Application of System Modeling of the Renewable Energy Production

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***Abstract*— Present situation of the electricity companies is very difficult due to two factors: the increased demand for electricity and the rising price of fossil fuels. The solution is to move towards the production of renewable energies. This work focuses on the systems analysis based on the Objectives Oriented Project Planning (OOPP) method of renewable energy production in particular of photovoltaic system and wind power. The objective of the analyses is to build a communication network between different renewable production sites, analyze and plan all installation projects whatever its nature and situation.**

***Index Terms*-- Renewable energy, Photovoltaic systems, Wind power, Systemic modeling.**

1. Introduction

The progression of technology and the improvement of manual systems to automated systems are a very important call to electricity. That is why researchers are making great efforts to improve the production of electricity, switch between production and demand, assure monitoring and real time supervision of all environmental changes to the power grid by a very intelligent network called Smart Grid.

In fact, the smart grid contains seven areas, the most important one is the production area, which is a large research area generally based on the renewable sources such as water, wind and sun.

The renewable energy sources are the cleanest, the most economical, nonpolluting and ecological character and overlooked their costs they are free and will never risk to be annihilated.

In this paper, we will be interested in the renewable energy production for which a systemic modeling method Objectives Oriented Project Planning (OOPP) is presented to give the best description for this system. This is why a research on a chain photovoltaic conversion and a chain wind conversion is presented.

2. Chain photovoltaic conversion

A photovoltaic panel (PV) is used either to directly operate a continuous load current, or connect to a public network or both together.

Figure 1 presents the different blocks of photovoltaic conversion chain.

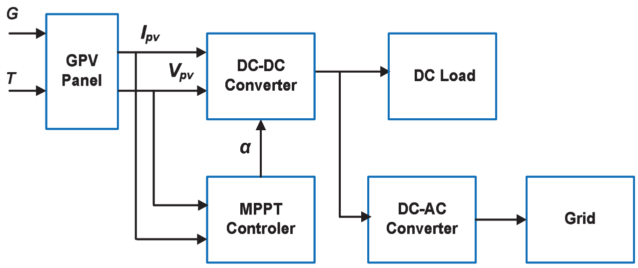

Fig. 1. Blocks of photovoltaic conversion chain.

In this section, we identify the different blocks of a photovoltaic conversion chain. This is why we start by modeling of a PV panel and then the adaptation system by static converter DC-DC, along with the ordering system with the approach perturbation and observation, and finally the adaptation system using static conversion DC-AC.

A. *Modeling of a photovoltaic module*

Photovoltaic solar energy is the direct conversion of energy from photons into electricity. The combination of several PV cells called module and the combination of several modules form a PV panel [1], [2], [3].

The cell of a PN junction photovoltaic submitted to the illumination can be schematized in Figure 2.

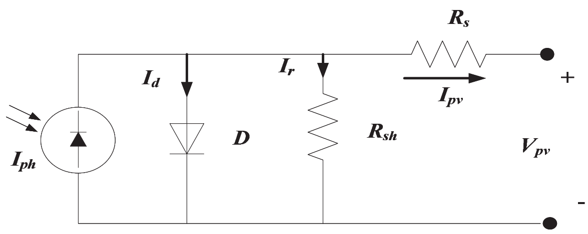

Fig. 2. Equivalent electric diagram of a PV cell [1].

The equivalent electric diagram of a PV cell can be modeled by equation (1)

$$I_{pv} = I_{ph} - I_d - I_r \quad (1)$$

Where: The photocurrent of the cell proportional to the sunning E_s is given by equation (2):

$$I_{ph} = I_{cc}\left(\frac{E_s}{1000}\right) \quad (2)$$

The current through the diode is given by the equation (3):

$$I_d = I_{sat}\left(e^{\left(\frac{q(V_{pv}+I_{pv}R_s)}{AKT}\right)} - 1\right) \quad (3)$$

The current derived by the shunt resistance is given by equation (4):

$$I_r = \frac{V_{pv} + I_{pv} R_s}{R_{sh}} \quad (4)$$

From equation (1), a simple methodology was developed to determine the characteristics of a cell or photovoltaic panel, like the short-circuit current I_{cc} and the open circuit voltage V_{oc} to infer the implicit mathematical expression of the current delivered by a photovoltaic cell, and its characteristic I-V.

