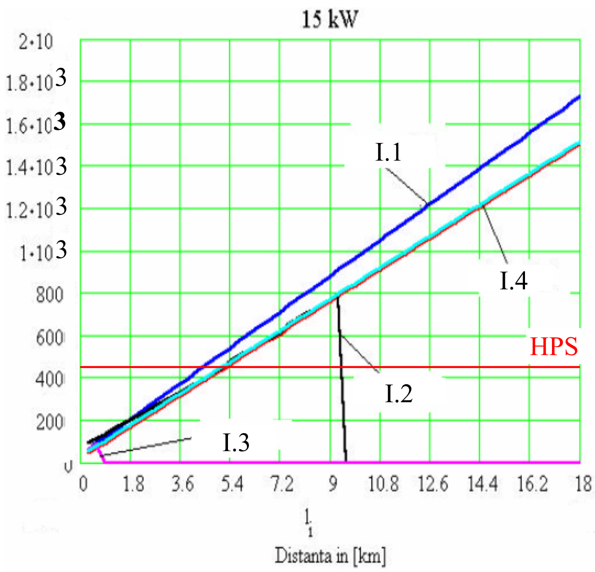


Fig. 4 - The distance - investment cost dependence

For the 11,47KW HPS from Table 4 the NPC of 150,910$ we multiply with 2,8 = the value of USD in 2005. The 422,548 mii RON are represented with red line.

We can easily see that an extension of the power grid within 4 kilometers for a 15kw consumer is a cost effective solution for I.1 variant, but if it is necessary to supply the same consumer situated above 5,4 kilometers, a hybrid power system is more suitable than the I.2 and I.4. variant.

4. CONCLUSIONS

Designing a cost effective hybrid power system to electrify an insulated rural area it's not an easy task. However it could be used a few solutions that can reduce the overall cost of that kind of systems. In this paper we identify some of them:

1. always using a smaller bulbs for lighting, LED technology is available and affordable, a relatively small investment in the initial phase of the design could lead to significantly economy of the hole project;
2. if the ac loads is the common 220V , 50HZ, it is better to choose 48V cc bus of the HPS;
3. to electrify a smaller number of insulated hamlets, the solution of individual HPS for each house is cheaper than a single common HPS due to the additional cost of low voltage grid and connectors;
4. Diesel groups running on cheaper fuel, such is GPL, leads in reducing the total net present cost of the HPS, usually this kind of genset is cheaper than one running on Diesel for the same KW installed;
5. always take into consideration the distance of the insulated hamlet from the connection point of the national grid. Not always a HPS is the cheapest solution, even if the renewable energy resource on site is attractive.

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