Impact of Optimal Integration of Dispersed Generation in an Electrical Distribution Network

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ABSTRACT

The impact of renewable energy dispersed generation (DG) in the electrical network in a way that increases the level of power also to ensure the continuity of service under better conditions Require many Big challenges, This paper provides a methodology solutions of hybrid photovoltaïque arry (PV) and wind turbine (WT) energy integration in the distribution electrical network with climate data from the wilaya of laghouat (Affiliated to Algeria) with maximal power level 500 kw and maximum power point tracking (MPPT) Incremental Conductance method follow-up to the maximum power point generated by the hybrid pv and wt system to ensure energy demand and improve the quality of electrical networks.

I. Introduction

In recent years, because of the high demand for electrical power in all sectors, there is dire a need to adopt the alternatives renewable energy resources into modern power grid. Renewable energy mostly used photovoltaic (PV), wind power, and hydroelectric power that are most appropriate for the climate and nature unlimited resources. Because of advancements in technology, the prices of PV panel, turbines, and hydel power are day by day decreasing [1]. if solar or wind are used to supply power to a stand-alone system, energy storage system becomes essential to guarantee continuous supply of power. The size of the energy storage depends on the intermittency level of the solar or wind. to guarantee continuous supply of power. The size of the energy storage depends on the intermittency level of the solar or wind [2].

Most utility systems use a traditional radial feeder system to delivery power to customer loads and implemented protection schemes only considering power flow in only one direction. The addition of DG changes energy flows which now can flow in either direction through system protection devices. The following protection issues must be considered when DG is being considered to be integrated with the utility: Short Circuit Power; Islanding; Reduced Reach of Impedance Relays; Reverse Power Flow; Voltage Profile; Auto Re-closure; Ferro-resonance; Grounding; and Safety. [3]

The wind energy has been used for centuries for navigation and agriculture. Today, the use and the technology of the wind energy developing very fast .as of the end of 2002, total global wind generating capacity exceeds 31,00 MW, and provides about 65 billion KWh of electricity annually [11].

A hybrid renewable PV–wind energy system is a combination of solar PV, wind turbine, inverter, battery, and other addition components. A number of models are available in the literature of PV–wind combination as a PV hybrid system, wind hybrid system, and PV–wind hybrid system, which are employed to satisfy the load demand [12].

The power-flow (PF) analysis has an important role for the design of DN. An efficient and good converging PF of distribution system is not only useful to obtain voltage and power loss of the network but also necessary for accurate selection of branch conductor and other aspect of planning [4]. This paper provides the impact of hybrid PV and WT system in the distribution network with climate data from the wilaya of laghouat (Affiliated to Algeria) maximum power point tracking (MPPT) Incremental Conductance method + Integral regulator.

I.1. Theoretical study

I.1.1 Definition of Distributed generation

Distributed generation is a new approach in the electricity industry and as the analysis of the relevant literature has shown, there is no generally accepted definition of distributed generation yet (see particular In the literature, a large number of terms and definitions is used in relation to distributed generation. For example, Anglo-American countries often use the term ‘embedded generation’, North American countries the term ‘dispersed generation’, and in Europe and parts of Asia, the term ‘decentralised generation’ is applied for the same type of generation [5].

I.1.2 Structure of the Algerian electrical network in the presence of new technologies

Modernization of distribution networks through the use of new automation, control and advanced metering technologies known under the term smart-grid as well as increasing the integration of renewable energy productions (such as: solar, wind) lead to major changes for operators and planners of distribution networks.

In Algeria, since the 1990s, an operation to modernize distribution networks has been started in order to have an automated network, this by integrating new technologies. The latter involves installing intelligent protection systems, fibre-optic links between high Voltage class B (HVB)/ high voltage calss A (HVA) (source stations, setting up smart switches, sensors, renewable energy sources and the installation of smart meters. [6].

I.1.3 Organization of the distribution network in the presence of the DGs

Previously, the distribution network designed to receive power from centralized production was completely dependent on this source to meet customer needs. Currently, and in order to strengthen the network and reduce this dependence by ensuring the quality and quantity of the power demanded, another generation known as decentralized generation or dispersed generation (DG) is installed at the level of the distribution network (figure 2). In order for this insertion to be efficient and profitable and to have a positive impact on the behavior of the network, its integration must be optimal while respecting the characteristics of the network.’

