KEY FEATURES OF THE CONSUMERS POWERED BY HYBRID ELECTRICAL GENERATION SYSTEMS

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Abstract – The paper aims to synthesize the characteristics, key features and specificities of the main consumers which is powered by hybrid electrical generation systems. Aspects related to load characteristics, voltage likely used, scheme and site layout, factors that influence the costs are followed and, in the final, conclusions are drawn.

Keywords: hybrid power system, renewable resources, insulated consumers, consumer key features

1. INTRODUCTION

Hybrid power systems (HPS) are defined as autonomous generating electrical energy which includes more than one power source and operates with the associate auxiliary equipment (including storage subsystems) to power an insulated consumer.

The power generating subsystems integrates different renewable resources subsystems such as: photovoltaic, wind, hydro and biogas.

The consumer connected with a hybrid power system presents some particularities which are not found at the consumer that is part of a national grid:

- It is located in area with low population densities;
- It is found far from national electrical grid;
- It is unlikely the extension of the distribution/transport lines to the site because of high cost involved;
- The site is finding often in ecological sensitive location;
- It requires high reliability and availability of the power supply.

2. SPECIAL CHARACTERISTICS OF THE INSULATED CONSUMER POWERED BY HPS

2.1. Warning systems

In this category enters flashing beacons, sirens and fog horns for maritime traffic and warning lights for high structure such as towers, telecommunications antennas, etc.

The most common powered scheme consists in PV cells and battery with DC connectors, the electronic parts being enclosed in hermetic case, fig. 1. shows a warning beacon scheme for maritime traffic.

The blocking diode prevents battery discharging over the PV panel and the photodiode assure flash operating of the beacon bulb.

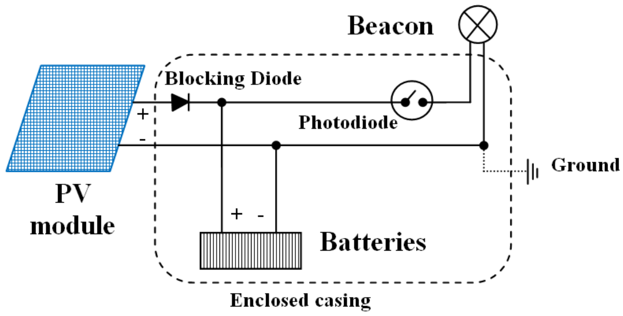

Fig. 1. Beacon warning system schematic [1]

Key features of these systems are:

- Operates in harsh environment, mostly at night;
- Power requirement are predictable, near 100% availability is required due to human life at stake;
- Usually needs 12V DC power supply;
- PV should be mounted in area clear from shading;
- Sealed batteries are preferred to prevent leakage or contamination of the electrolyte, this kind of batteries offers also a low maintenance requirements;
- No controller needed because the battery is large relative to PV size and the probability of overcharging is low.

2.2 Telecommunications

Usually the telecommunication devices, both in radio wave and microwaves, operate at 12, 24 or 48V DC, the “transmission” mode having the biggest current, reaching even 50A, depending on the device type.

The “standby” mode have the lowest current, 2A or less and the” receiving” mode can reach only 10A [1].

Hence, HPS for this consumer are structured around DC bus architecture, fig. 2., renewable and storage subsystems operating in parallel and, when the battery discharge level drops under a preset level, the Diesel group starts. Because of the charge current levels can be high, and simplicity of the scheme is desired, it can be used multiple charge controller in parallel [1].

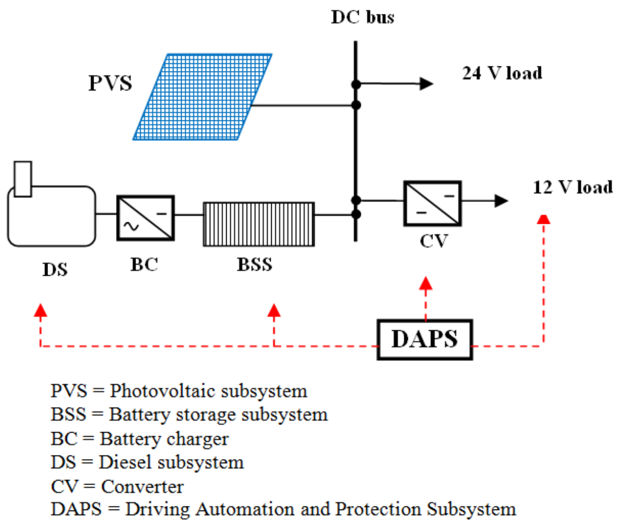

Fig. 2. DC bus architecture of the HPS for telecommunications [1]

A particularity of this consumer is that it includes additional loads such as: alarms, ventilations, lighting and small appliances for operator's comfort. Usually these appliances are in AC so, a DC-AC bus architecture is often used for the HPS, fig.3.

