REVIEW PAPER ON HYBRID ENERGY SYSTEM

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Abstract : With the oil crisis announced in recent years, the use of alternative energies is expanding rapidly; among them, photovoltaic energy is a promising technology in terms of security of supply and preservation of the environment. However, it has two main disadvantages: the energy production is not continuous and the voltage across the panels depends strongly on the connected load.

Hybrid systems are categorized into two groups. In the first group, we find hybrid systems, working in parallel with the power grid, also called grid-connected. These systems help to satisfy the load of the electrical system. Hybrid systems in the second group operate in isolated or stand-alone mode. They must meet the needs of consumers located in remote areas of the electricity grid: mountain huts, islands, isolated villages, road signs and the like. This paper presents a review on the development of energy source models.

Keywoords - PV, RE, RES, Solar Energy, Wind Energy

1. INTRODUCTION

The evolution of man has been marked by the control of fire. The domestication of this form of energy has been a major turning point in the evolutionary and cultural aspect of man. Allowing him to cook his food, to get heat. Through this race for evolution, man is currently at the centre of the profound alteration of the chemical composition of the Earth by the growing rejection of greenhouse gases. Creating an imbalance in the natural evolution of the climate by the increase of the average temperatures of our planet (global warming) causing a climate change. As scientific studies of physical phenomena proved the central role of human activity in this change, the various global actors became aware of the short and long-term adverse effects of global warming. Thus, like Homo-sapiens, the modern man asks again the same question: how to control energy? However, this time, there is another question as final as the first: how to control its impact on its environment?

One of the preferred solutions is the use of renewable energies. Since the 1980s, their technologies have made considerable progress to the point that today they have reached a certain maturity as their development has grown exponentially.

Renewable energy (RE) technologies such as: wind, photo-voltaic have finally reached ripeness and the eventual ability of cost effectiveness. However, depending on the meteorological aspect of their location, they suffer from a major drawback which is their intermittency.

In this, the use of hybrid systems combining multiple sources, such as renewable energy systems (RES), the national distribution network (historic electricity grid) or conservative energy sources and storage systems, is usually considered by all as a solution for the future, both effective and consistent. Many analyses (planning and sizing) were carried out on single-source RESs, with the main objective of determining the best configuration of the system for efficient and safe operation [1].

They can be developed in a substantial way for urban electrification or remote (rural) sites. When the cost of extending the grid for rural electrification is prohibitive due to geographical isolation, low population density, or limited financial resources.

2. RENEWABLE ENERGIES

Renewable energies have the highest growth rate among energy sources. There are a number of factors behind this increased focus on renewable energy sources.

2.1 Sub-Types of Renewable Energy

Although the use of fossil fuels can be significantly reduced, and nuclear energy has no long-term alternative, the question remains how can future energy supply be secured?

The first step is to dramatically increase the efficiency of energy consumption. The second is to develop renewable energy sources. Indeed, with the world's growing population and unmet demand from developing countries, the only option to cover global energy demand in a climate-sustainable way is energy efficiency.

Types of renewable energy can be partitioned into three areas:

- Geothermal energy
- Planetary energy
- Solar energy

2.2 Geothermal Energy

It utilizes the stored heat of the Earth. Geothermal power plants can use this heat by converting it into electricity or by supplying district heating systems. The total heat content of the Earth is of the order of 12.6×1024 MJ, and that of the crust, of the order of 5.4 × 1021 MJ [5]. This huge quantity can be compared to the world's electricity production in 2007 which was 7.1×1013 MJ [6].

2.3 Planetary Energy

The movement of celestial bodies results in continuously varying forces at every point on the surface of the Earth [7]. Tidal energy can be used by power stations on the coast with high tide beaches [8]. The basic principle of the use of tidal energy is to remove from the sea, by means of dams, one or more marine areas, transformed into reservoirs, so as to obtain a difference of level on both sides. A dam - factory. As the level of the sea varies, with a period of the order of magnitude of the half-day on the coasts, unless taking special precautions the available fall also varies, and especially cancels periodically [9-11]. This variation creates potential energy corresponding to the elevation of the water, which can easily be converted into mechanical energy thanks to the dam-turbine pair [12]. This energy is however limited; the power dissipated by the tides of the terrestrial globe is of the order of 3 TW [13], a third of which is dissipated in the coastal seas. Assuming that we know how to use 20%, the annual tidal energy that we would obtain would be of the order of 400 TWh. Relatively small amount However, large powers can be installed in some privileged sites. Today, only a few tidal power plants are in operation [14].