Similarly, for mathematical modeling of a PV panel, you should have the actual realization of the module structure, such as the inclusion of cells in a PV module is as needed of the charge in three types [4], [5], [6]:

- The cells are associated in series: The series connection of PV cells Ns delivers a voltage equal to the sum of the individual voltages and a current equal to that of a single PV cell.
- The cells are associated in parallel: The parallel combination of the PV panels delivers a current equal to the sum of the individual currents and a voltage equal to that of a single PV cell.
- The cells are associated in parallel and in series: mixed, to increase the current and the voltage.

The general case, the modeling of a PV panel is down by equation (5).

$$I_{pv} = N_p I_{ph} - N_p I_{sat}\left(e^{\left(\frac{q\left(\frac{V_{pv}}{N_s}+\frac{I_{pv}R_s}{N_p}\right)}{AKT}\right)} - 1\right) - \frac{N_p V_{pv} - I_{pv} N_s R_s}{N_s R_{sh}} \quad (5)$$

B. Adaptation system by the DC-DC converter

The converter is used to adapt the energy from the PV panel with load. In the case of a booster converter, the voltage's nature does not change but the voltage level increases (Fig.3).

In order to make the converter operate in a continuous conduction mode, the IGBT must be opened and the current going through the inductor is not canceled [7], [8].

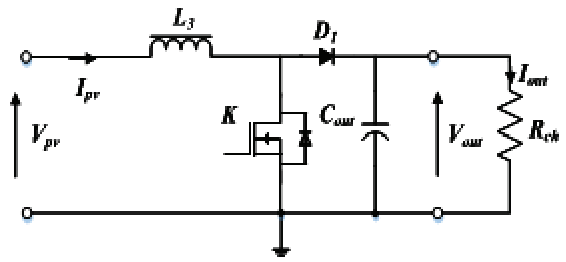

Fig. 3. Typical structure of DC-DC boost converter.

In this case the division of the output voltage of the chopper by its input voltage is equal to:

$$\frac{V_{out}}{V_{pv}} = \frac{1}{1-\alpha} \quad (6)$$

With α: the duty cycle.

The nonlinear characteristic of the PV module and sensitivity to external conditions induces energy losses hence the fluctuation of the output voltage can damage the load. Needless to say, the importance of a control system is essential.

C. Ordering system with the approach perturbation and observation.

Command systems that are mentioned later in systems analysis have the same purpose; it is the search of the maximum power point tracking MPPT. But the performance, implementation, complexity and rapidity will differ from algorithm to another.

The photovoltaic panels are subjected to change conditions in the sunshine and temperature. These changes materialize the need of a power extraction optimization algorithm that is changing the values of voltage and current of the photovoltaic generator to MPPT [9], [10].

The algorithm studied in this research is the perturbation approach and observation which changed in a block diagram (Fig.4).

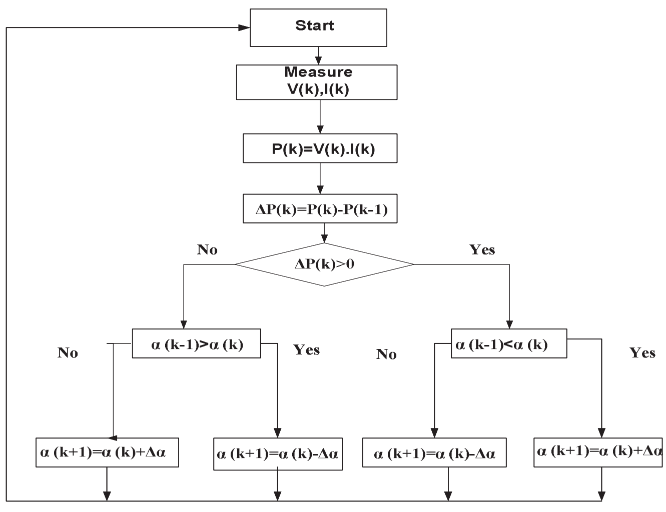

Fig. 4. Flow chart of perturbation and observation algorithm.