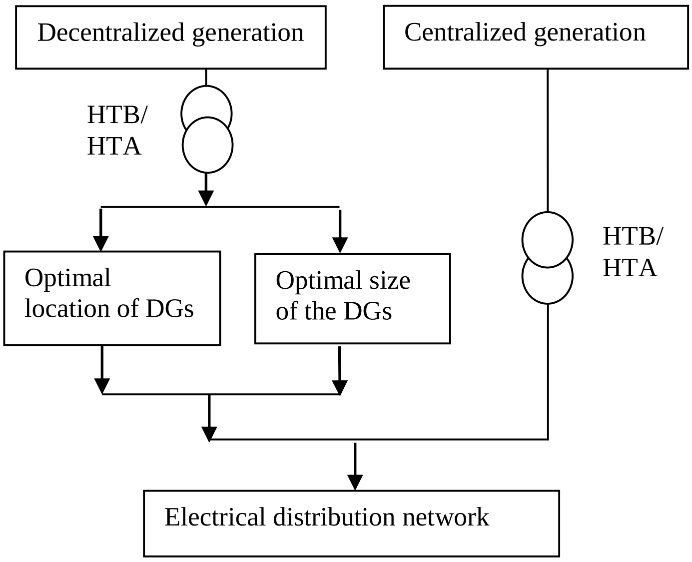

Figure1: optimal integration of the DG system in the electrical distribution networks [7].

I.1.4 Variation of Hourly power generated by photovoltaic source and wind energy

The DG system as an intermittent source of electrical energy and connected at the level of distribution networks can cause changes in power transits and in the operating strategy of these distribution networks.

The following graph presents the different meteorological parameters of the site kheneg-laghouat (algerie)

during the day of 01/01/2020 in winter(W) and 01/06/2020 in summer(S) from 6 am until 8 pm as well as the total power produced by the PV and wt peak power (Pc) of 500 kW.

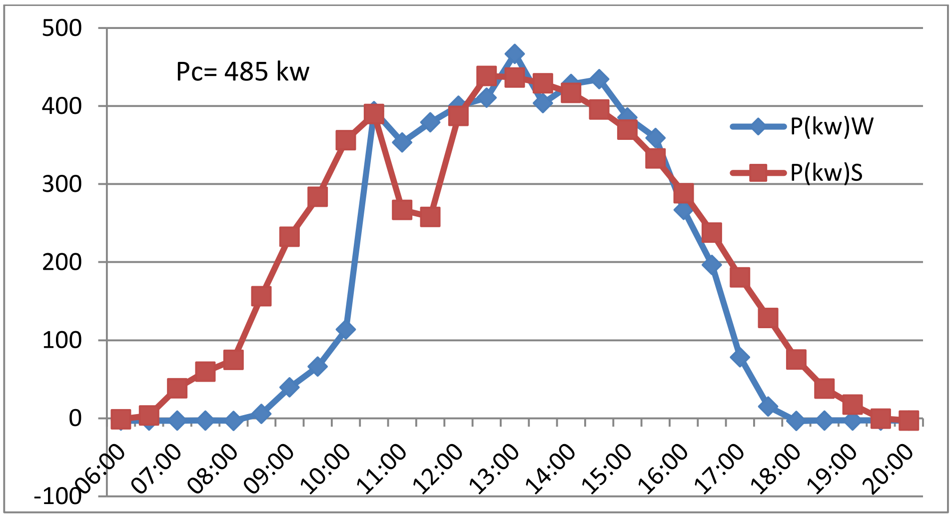

Figure2: Power generated by the PV source and Wt for a day of winter and summer

The performance and efficiency of photovoltaic modules is influenced by several factors such as solar radiation, ambient temperature, humidity, wind, shading and sand dust accumulation [8-13]. Several studies and research studies have evaluated the performance of photovoltaic modules in different climatic conditions, in particular the effect of sand dust accumulation and partial shading on energy loss in photovoltaic modules and arrays [13].

I.2. Distribution System Load Flow Analysis

Consider a distribution network with a radial configuration consisting of a set of branches; modeled as a series resistor with pure inductance with presence DG.