2.4 Solar Energy

The sun is by far the biggest source of energy. The amount of energy that humans use each year, is supplied to the Earth by the Sun in one hour. The massive power that the Sun continually supplies to the Earth makes any other source of energy, whether renewable or not, microscopic [15].

By using the first ten-thousandth part of the incident sunlight, we would cover all of humanity's energy demand.

Solar energy, is available everywhere on the Earth, in equal quantity in the year. Easy to operate, it performs well thanks to current technology, and seems to have a promising future matched to other forms of energy [16].

The Use of Direct Solar Energy

There are three ways to transform solar energy "directly": thermodynamic, thermal and photovoltaic [17].

Thermodynamic Solar Electricity: This technology consists of heating a heat transfer fluid at high temperature (ranging from 250° to 1000° C, depending on the techniques used) by solar radiation for the production of electricity or energy supply of industrial processes. There are parabolic or parabolic troughs, and so-called "tower" power plants, for which a multitude of steerable heliostats concentrate solar energy on a single boiler located on a tower [18].

Parabolic trough technology is the most common. It requires a lot of sunshine, a high temperature and a large floor area. As a result, plants using this technology are often built in deserts or other arid areas of the globe. It is currently used by the world's most powerful solar power plants in the south-western United States and southern Spain. Some plants are now able to produce electricity continuously, thanks to a heat storage system [19] [20].

Solar Thermal Energy: Solar thermal energy is mainly used for domestic hot water heating and space heating [21]. The operating principle of solar thermal energy is simple. Solar collectors installed most often on the roofs absorb the solar radiation and transmit it to a storage tank intended to attenuate the discontinuity of the sunshine and to supply the hot water production systems. Solar thermal energy is particularly easy to implement for new or renovation projects [22]. This simplicity of operation guarantees a high reliability over time.

*Solar Photovoltaic Electricity:*It is the oldest and most widely used application for millions of systems around the world. As early as the 1960s, photovoltaic solar modules became predominant for satellites, compared to most other solutions for reasons of weight and reliability [23]

Photovoltaic solar energy is an interesting way to reduce electricity distribution costs in some regions. Particularly available in most countries around the equator, the sun is an energy source of considerable reliability. Solar photovoltaic presents an energy and environmental balance quite favourable.

3 DEVELOPMENT OF ENERGY SOURCE MODELS

With a still under-exploited potential, solar photovoltaic and wind power have real economic and ecological benefits. On the other hand, the complementarity they offer in terms of daily energy production leads to systems based on their mutual combination or with other conventional sources of energy. This gives these systems architectures that require almost no (or little) storage.

These systems are hybrid by constitution and operation. They can be decentralized or interconnected to the national network. Photovoltaic / wind hybrid systems are accepted as a sustainable substitute for energy supply [24].

The simulation of such a system is obtained by finely modeling all of its components [25] [26], [27] in order to optimize its operation. An optimized energy system is a well-designed system characterized by its cost-effectiveness, reliability and quality especially in terms of comfort-customers.

Clearly, knowledge of all factors that affect system performance is a prerequisite for accurate modeling [28]. Various optimization techniques for the modeling and design of the photovoltaic / wind hybrid system, by modeling wind generation, photovoltaics and its optimization have been reported in the literature [29]. Ai et al [26] presented a comprehensive set of harmonic calculation methods for the optimal sizing of photovoltaic / wind hybrid systems by developing a set of harmonization computation programs with the adoption of more practical mathematical models for the characterization of system components [30].