The command offered by this approach obliges the operating point of the photovoltaic generator to approach the maximum power point and oscillate around it either by a linear positive or negative variation in voltage of the photovoltaic generator through time [10].

D. Adaptation system by converter DC-AC

The DC-AC converter is used to adapt the energy from the PV panel either directly or by the intermediary of a Boost converter. This converter changes the nature of the continuous voltage to the alternative and stabilizes the voltage level after the PV panel. It can be a mono-phase for operating charges or three-phases for delivering energy to the grid (Fig.5) [11], [12], [13].

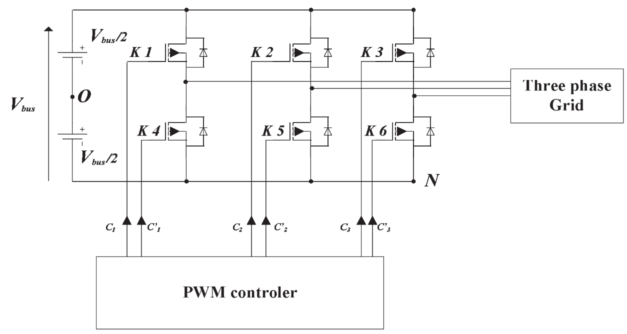

Fig. 5 Three phase voltage inverter connected to a grid.

3. CHAIN WIND CONVERSION

In this section, we identify the different blocks of a wind conversion chain (Fig.6). This is why we start by modeling of turbine, the multiplexer, the generator, and finally the converter [13], [14], [15], [16].

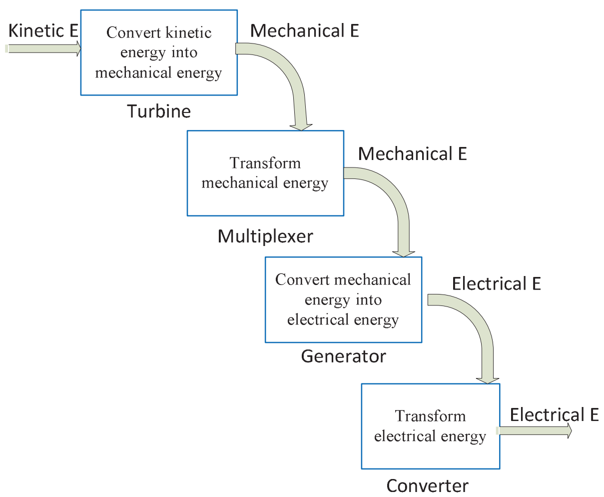

Fig. 6 Blocks of wind conversion chain.

A. Modeling of the turbine

The aerodynamic torque of slow shaft is down by equation (7):

$$C_{aero} = \frac{P_{aero}}{\Omega_T} \tag{7}$$

Where: The aerodynamic power is given by the equation (8):

$$P_{aero} = P_w C_p(\lambda) \tag{8}$$

The power of wind is given by equation (9):

$$P_w = \frac{\rho S R^2 V^3}{2} \tag{9}$$

The specific speed is given by equation (10):

$$\lambda = \frac{R\Omega_T}{V} \tag{10}$$

B. Modeling of the multiplexer

The generator torque of fast shaft is given by equation (11):

$$C_G = \frac{C_{aero}}{M} \tag{11}$$

Where: M is the multiplication ratio.