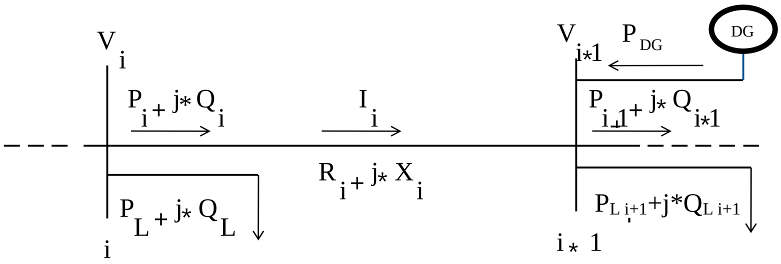

Figure 3: Radial line with insertion of a DG Distribution System Load Flow Analysis

Line current :

$$I_i = \frac{S_i^*}{V_i^*} = \frac{P_i - J*Q_i}{V_i^*} \quad (1)$$

Active power losses :

$$P_{acloss} = R_i \left(\frac{P_i^2 + Q_i^2}{V_i^2} \right) \quad (2)$$

Reactive power losses

$$P_{reacloss} = X_i \left(\frac{P_i^2 + Q_i^2}{V_i^2} \right) \quad (3)$$

In the balance of power becomes:

$$P_{generation} + \sum_{i=1}^{nbDG} P_{DJ} = \sum_{i=1}^{nbr} P_{losses} + \sum_{i=1}^{nbj} P_{Li} \quad (4)$$

(nbr) and (nbj) respectively number of branches and bus bar in distribution networks.

I.2.1 DG system modelin

a) PV modeling:

To develop a precise equivalent circuit for a PV cell, it is necessary to understand the physical configuration of the elements of the cell as well as the electrical characteristics of each element. According to this philosophy, several electric models have been proposed to represent the photovoltaic cell. The single equivalent circuit diode as shown in Figure (1) is the most commonly used model for large PV generators [14].

NB: PV models to be included in the load-flow we use the both a PQ-bus model.

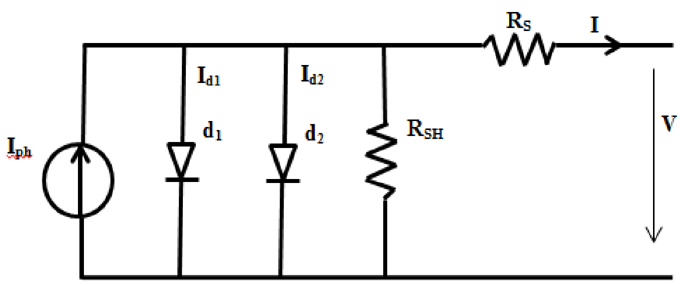

Figure 4: I-V curve for solar cells

The current equation (I) is given by :

$$I = I_{ph} - I_{s1}\left(e^{\frac{q(V+IRs)}{n1KT}} - 1\right) - I_{s2}\left(e^{\frac{q(V+IRs)}{n2KT}} - 1\right) - \frac{V+IRs}{Rsh} \quad (5)$$

short circuit current (at V=0)

$$I_{sc} = I \quad (6)$$

Fill factor:

$$FF = \frac{P_{max}}{P_T} = \frac{I_{MP} \times V_{MP}}{I_{SC} \times V_{OC}} \quad (7)$$

The efficiency of the solar cell:

$$n = \frac{P_{out}}{P_{in}} \rightarrow n_{max} = \frac{P_{max}}{P_{in}} \quad (8)$$

b) WT Modeling:

Neglecting the active power losses in the PQ-bus model, the generated active power P is assumed to be equal to the mechanical power Pm (wind turbine mechanical power output). The mechanical power is assumed constant and calculated as a function of the wind speed by means of the power curve for the turbine [8].

NB: WT models to be included in the load-flow we use the both a PQ-bus model.

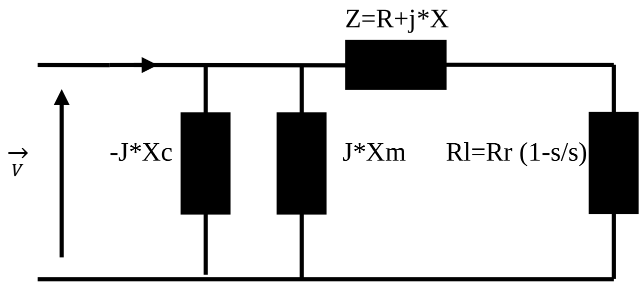

Figure 5: Equivalent circuits of an asynchronous generator

V is the bus voltage, X is the sum of the rotor Xr and stator Xs leakage reactances, Xm is the magnetizing reactance, Xc is the reactance of the capacitor bank used for power factor improvement, R is the sum of the stator Rs and rotor Rr resistances, and s is the slip.

