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# System Analysis of a Hybrid Renewable Energy System

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**ABSTRACT**

Renewable energies are important components of sustainable development. Indeed, coupled with a rational use of energy, they reduce the use of conventional energy systems based on resources of fossil and fissile origin, and so therefore the pressures environmental and socio-economic use. Renewable energy aims to offer an energy service to our society at an acceptable price. But on the other hand, the cost of this service has an impact on the local economy, the environment and society in general. Compared to conventional solutions, enhancement of renewable energy creates more jobs, strengthens the local economy, reduces the environmental impact and reduces the lust on the stocks of energy and therefore it is a source of peace. In this paper, we are interested in the study of a hybrid renewable energy system: wind – photovoltaic – accumulator. The objective of this paper is to propose a novel approach of system analysis based on the OOPP method (Objective Oriented Project Planning) of a hybrid renewable energy system.



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## 1. INTRODUCTION

Nowadays the modeling and the simulation are become a scientific and technological issue. In fact, computerized design tool becomes essential industry in effect these tools for prediction and analysis of a system behavior, to reduce the costs and time of study of a new product by postponing the prototyping phase as far as possible.

The evolution of digital calculation tools allows us to consider very seriously the modeling of a complex system for example a Hybrid Renewable Energy System (HRES). It must certainly adapt the representation level of each model in the objectives of the user but needed before the interconnection of all these models together to have a global representation of the HRES.

In recent years, a growing market demand grew for renewable energies; they are key elements of sustainable energy supply. Renewable energy includes a large number of different systems according to the valued resource and the form of energy obtained [1], [2].

The developments observed are improving of processing and the decrease in the cost price of the useful energy produced than the quality of energy services and increased the operation comfort. On the side of the resource, the potential of renewable energies could far exceed our needs, but their contribution to the energy balance depends on available surfaces, investments for their equipment and the reduction of our consumption.

It seems in fact important to offer a systemic model describing the functioning of a HRES. To reach this objective, the Objective Oriented Project Planning (OOPP) method seems to be a promising research method. The objective of this paper is to propose a global system analysis based on the OOPP method of a complex system. A case study of a PV/Wind hybrid energy system is presented.

## 2. PART OF RENEWABLE ENERGY

Renewable energies exploit energy sources of natural origin (sun, wind, water...). They represent energies of future in the measure where they are inexhaustible and preserve the environment [3].

Tunisia at the head of the Maghreb countries to implement national programs for the use of renewable energy grants a particular interest in this vital area given its active role in the economic, social and environmental. In addition, the energy is one of the main axes of the Tunisian energy policy with an institutional and regulatory framework to address these challenges (Figure 1).

Figure 1. Supply and demand for renewable energy in Tunisia

Indeed, the development of renewable energy to improve the energy balance of the country, to cover its needs at least cost, to guarantee the supply of rural and isolated regions energy and reducing pollution from conventional energy [4], [5].

The sources of renewable energies allow obtaining after transformation of mechanical energy, electricity, heat or fuel. Coupled with a rational use of energy, they allow to reduce the consumption of origin both fossil and fissile fuels, and consequently reduce the impact environmental and socio-economic needs energy to describe our system.

The objective of the renewable energy is to: reduce the deficit to the level of energy balance and payments balances of provide energy access to the populations of rural areas reduce emissions.

### 2.1. Photovoltaic solar energy

Means the electricity generated by processing of a part of solar radiation with a photovoltaic cell. Several cells are connected together to form a solar panel (or module) photovoltaic. Several modules that are grouped in a photovoltaic power plant are called photovoltaic field. The term can refer either photovoltaic physical phenomenon - the photovoltaic effect or related technology [6], [7], [8].

Photovoltaic systems are used for 40 years. Applications began with the space program for radio transmission satellites. They continued with tags offshore equipment and remote locations in all countries of the world, using batteries to store electricity during hours without sunlight (Figure 2).

Solar electric systems offer many advantages, including:

- They are safe, non-polluting and silent;
- They require almost no maintenance;
- They operate profitably in remote areas and in many residential and commercial applications;
- They are flexible and can be expanded at any time to meet your needs electricity;
- They give you greater independence - independent operation of the network or system backup during power outages.