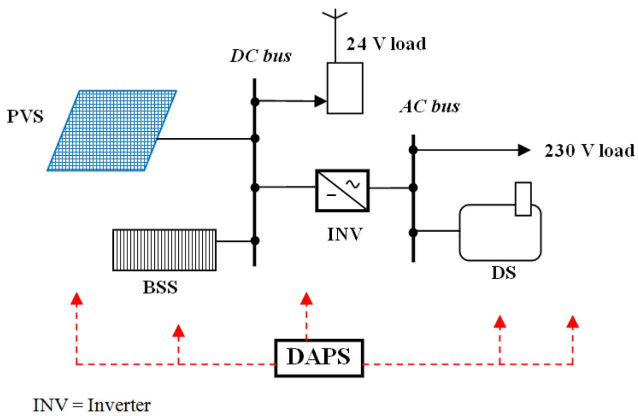

Fig. 3. Example of DC-AC architecture of the HPS for telecommunications

2.3. Lighting

In this category enters a large range of applications such as: security and area lighting, billboards, residential exterior, emergency lighting.

The architecture of the HPS can be either DC bus or DC - AC bus, depending of the bulbs type used. In case of DC-AC bus, the reliability of the inverter is critical and influences the system life duration and costs [1].

Every type of bulb has its own key feature that influence the HPS design, thus [1,2]:

- Utilizing DC bulbs leads in lowering the loads needed to be cover by HPS;
- Utilizing AC bulbs increases the installed power, but LED bulbs are the most efficient and lowers the [Ah] required;
- Starting the gas bulbs (mercury vapors and sodium) in cold weather can be a problem;
- Utilizing a well designed reflector or/and diffuser lower the total PV power required.

2.4. Refrigeration

Refrigeration systems are utilized in remote areas with warm climate where is needed to keep cool medical supply (vaccines, different kind of serum and antidotes, etc.), fresh milk or other important food for the community.

The main features of that kind of consumer are the following [1]:

- DC refrigerators are more energy efficient than equivalent in power AC device;
- If the regular use of ice is required, the AC refrigerator is better or it must utilize a DC device with two separate compressors, because of large amount of power needed;
- Manual defrosting unit lower the power demand;
- Proper training in operate and maintenance of the unit is mandatory, a carless use lead to fail in operate the unit;

The main factors that influence the HPS installed power to supply refrigeration units are [1]:

- Number of utilizes served;
- Insulation quality of the unit;
- Material temperature introduced in the unit;
- Utilization cycle and ambient temperature;
- Type of compressor used (with or without coolers).

2.5. Water pumping

HPS must replace the manual water lifting devices from insulated areas which are used for stock watering and village water supply, or the large Diesel groups driven large irrigations pumps. It must offer simplicity, reliability and low maintenance necessary, a water pumping system driven by HPS are represented in fig. 4.

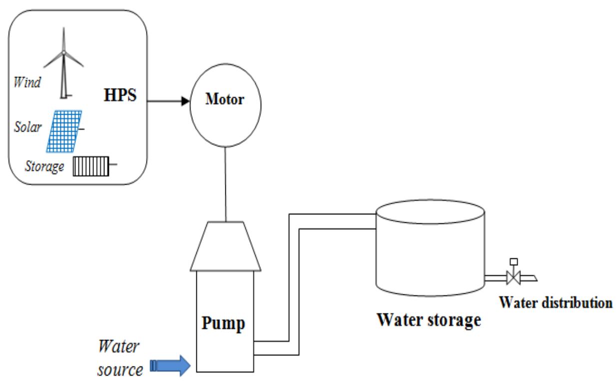

Fig. 4. Principle scheme of water pumping driven by HPS

Consumers of these systems consist mainly in DC motors at 12-48 V (with or without collector brushes) and AC 230/400V at 50Hz synchronous or asynchronous motors, driven a large variety of pumps types [1,3].

The most commonly used pump configurations are [3]:

- Submersible pump: the motor and the pump are enclosed in to a common case which is submerged in the well. It is used till 20m depth and the pump are centrifugal type;
- Surface pump: the motor is at the surface and the pump is immersed. It is used for deep well (>20m) and the pump is driven by a beam;
- Floating pump: it is used when the water source consist of a pond or lake. The pump and motor are mounted on a floater device, water are driven ashore through a hose.

To assure a continuous water flow the pumping systems has a water storage system, which can be of two types: open basins and enclosed tanks. The main disadvantage of the open basins is that it can be easily contaminated with debris carried by the wind (leafs, dust, etc.). On the other hand the tanks can be expensive and requires a support structure at height [1,3].