For wind energy, it is the autonomy in electricity, the possibility of producing day and night and a reduced environmental impact by simple precautions towards the population and the landscape. As for photovoltaic energy, its main benefits are: reduced environmental impact, abundant energy, affordable implementation and cost, and light maintenance requirements [33] [34] [35] [36] [37].

4 HYBRID SYSTEM

For workable growth, the use of energy systems with renewable energy sources has become indispensable.

Following headings present the different features of the hybrid photovoltaic-wind system, based on the different definitions of the constituents of this system.

4.1 Presentation of the Hybrid Photovoltaic-Wind System

In our particular case, we are interested in the systems of small powers which regroup two parts namely the wind turbine and the solar panels. These two sources of energy production pass through an electrochemical storage (see Figure 1), and produce DC easily convertible into alternating current, thanks to the integration of an autonomous inverter in the circuit [38]. By coupling these systems and associating them with an energy storage device, we will then have the following advantages:

- Operation of the system without interruption;
- Possibility of preserving the surplus energy produced by this system;
- Security of supply in all weather conditions [38].

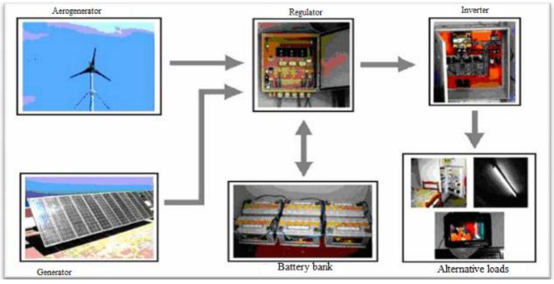

Figure 1: Synoptic diagram of the hybrid system studied [38]

4.2 Major components of the Photovoltaic Hybrid Energy System

The hybrid photovoltaic-wind systems generally include:

- A generator system;
- A regulation system;
- A storage system;
- Power equipment;
- A load.

The generator system is composed of photovoltaic modules and wind turbines. It is essential that both operate at the same nominal voltage 12 or 24 V and in direct current. Regulation must take account of the fact that these are two different types of currents:

- The photovoltaic fairly constant and of a low threshold [39],
- Wind, very variable.

The control system will therefore be responsible for operating the generator system at an optimal point for charging the batteries.

4.3 Descriptions of the Components of the Hybrid Photovoltaic-Wind System

4.3.1 Photovoltaic Generators

A photovoltaic generator is formed at the base by photovoltaic cells. They produce electricity from the moment they are exposed to solar radiation. They do not pollute, have no moving parts, require virtually no maintenance and produce no noise. The photovoltaic cell is therefore a safe and environmentally friendly way to generate energy. The output power is calculated by:

$$P_{pv} = \frac{G}{1000} \times P_{pv,rated} \times \eta_{MPPT} \qquad (1)$$

Where, G is perpendicular radiation at array's surface (W/m2),

$P_{pv,rated}$ is rated power of each PV array at G =1000W/m^2

η_{MPPT} is the efficiency of PV's DC/DC converter and for MPPT system.

4.3.2 Wind Generator

A wind system or a wind turbine or a wind turbine can be defined as: a system composed of elements capable of transforming part of the kinetic energy of the wind (fluid in motion) into mechanical energy and then into electrical energy [40].

Most commercial wind generators, especially large ones, have a horizontal axis. The market share represented by vertical axis systems is tiny. Large wind turbines are sometimes built in isolation or grouped into groups (wind farms) with ten or more elements, sometimes even hundreds [41].

The different elements of a wind turbine are designed in a way to maximize the energy conversion, therefore a good fit between the torque / speed characteristics of the turbine and the electric generator is necessary [42].

Wind turbine power is expressed as:

$$P_{WG} = \begin{cases} 0 & V_W \le V_C, V_W \ge V_F \\ P_R \times \left[\frac{V_W - V_C}{V_R - V_C}\right]^3 & V_C \le V_W \le V_R \\ P_R & V_R \le V_W \le V_F \end{cases} \qquad (2)$$

Where,

P_{WG}: The wind turbine output power (Watt). PR: The wind turbine rated power (Watt).