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Figure 2. Photovoltaic array

First, high reliability - it has no moving parts which make it particularly suitable for remote areas. This is due to its use on spacecraft. Then, the modular nature of photovoltaic panels allows a simple and adaptable to various energy needs. Systems can be designed for power applications ranging from milliwatts to megawatts.

Operating costs are very low given the reduced maintenance and they require no fuel or transportation or highly specialized personnel.

Finally, photovoltaic technology has qualities ecologically because the finished product is non-polluting, quiet and does not disturb the environment if it is the occupation of space for large installations.

The photovoltaic system has disadvantages:

- The manufacture of photovoltaic module is the high technology investment and requires a high cost.
- The actual yield conversion module is low (the theoretical limit for crystalline silicon cell is 28%).
- Photovoltaic generators are competitive with diesel generators for low energy demands in isolated areas.
- Finally, when the storage of electrical energy in chemical form (battery) is required, the cost of the PV generator is increased. Reliability and performance of the system, however, remain equivalent as long as the battery and associated components are carefully selected regulations.

### 2.2. Wind energy

The wind energy is one of the most promising energy sources while offering the fastest growth rate to the world. In fact, the wind energy production doesn't loosen any gas to greenhouse effect and generate few negative effects on the environment [9], [10].

An example of an aerogenerator has a generating synchronous that function variable speed. The regulation of power is assured by a system to wedging of blades that permits the variable-speed working. The speed of the turbine and the frequency of the network are uncoupled through the intermediary of a system of power conversion that takes in charge as the excitation of the generating (Figure 3).

The working of an aerogenerator is managed by a control and command unit that controls the electric and mechanical parameters of the machine while acting at the same time on the device to wedging of blades and the system of power conversion, it assures so the optimization of the electric energy produced.

The blades and skiff are supported by the tower formed of four bridles: a lower bridle, a superior bridle and two intermediate bridles. To different levels of the lower bridle are placed the cupboard of the control and command accompanied by the connection cell respectively, the transforming elevator and to a superior level, the device of power. To access the different elements of the aerogenerator, an elevator is installed to the basis of the tower.

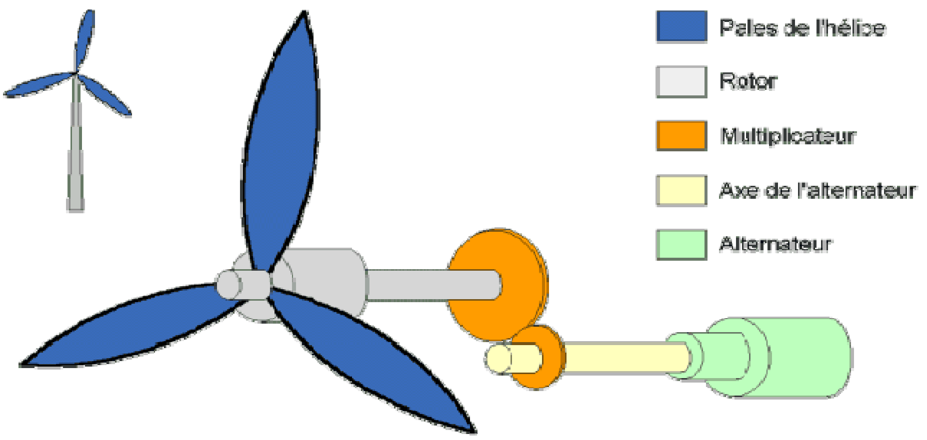


Figure 3. Simplified diagram of a conventional wind

## 3. CASE STUDY OF A HYBRID REWABLE ENERGY SYSTEM

Hybrid Renewable Energy Systems (HRES) are becoming popular for remote area power generation applications due to advances in renewable energy technologies and subsequent rise in prices of petroleum products. A hybrid energy system usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply.

For many applications of sensitive and strategic interest as the relay of telecommunications, border crossings, isolated habitat, clinics, etc., off-grid of conventional electricity, permanent primary energy source availability is vital and conditioning in a very large extent, the reliability of the facilities and their continuous operation. Conventional technological solutions by conventional electrochemical storage are expensive, technically limited in power and limited in capacity [11], [12].