Estimates the generated output power and torque by the wind turbine by giving the formula :

$$P_t = \frac{\lambda_p C_p A V^3}{2} \quad (9)$$

Torque developed by wind turbine given as :

$$T_t = \frac{\rho_t}{\omega M} \quad (10)$$

With:

$$\lambda = \frac{\omega R}{V} \quad (11)$$

Where :

PT = output power (w); Tt = the torque developed by wind turbine (N); Cp = the power co-efficient; λ = the tip speed ratio (m/s); ρ = the air density in kg/m^3; A = the frontal area (m^2) of wind turbine; and V = the wind speedin m/s.

I.2.2 Maximum Power Flow Control

The grid connected inverter is a current control type because the AC voltage is fixed by the grid. Therefore, the DC link voltage in the HOTT is kept within a certain range for stable operation by controlling the AC output current of the grid inverter. The AC output current of the grid inverter is controlled so as to give the maximum output power with a certain DC voltage. This control is based on the Maximum Power Point Tracking (MPPT) algorithm. [8].

These, techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change or wind speed, hardware needed for the implementation or popularity, among others. Some of the most popular MPPT techniques are:

- Perturb and Observe (hill climbing method).
- Incremental Conductance method.
- Fractional short circuit current.
- Fractional open circuit voltage.
- Fuzzy logic.
- Neural networks.
- Ripple Correlation Control.
- Current Sweep.
- DC-link capacitor droop control.
- Load current or load voltage maximization.
- dP/dV or dP/dI Feedback control [9].

MPPT for this work is :(Maximum power point tracking by incremental conductance method + Integral regulator). (Solar PV and WT).

I.2.2 Incremental Conductance Algorithm (Inc)

Due to the shape of the current–voltage characteristic of the PV module/array. The incremental-conductance (InC) MPPT technique operates by measuring the PV module/ array output voltage and current and comparing the value of $\frac{\partial I_{pv}}{\partial V_{pv}}$ with $-\frac{I_{pv}}{V_{pv}}$ then, the power converter is controlled based on the result of this comparison, according to the flowchart following:

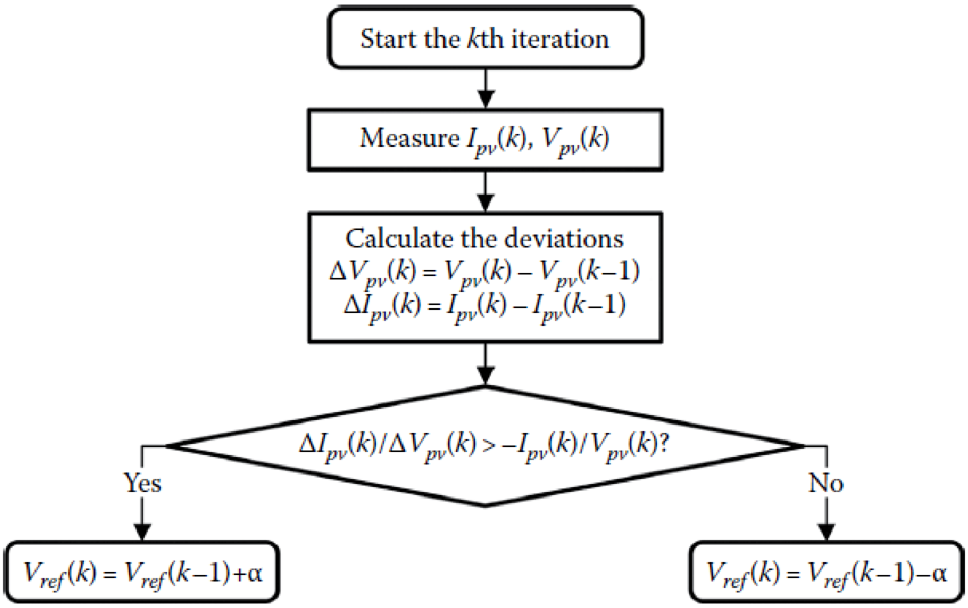

Figure 6: A flowchart of the InC MPPT algorithm based on the procedure presented in Elgendy et al. (2013)[10].