C. Modeling of the generator

The mechanical torque is down by equation (12):

$$C_{mec} = C_G - C_{aero} - C_{vis} = J\frac{d\Omega_{mec}}{dt} \tag{12}$$

Where: The friction torque is given by equation (13)

$$C_{vis} = f\,\Omega_{mec} \tag{13}$$

D. Modeling of converter

The electric power is given by equation (14)

$$P_{élec} = C_G \Omega_G \tag{14}$$

4. RESULTS OF SYSTEM MODELING

Because of the complexity of some systems and the diversity of the interactions among its components, we suggest in this research, on the one hand, the need for systemic modeling for the resolution of these complex problems and offer communication support between its different users, on the other hand. Indeed, for analyzing and modeling of complex systems, we find various categories and a multitude of application areas.

We also in, this article, we used the systemic OOPP method for the description of the field of renewable production.

A. Presentation of method

The OOPP method is considered as communication device, an analysis and a project planning, whatever its nature and its location [22], [23]. It is made up of three essential stages: 1st problem analysis stage; 2nd objective analysis stage and 3rd stage of activity planning.

The problem analysis stage is very frequent that the conception and implementation of a project meets many problematic situations expressed by a sponsor [22], [23].

The approach used is federative since endorses the principle of organizing workshops bringing together variety of competence domain. This is why the analysis of this situation must be conducted according to a structured methodology based on causal logic identifying its effects and causes (Fig.7).

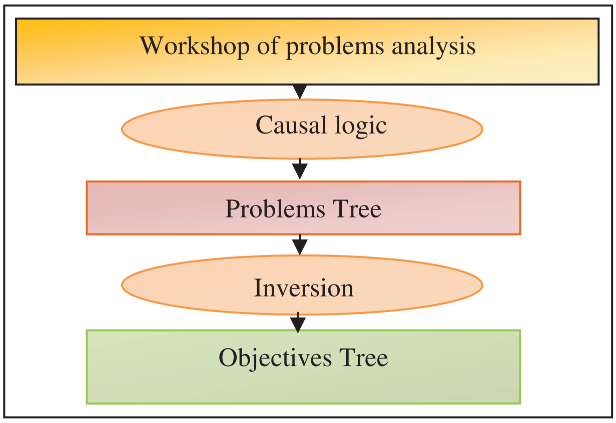

Fig. 7. OOPP method.

The objectives of the analysis step are presented by the Tree of problems constituting a negative report, allows a simple inversion (transform a negative state to a positive one) to build a Tree of Objectives which constitute the basis of any plan Action.

A causal logic of problem analysis, logical is made to correspond "means-end" for developing the objectives tree. This is how we establish connections:

Central Problem: PC → Global Objective: OG
Direct Cause: DC → Specific Objective: OS
Sub-Cause: SC → Result: R
Sub-Sub Cause: SSC → Activity: A

To analyze an objective, a result, an activity or a derived activity, is arisen whenever we are confronted with the question: What is to be done to achieve the discussed objective or achieve the result that should perform the identified activity?

The answer of this question is made by the decomposition of the level of analysis in the lower levels.

The OOPP method allows, in addition to the determination of the different steps in the analysis of a project from: follow its evolution, evaluate the project at its various stages; identify dysfunctions and deviations between performances and planning; analyze the causes, identify the responsibility [24], [25].

Finally, the activity planning stage is represented by an activity matrix also called activity planning scheme.

This matrix is composed of the activity sequence number, the activity code, the activity designation, the person in charge of the activity, the staff responsible for the activity, the objectively verifiable indicator (OVIs), the Source of verification (SOVs), the necessary resources according to their category: infrastructure, human resources, equipment and consumables, logistics (energy, transport...).

B. Systemic modeling of the PV generation

Analysis of a PV generator with the systemic method OOPP allows us to scale well a PV system with a study that contains the best choice of components according to the charge and the installation site.

In this part, we introduce the information matrix of the third step of the OOPP method associated to the general objective (GO: Identification of PV production). This first specific objective is presented in table 1.