Those made by the generators, share the need to supply fuel and maintenance, have drawbacks related noise, pollution and especially their poor performance at partial load. New technology solutions, made by hybrid systems, even if they are competitive again economic steps, however offer a high security. However, in view of the need for sustainable development, these solutions, with the support of the public will, can be economically viable in the medium and long term.

A hybrid power generation system, generally, is one that combines and leverages several sources available easily mobilized. The system that interests us brings together two parts for the production of energy through electrochemical storage in our case; we are interested in systems of small powers producing easily DC convertible.

Hybrid systems can address limitations in terms of fuel flexibility, efficiency, reliability, emissions and / or economics. Incorporating heat, power, and highly-efficient devices (fuel cells, advanced materials, cooling systems, etc.) can increase overall efficiency and conserve energy for a hybrid system when compared with individual technologies. Achieving higher reliability can be accomplished with redundant technologies and/or energy storage. Some hybrid systems typically include both, which can simultaneously improve the quality and availability of power.

Hybrid systems can be designed to maximize the use of renewable, resulting in a system with lower emissions than traditional fossil-fueled technologies. Hybrid systems can be designed to achieve desired attributes at the lowest acceptable cost, which is the key to market acceptance [10]. Figure 4 presents different hardware components of the example of a HRES.

To get constant power supply, the output of the renewable may be connected to the rechargeable battery bank and then to the load. If the load is alternating current (AC), then an inverter is used to convert the direct current (DC) supply from the battery to the AC load. Consideration about voltage transition among modules starting from Wind Generator, Battery Charger Controller and Inverter should be subject to voltage standard which mainly focus about voltage compatibility.

Figure 4. Diagram of an example of a HRES

## 4. THE NEED FOR SYSTEM ANALYSIS

System Analysis seeks to understand what humans need to analyze data input or data flow systematically, process or transform data, store data, and output information in the context of a particular project. Furthermore, system analysis is used to analyze, design, and implement improvements in the support of users and the functioning of projects that can be accomplished through the use of computerized information systems.

Installing a system without proper planning leads to great user dissatisfaction and frequently causes the system to fall into disuse. SA lends structure to the analysis and design of information systems, a costly endeavor that might otherwise have been done in a haphazard way. It can be thought of as a series of processes systematically undertaken to improve a project through the use of computerized information systems. System analysis involves working with current and eventual users of information systems to support them in working with technologies in an organizational setting.

User involvement throughout the systems project is critical to the successful development of computerized information systems. Systems analysts, whose roles in the organization are discussed next, are the other essential component in developing useful information systems.

Users are moving to the forefront as software development teams become more international in their composition. This means that there is more emphasis on working with software users; on performing analysis of their projects, problems, and objectives; and on communicating the analysis and design of the planned system to all involved.

There are many methods that have been used to enhance participation in information systems planning and requirements analysis. We review some methods here because we think them to be fairly representative of the general kinds of methods in use. The methods include Delphi, focus groups, Structured Analysis Design Technique (SADT), Objectives Oriented Project Planning (OOPP), multiple criteria decision-making (MCDM), and total quality management (TQM).

The objective of the Delphi method is to acquire and aggregate knowledge from multiple experts so that participants can find a consensus solution to a problem [13].

A second distinct method is focus groups (or focused group interviews). This method relies on team or group dynamics to generate as many ideas as possible. Focus groups been used for decades by marketing researchers to understand customer product preferences [14].

MCDM views requirements gathering and analysis as a problem requiring individual interviews. Analysts using MCDM focus primarily on analysis of the collected data to reveal users' requirements, rather than on resolving or negotiating ambiguities. The objective is to find an optimal solution for the problem of conflicting values and objectives, where the problem is modelled as a set of quantitative values requiring optimization [15].

TQM is a way to include the customer in development process, to improve product quality [16]. In a TQM project, data gathering for customers needs, i.e., requirements elicitation may be done with QFD.

The SADT method represent attempts to apply the concept of focus groups specifically to information systems planning, eliciting data from groups of stakeholders or organizational teams [17]. They are characterized by their use of predetermined roles for group/team members and the use of graphically structured diagrams. SADT enables capturing of a proposed system's functions and data flows among the functions.