I.3 Problem formulation:

the minimization of the sum of the active power losses:

$$Fobj = \min \sum_{i=1}^{nbr} Plosses$$

Constraints are defined as follows :

The transited power limit of a branch :

$$\left| P^{ij(ligne)} \leq P^{ij(maxligne)} \right|$$

The amplitude of the voltage of each bus bar:

$$v_i \leq v_{i\,min} \leq v_{i\,max}$$

The limits of the powers generated by the DGs

$$P_{DGi}^{min} \leq P_{DGi} \leq P_{DGi}^{max}$$

II. Simulation Result and Discussion

1st segment with only DG (PV)

S=2500 MVA (apparent power)

V=25 KV (tension complexus)

F= 50 HZ (frequency).

Power active consumption total =32.1 MVA

Power active consumption = 2.4 MVAR

Selected PV characteristic

Module	Sunpower SPR-315-E-WHT-D
Parallel strings	66

Series-connected modules per string	5
Open circuit voltage Voc (V)	64.6
Short-circuit current Isc (A)	6.14
Voltage at maximum power point Vmp (V)	54.7
Current at maximum power point Imp (A)	5.76
Maximum Power (W)	315.072
Cells per module (Ncell)	96

Using data from our studied distribution network

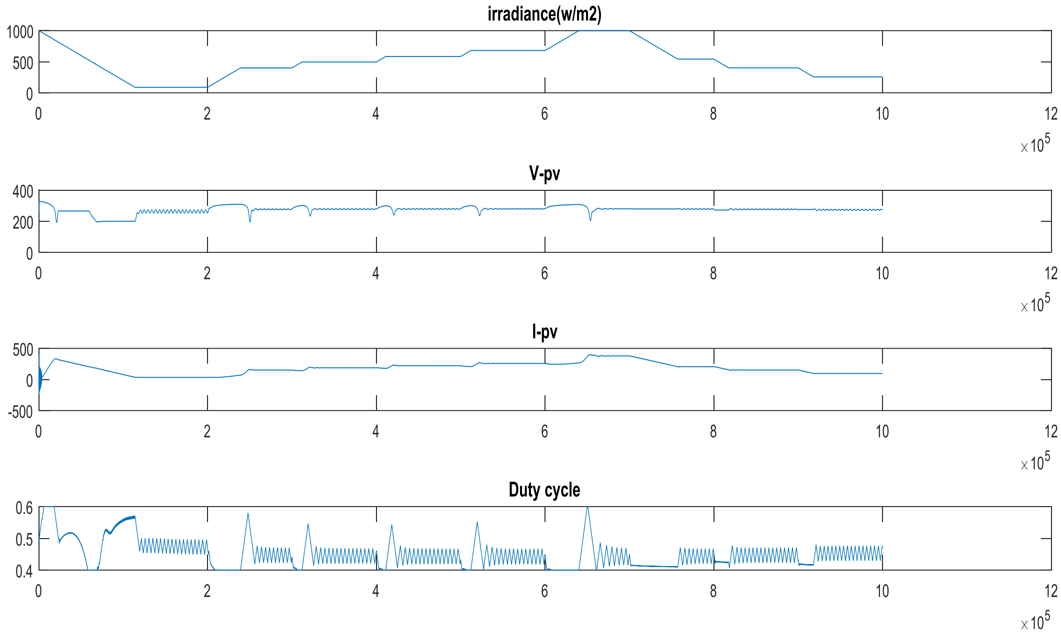

Figure 7: the voltage and current and power and the duty cycle as a fucntion of the variation of PV irradiance