TABLE I

Analysis of the photovoltaic production

1	SO1	Photovoltaic production cycle identified
2	R1.1	Transformation of solar radiation into electricity identified
3	A1.1.1	Identify the different photovoltaic cells
4	S1.1.1.1	Identify monocrystalline cells
5	S1.1.1.2	Identify polycrystalline cells
6	S1.1.1.3	Identify amorphous cells
7	A1.1.2	Modeling a photovoltaic cell
8	S1.1.2.1	Determining the characteristics of a photovoltaic cell
14	S1.1.2.2	Placing the cells depending on the load
18	S1.1.2.3	Model a photovoltaic panel
19	R1.2	Voltage regulation according the load used
20	A1.2.1	Use a DC-DC converter
21	S1.2.1.1	Using a boost converter
22	S1.2.1.2	Using a buck converter
23	S1.2.1.3	Using a buck-boost converter
24	A1.2.2	Use MPPT command
25	S1.2.2.1	Using perturbation and observation approach
26	S1.2.2.2	Using the approach of open circuit and short circuit
29	S1.2.2.3	Use incrementing the conductance approach
30	S1.2.2.4	Use artificial intelligence approach
34	A1.2.3	Use a DC-AC converter
35	A1.2.4	Connect the output voltage by the load
36	R1.3	PV plant monitored and supervised
37	A1.3.1	Install a sun sensor
38	A1.3.2	Install a temperature sensor
49	A1.3.3	Install a voltage sensor
40	A1.3.4	Install a current sensor
41	A1.3.5	Install a steering Pc
42	A1.3.6	Install an energy meter

C. Systemic modeling of the wind generation

Analysis of a wind turbine with the systems approach OOPP allows us to describe its operation, to cite these components, to make the right decision for installation and to present different methods of supervision and control.

Identification of wind production is the general objective of systems analysis. Two specific objectives are presented in table 2; each identifies different types of wind turbines and as components necessary for the wind farms.

This method allows us, on the one side, to study the installation site, to make the right choice of components for each central and to guarantee a very high level of control and supervision such as the control of atmospheric criteria, the functioning of production chains, the stability of frequency and the continuity of production.

On the other side, it needles to creation of communicative interface between the different production sites, which helps to manage the production as well as the driving of distribution.

TABLE II

Analysis of a wind farm

1	SO1	Different types of wind turbines identified
2	R1.1	Wind turbine with vertical axis identified
3	A1.1.1	Present the Darrieus wind turbine
4	A1.1.2	Present the Savonius wind turbine
5	A1.1.3	Present wind helical Savonius
6	A1.1.4	Present wind Darrieus-Savonius Hybrid
7	A1.1.5	Present the H-Type for wind turbines with a vertical axis
8	R1.2	Wind turbine with horizontal axis identified
9	A1.2.1	Present wind to 3 wings
10	A1.2.2	Present wind to 2 wings
11	A1.2.3	Present wind to 1 wing
12	SO2	Components necessary for the wind farms identified
13	R2.1	Integration of the rotor identified
14	A2.1.1	Integrate the wind turbine blades
15	A2.1.2	Integrate the primary shaft
16	R2.2	Integration of the nacelle identified
17	A2.2.1	Integrate the speed multiplier
18	A2.2.2	Integrate the secondary shaft
19	A2.2.3	Integrate the generator
20	A2.2.4	Integrate the electrical controller
21	A2.2.5	Integrate the various cooling devices
22	A2.2.6	Integrate the nacelle orientation device
23	R2.3	Integration of the tower identified

5. Conclusion

Several researches based on the power grid and the production of renewable energy has been made to study the problems of electricity and predict in equivalence between demand and production in order to find solutions. One of these solutions is the use of unconventional means such as wind, sun...

This paper presents a system modeling of the renewable production using the OOPP method to create a dialogue interface between man and the automatic system and to facilitate communication between different areas of a smart grid.

This method brings about a good satisfaction at the time of its exploitation and several researches have been done very well to develop tools and to prove its efficiency for the scheduling of projects.

Starting from this case study of system modeling on photovoltaic system and wind power system discussed in this paper, work is in progress to develop the general methodology of modeling and simulation of a smart grid.

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