The size of a pumping system powered by a HPS depends of the following factors [1,3]:

- Water necessary at the consumer;
- Level and pumping characteristics of water available at source;
- Renewable resource availability on site;
- Climate and temperature variations.

2.6. Cathodic protection

Corrosion appears at metallic buried structures (pipe lines, reservoirs, etc.) due to differences of the soil properties (ph, moist, ion concentrations, O_2, etc.). The variation of these parameters can produce a current between two parts of the metallic structure, the part in which the current flow is called cathodic zone and the part in which the current leaves is named anodic. The metal will be corroded in anodic zone, the soil playing the role of electrolyte [4].

Cathodic protection consists in causing a current to flow into the protected zone of a structure. This can be achieved by a small PV based HPS to provide the current needed, at the positive terminal being connected the anode and at the negative terminal the structure itself, fig. 5.

The main characteristics of these systems are [1,4]:

- Injection currents are relatively easy to determine;
- Can be utilized for any type of soil;
- Can be utilized for any type of structure;
- Have low cost per area to protect;
- Have long lifetime (over 40 years).

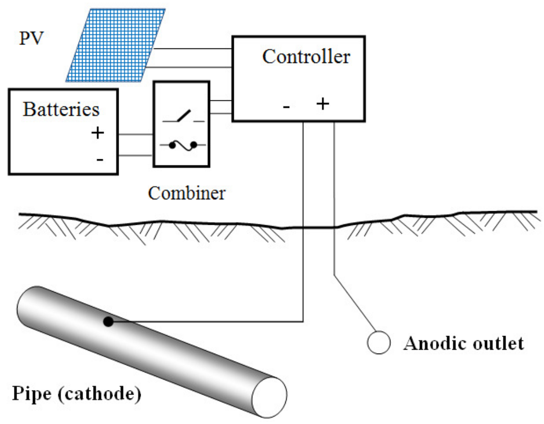

Fig. 5. Small HPS for cathodic protection [1,4]

Because it is a remote autonomous system, the charge controller reliability is critical and the battery must be large enough to accept the charge current in good weather [1].

2.7. Residential

In this category enters a variety of consumers with different needs and load demands such as: alpine refuges, mountain cottages, vacation homes, homeowners, hamlets and whole insulated community. HPS can be of two types: individual, each house having its own power system (fig. 6) and common, when one large HPS supply power to each consumer via a mini grid (fig. 7).

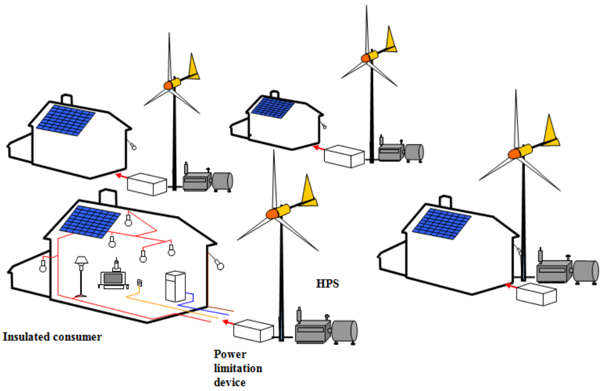

Fig. 6. Individual HPS

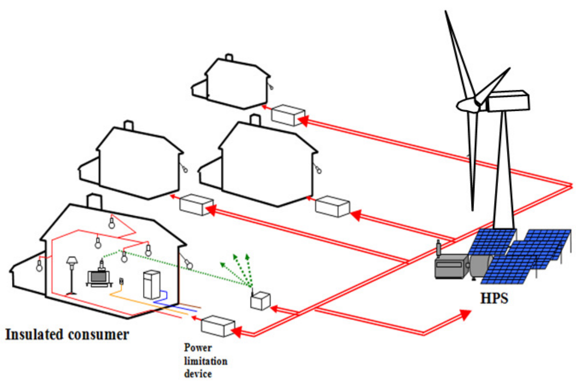

Fig. 7. Common HPS

Regardless of size and type, the HPS must satisfy the following features:

- To assure power autonomy of the consumer;
- To operate completely autonomous, without any human intervention;
- To supply high quality power at reasonable cost of energy;
- To have initial investment and lifetime cost as low as possible.

To fulfill this entire feature requires efforts both from designers and from consumer's part thus: designers have to take into account all the aspects of HPS implementation and design, choosing the best solution, consumer have to understand all the HPS operating limitation, restraining from all form of power abuse (basically using power limitation device and methods) [5].

2.8. Water desalination

Implementing HPS to water desalination unit can be done in two ways: for small autonomous unit by powering it completely and for large desalination plant by powering only small consumers within (circulation pumps, auxiliary consumers, etc.) in order to reduce the amount of energy used [6,7].