V_W: The wind speed (m/s).

V_C, V_F, V_R: Cut-in, cut-out and rated or nominal speed of the wind turbine (m/s) respectively.

4.3.3 Storage Systems (Battery Bank)

Energy storage is often used in small hybrid systems in order to be able to supply the load for a relatively long time (hours or even days). It is also sometimes used with hybrid system connected to large isolated AC grids. In this case, it is used to eliminate short-term power fluctuations [43].

Energy storage is usually done with batteries. Batteries are usually of lead - acid type. Nickel - cadmium batteries are rarely used. There are other forms of storage, but little used, such as pumping water, flywheels and hydrogen storage.

In the case of storage by pumping water, the energy produced is used to fill a storage tank whose water is to be turbined to restore energy [43].

The principle of flywheel is simple. It is a matter of storing energy by rotating a large mass [44]. The kinetic energy obtained can be restored to the demand in the form of electrical energy, using an electric machine in generating mode.

However the Hydrogenis the lightest gas. This poses a real storage problem. The volumetric energy density of hydrogen is only advantageous in the liquid or compressed state (700 bars). There are multiple modes of storage of hydrogen: compressed, liquefied, metal hydrides, activated carbon, nano fibers and carbon nanotubes etc. While the first two modes of storage are currently the most used, they are far from satisfactory.

Battery charging quantity is expressed as:

$$P_b(t) = P_b(t-1).(1-\sigma) + [P_z(t) - P_l(t)/\eta_{inv}].\eta_{bc} \quad (3)$$

When the total output power of the turbine and PV cells is less than the load power, the battery is in the state of discharging, and the charged quantity of the battery at the moment of (t) is expressed by:

$$P_b(t) = P_b(t-1).(1-\sigma) + \left[\frac{P_l(t)}{\eta_{inv}} - P_z(t)\right].\eta_{bf} \quad (4)$$

Where,

$P_b(t)$: Battery charged quantity at time (t).

$P_b(t-1)$: Battery charged quantity at time $(t-1)$.

σ: Battery self-discharge rate per hour.

$P_z(t)$: The total output power of the turbine and PV cells in the time interval $(t-1, t)$.

$P_l(t)$: The total load power in the time interval $(t-1, t)$.

η_{inv}: Inverter efficiency.

η_{bc}: Battery charging efficiency.

η_{bf}: Battery discharging efficiency

4.3.4 Converters

In a hybrid system, converters are autonomous when they impose their own frequency on the load. The non-autonomous inverter requires the presence of an AC source to operate. There are also inverters that can ensure the two operating modes: autonomous or in parallel with another generator. These are the most flexible, but are also the most expensive. Sometimes the rectifier and inverter functions are performed by a single device.

4.3.5 Loads

Electrical loads make electrical power useful. There are resistive and inductive loads. Resistive loads include incandescent bulbs, water heaters, etc. Devices using electrical machines are resistive and inductive loads [45].

4.4 Description of Hybrid Energy System

The sunny days are generally characterized by a weak wind activity while the strong winds are observed on cloudy days or at night (See Figure 2) [46].

Where,

A: Photovoltaic Panel

a: Surge arrester

B: Wind turbine

m: Battery monitor

R: Battery charger

S: disconnector

1: Protective circuit breaker

2: Charge / discharge controller

3: DC circuit breaker

4: Battery

5: Inverter

6: Electrical connection box

7: Electric charge

Figure 2: Hybrid Photovoltaic-Wind Energy System [46]