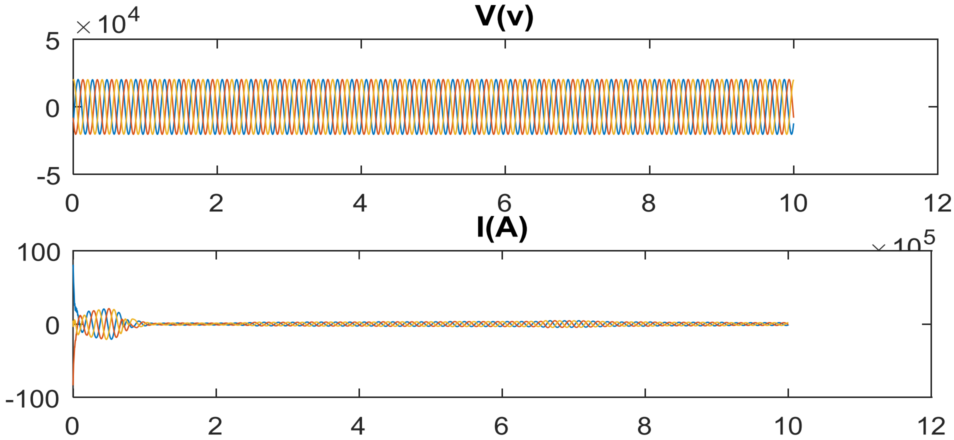

Figure 8: The voltage and current of grid graph as a function time

2nd segment with tow DG (PV+WT):

Selected WT characteristic

Nominal mechanical output power (W)	8500 λ_r
Base power of the electrical generator (VA)	8.5e3/0.9
Power factor	0.9
Base wind speed (m/s)	0.8
Maximum power at base wind speed (pu of nominal mechanical power)	0.8
Base rotational speed (p.u. of base generator speed)	1
Pitch angle beta to display wind-turbine power characteristics (beta >=0) (deg)	0
Stator phase resistance Rs (ohm)	0.425
Armature inductance (H)	0.000395

The relation between Cp and tip speed ratio λ_r at a particular value of blade pitch angle β will be presented represented in the following graph:

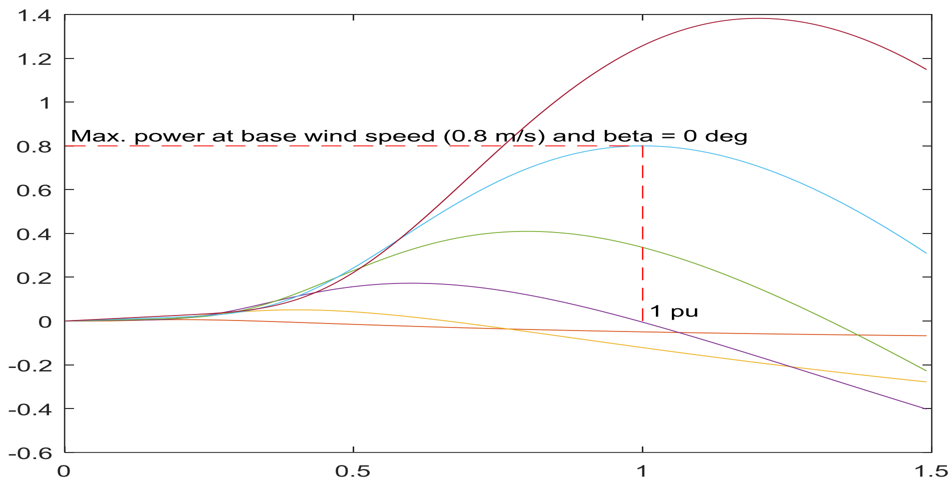

Fig. 9 Power coefficient Cp as a function of tip speed ratio

λ_r

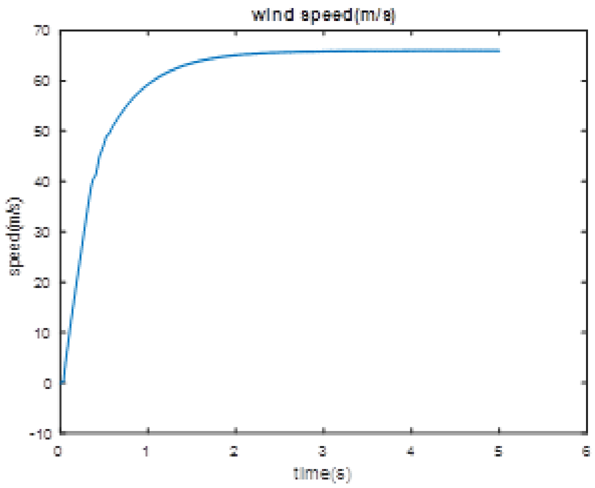

Figure 10: wind system speed characteristic

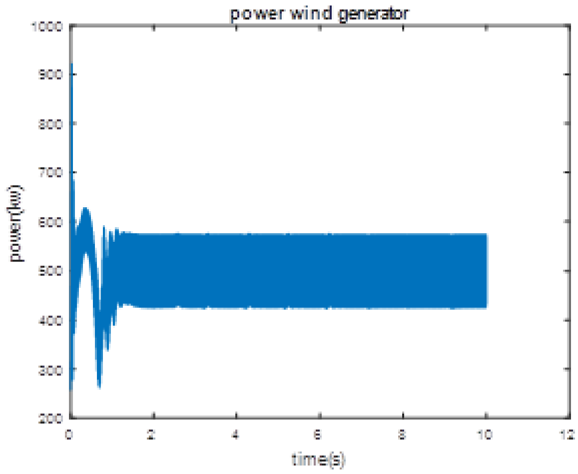

Figure 11: wind system generator characteristic

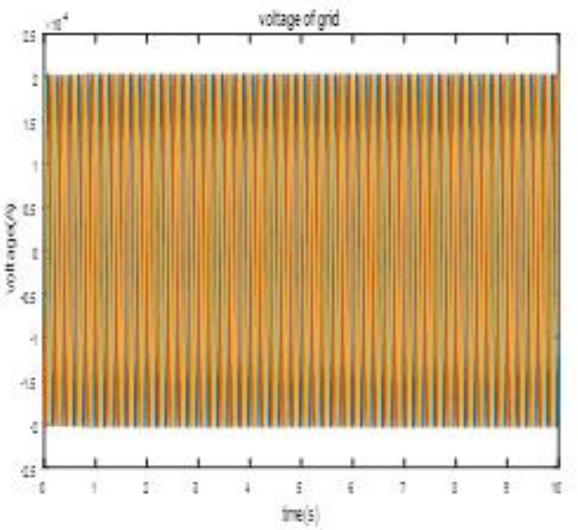

Figure 12: the voltage of grid graph as a function of time

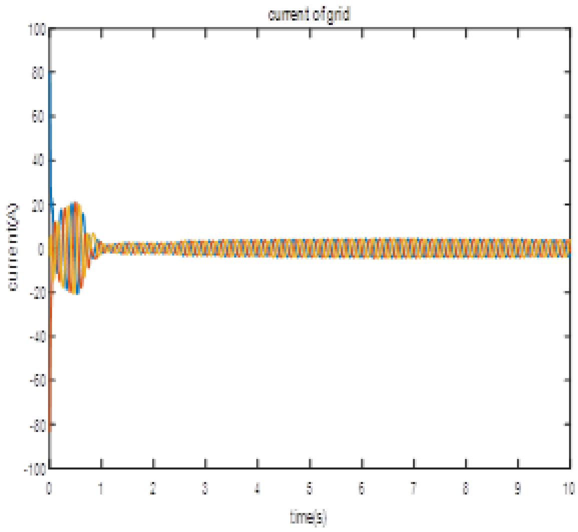

Figure 13: the current of grid graph as a function of time

Among the parameters affected on the efficiency of our energy source such as the wind speed factor for the WT also the temperature and solar arradiance.

From all these curves, we can see that consumption and PV and WT production (intermittent source) do not have the same pace during the day which can induce adverse changes in the voltage of the distribution network (especially surges due to the strong injection of power) and then require optimal integration of the DG and coordination between the voltage adjustment devices and even a reconfiguration of the network in an optimal way. If necessary.

The voltage profile is improved after the insertion of PV and WT arrived to a 20 kv base tension also increased power level

III. Conclusion

In this work, based on the climatic values of Laghouat, Algeria, for 01/01/2020, we have seen the effect of wind and solar energy on the distribution network taking into consideration the variation of the power generated by the PV and WT on the variation of the power requested under technical, safety and geographic constraints. By improving the quality of energy, both in voltage and reducing losses in the electrical network.

The (MPPT) Incremental Conductance Method, the main advantages of this method are that they are generic, that is, they are suitable for any PV array, they do not require any information about the PV array, they work reasonably well in most conditions, and they are simple to implement in a digital controller with minimum computational demand.

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