The OOPP method also referred to as Logical Framework Approach (LFA), is a structured meeting process. This approach seeks to identify the major current problems using cause-effect analysis and search for the best strategy to alleviate those identified problems [18], [19], [20]. OOPP method has become the standard for the International Development Project Design. Team Technologies have continued to refine the approach into TeamUP [21], [22].

## 5. RESULTS OF SYSTEM ANALYSIS

In this part, we propose a system analysis of a HRES. To this effect, our analysis will especially focus on the analysis of the objectives using the OOPP method.

In order to take to good the task of system analysis of HRES, it is necessary first of all to adopt a referential of data. This referential is centered on:

- The exploitation database of an example of an aerogenerator available in Sidi Daoud in Tunisia that includes a manual of maintenance (frequency converter, installation description, electric, transforming, generating facilities plans) as well as a manual of operation (working description, working sequences, communication software).
- The exploitation of constructor data (multiplier, generating, device of braking, device of orientation, hydraulic power station, sensors...).

The result is corresponding OOPP model has been built in order to represent the HRES. An important point must be noticed: the point of view of the analysis is that of a person without concrete experience on the renewable energy, i.e. only through a bookish knowledge, whose objective is the use of the final model describing the HRES.

The Global Objective (GO) is: "Production of electrical energy using a Hybrid Renewable Energy System" and we identified 5 Specific Objectives (SO) (Table 1).

Table 1. OOPP nalysis of a HRES

| N° | Code | Designation |
|---|---|---|
| 1 | GO | Production of electrical energy using Hybrid Renewable Energy System assured |
| 2 | SO1 | Supplying of the electrical energy using a photovoltaic generator assured |
| 3 | R1.1 | Communication with the system assured |
| 4 | R1.2 | Treatment of the data assured |
| 5 | R1.3 | Management and modulation of the energy assured |
| 6 | R1.4 | Allocation and protection of the installation assured |
| 7 | R1.5 | Conversion and storage of the energy assured |
| 8 | R1.6 | Acquisition the system states assured |
| 9 | SO2 | Supplying of the electrical energy using a wind generator assured |
| 10 | R2.1 | Treatment of the data assured |
| 11 | R2.2 | Management of the energy assured |
| 12 | R2.3 | Conversion of the energy assured |
| 13 | R2.4 | Acquisition of the data assured |
| 14 | SO3 | Management and transformation of the energy using a converter assured |
| 15 | SO4 | Storage of the energy using batteries assured |
| 16 | SO5 | Measurement and record of the data using measures interfacings assured |

So, we identify through the OOPP method the different functions accomplished by the different compartments of the HRES. It will permit us thereafter to analyze the HRES of manner in organs functions and organs components until to arrive to the elementary organ of the HRES called the component.

For instance, the main functions of the aerogenerator are accomplished respectively by the following systems:

- System of captation and transmission: Regroup the necessary elements to transform the kinetic energy of wind in mechanical energy of rotation adapted to the generating.
- System of production of the electric energy: Permits to convert the mechanical energy of rotation in electric energy adapted to the generating.

- System of control and command: Contain the programmable automaton, its peripherals as well as the different sensors. This system permits the automatic working of the aerogenerator.
- Support and Logistics: Regroup elements that cover the skiff, the support of the skiff (tower) as well as and the hydraulic and electric feeding of the machine.

The hierarchical analysis of the HRES is constituted of three levels; a first level formed by the four systems of the machine formed by organs functions decomposable in organs components. This analysis permitted to identify systems in dynamic interaction, organized to assure the conversion of the kinetic energy of wind in electric energy adapted to the network.

## 6. CONCLUSION

In this article, we presented a study of hybrid renevelable energy systems (HRES) on the one hand, and a system analysis based on the OOPP method of a PV/Wind hybrid energy system, on the other hand. In fact, hybrid power systems combine two or more energy conversion devices, or two or more fuels for the same device, that when integrated, overcome limitations inherent in either. They can offer solutions and value to customers that individual technologies cannot match.

This analysis was permit to identify the different functions and components of the HRES as well as the technical constraints under which it is submitted (feature technical conditions of working, vibrations, clutter, power, precision…). This novel approch of analysis enable us to solve a real world problem related to renewable energy technology and management.

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