a: Surge arrester: The surge arrester or "surge suppressor" will protect the system against atmospheric surges such as lightning by deriving the surge current to ground. It is usually placed after the panel, in the junction box, to dissipate the excess energy and clipping the voltage surges. In the hybrid case it will also be placed in the junction box associated with the wind turbine.
m: Battery Monitor: Displays the voltage, current, and ampere-hour values of the battery to check and monitor its status.
R: Battery charger: The purpose of this device is to control and regulate the charge of the battery.
S: Disconnector: This is a stop switch that is placed after the wind turbine. Its role is to isolate the whole system from the wind turbine, so as to allow the maintenance or repair of electrical equipment. It will also provide protection against overcurrents due to electrical faults.
1: Circuit Breaker: This is a DC circuit breaker that is installed between the photovoltaic panel and the controller to isolate and protect the system when servicing the panel or when an electrical fault occurs.
2: Charge / discharge controller: It is installed between the battery and the photovoltaic panel; it is used to control the current that comes in or out of the battery to prevent it from being damaged by excessive charge or discharge.
3: DC Circuit Breaker: This is a dc circuit breaker that is installed between the battery and the inverter to isolate and protect the inverter battery circuit from electrical faults. It is essential when the inverter is not itself equipped with a low voltage protection. Instead of the circuit-breaker, however, a fuse connected to the ungrounded conductor can be used. All these devices must comply with current standards and codes for DC and AC installations.
4: Battery: The battery should be installed in an insulated enclosure or plastic bin with a lid and stored in a well-ventilated area, as it is sensitive to temperature variations.
5: Inverter: The inverter converts the DC current from the battery into the AC power required to operate most domestic electrical appliances. Be careful when choosing the inverter because the waveform it reproduces may not be suitable for some devices; So the inverter must be able to absorb the power peak when they are switched on. Prefer a high efficiency inverter and install it as close as possible to the battery to reduce electrical losses in the conductor wires.
6: Electrical connection box: It contains the main circuit breaker, the fuses or the secondary circuit-breakers essential for the protection of the electrical appliances of the house. The various electrical circuits of the house are attached to it to be protected (e.g.: The lighting circuit, that of small appliances and that of large electrical appliances).
7: Electric charge: Electric charge is the amount of energy consumed by all the appliances in the house (e.g. lighting, appliances, electronics, etc.). It is advisable to choose "eco-energy" appliances and to change the way they consume electricity. For example, turn off the devices you are not using. In many cases, the malfunctions encountered are due to an inadequate choice of electric appliances with excessive consumption.

4.5 Advantages and Limitations of Hybrid Systems

The most widespread hybrid systems are characterized by a wind-photovoltaic coupling. The advantage of combining these two energy sources is justified by the fact that they present the best shared resources. Complementarity of these two resources is very significant whether on an annual or daily scale. Indeed, the wind blows more during the winter and the autumn and it decreases in the spring while the most intense solar radiation is during the summer. Similarly, on a day, solar radiation is stronger during the day while the wind can blow also at night. This seasonal and daily complementarity of solar and wind resources allows the isolated site, for example, to have a more reliable energy availability which, of course, depends on the site of installation. Thus, the introduction of a hybrid system by combining a photovoltaic panel and a wind turbine with a diesel-powered emergency generator could address energy requirements throughout the year. However, the diesel engine requires a supply of fuel. Its use in isolated sites can thus be polluting, noisy and economically less viable compared to renewable energy sources. In several applications, the diesel engine is avoided by including in the systems an energy storage device by electrochemical accumulator. Since storage costs represent the main economic constraint, hybrid systems must be suitably designed to minimize the need for energy storage in the case of autonomous operation. In some systems, the use of a new hydrogen-based storage technology synthesized by water electrolysis appears to be a privileged outlet for renewable energies [47]. Thus, the hydrogen fuel cell of renewable origin would constitute a completely clean and available channel. In addition, storing hydrogen at the same time as generating electricity in a wind farm coupled with a solar power plant will absorb the surplus of these "variable energies". However, this hydrogen sector, although very promising, still suffers today from its profitability. Also, the most common storage at this time is electrochemical storage in the form of batteries.

5 CONCLUSION

The use of photovoltaics in isolated areas is undoubtedly of great advantage, because of its ease of implementation and the little maintenance it requires. But, the photovoltaic delivered is quite expensive for medium and high power compared to other energy sources. Thus, specialists have been led to couple several energy systems, in order to make a priori less random the input variables and on the other hand to seek an optimization of the storage. Such combinations of energy sources are referred to as hybrid systems.

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