Desalination units are energy intensive and the technology used is a driving factor when it has to be powered by HPS, table 1 presenting typical energy consumptions for different desalination process.

Table 1. Power consumption for different type of desalination processes [6]

Technology	Thermal Energy [kJ/kg]	Electrical Energy [kWh/m^3]
Sea water		
Multi-Stage flash	190-290	4-6
Multi-Effect Distillation	150-290	2,5-3
Compressed Vapor (CV)	-	8-12
Reverse Osmosis (RO) without energy recovery	-	7-10
Reverse Osmosis (RO) with energy recovery	-	3-5
Brackish water		
Reverse Osmosis (RO) without energy recovery	- -	1-3
Reverse Osmosis (RO) with energy recovery	-	1,5-4
Electrodialysis (ED)	-	1,5-4

Small desalination unit utilizing RO with capacity of (5-15)m^3/day is the most suitable to be powered by HPS because, as shown in table 1, it has low consumption and are the most efficient in terms of flexibility, reliability and maintenance simplicity [6].

HPS architecture can be with DC-AC buses, the consumer to be fed being an AC motor which drives the pump from RO hydraulic circuit, fig. 8.

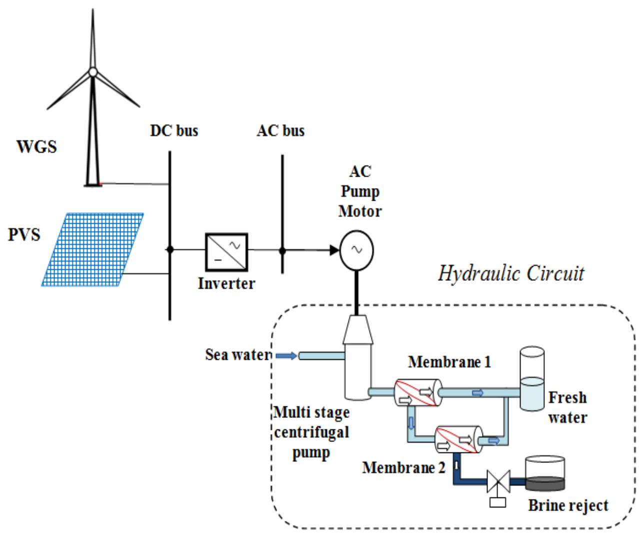

Fig. 8. Scheme of small RO desalination unit powered by HPS [8]

The renewable subsystems can contain, depending on renewable resources availability on site, PV panels and/or wind generation subsystems (WGS). The storage subsystem consists mainly from battery bank, but studies conducted shows that it can be missed from HPS [8].

In order to reduce the costs, controlling the systems can be done by controlling the DC-link with the field oriented induction controllers method in order to produce maximum water quantity in good weather conditions [8].

However a controller based on programmable computer, a battery bank and a Diesel group is mandatory in order to assure high degree of continuous and autonomous operation necessary for remote areas in all weather conditions.

3. CONCLUSIONS

1. The consumers powered by HPS are constituted in a large variety of power and it can include: small beacon devices, telecommunications, lighting, refrigeration, water pumping, cathodic protection, residential and energy intensive desalination units;

2. Consumers has key feature on which must be taken into account when they are connected with a HPS:

- Usually are located in remote area;
- Must be supplied with power in all weather conditions ;
- Often requires high availability of power supply;

3. Consumers are very different in size and operating cycles and their different needs and load demands influence the architecture and size of installed power of the subsystems within HPS;

4. Usually PV based HPS dominates the small loads and WGS in parallel with PV have potential for large loads;

5. HPS architecture must be designed to assure:
   - A high degree of reliability and availability of the power supply;
   - Flexibility and maintenance simplicity;
   - Autonomous operation in remote areas;
   - Lower investment and lifetime costs;
   - Affordable cost of energy;

6. International experience is a valuable source for designers, their recommendations must be take into account when HPS supply a remote consumer [1]:
   - Deep cycle batteries it's a must within the HPS storage subsystems to cover the necessary loads;
   - Sealed batteries are preferred in order to achieve low maintenance actions and to assure environment protection;
   - Array tracking supply with up to 40% more power than static mounting in case of PV module used;
   - Inverter and charge controllers are critical and influence the HPS costs;
   - Controllers based on programmable computer assure a high degree of automation and in combination with storage and Diesel subsystems supply power in any weather conditions;
   - Support structures must be anodized aluminum, galvanized or stainless steel, designed to resist at maximum anticipated wind velocities;
   - Restricting access on the HPS subsystems with fencing must be done if the vandalism or animals trespassing is a possibility;
   - Lightning protection and good grounding must be consider in order to assure high degree of consumer protection;
   - User training in proper operation and maintenance of the system assure the success of electrification with HPS.

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