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CENTRALIZED ALGORITHM FOR WIND FARM SUPERVISION

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ABSTRACT
Nowadays, the research related to the wind farms is oriented to the development of supervision algorithm to manage the active and reactive powers as well as to provide an ancillary system. This paper proposes Proportional integral **[PI]** regulators algorithm for wind farm supervision. This control system is based on two control levels: A supervisory system controls active and reactive power of the whole wind farm by sending out set points to all wind turbines, and a machine control system ensures that set points at the wind turbine level are reached. The whole control is added to the normal operating power reference of the wind farm established by a Supervisory Control. Finally the performance of the proposed algorithm is verified through simulation results considering a wind farm of three generators **DFIGs** (1.5 MW).

***KEY-WORDS*: wind farm supervision, Doubly fed induction generators DFIG, PI Proportional Integral controller,**

1. INTRODUCTION

For several years, the environmental protection has caused much attention, and consequently, several technologies are developed. It's the case of the wind power. Nowadays, this source of energy is still used for water pump but it's mainly used for electricity production and this without any harmful impact to the environment. The high costs of exploitation of the nuclear, thermal power stations and the fossil fuels also, made possibility of wind power being more competitive.

Today, the rate of penetration of wind farms becomes increasingly significant in the electrical network. However, several problems of instability are generated at the time of the connection of these farms to the network, because so far it does not participate to the ancillary system (voltage regulation, frequency regulation, black-start, operation in islanding). Following these problems of instability of the electrical network; ones procedure of obliteration must be necessarily planned by the manager of network, which causes a forced disconnection of the wind generators based on the network instability, furthermore, the supervision of the wind farms is considered to be necessary in order to connect them to the electrical network without disregarding the quality of electric power produced.

The recent research tasks in the field of wind Farms are directed to design supervision algorithms for wind farm with the aim of distributing the references of active and reactive powers on different wind generators. In this context, several algorithms were proposed [2][8][10][18] and can be classified mainly in three categories:

The first algorithms are based on Proportional integral regulators PI; this class of algorithms regulates the problem of the supervision by using a simple PI regulator [1]. Two algorithms can be distinguished; the first uses this regulator to regulate the power-factor [2][3], while the second one regulates the active and reactive power directly [1] [10] [20], but the risk of the wind generators saturation is presented as the major problem of these algorithms, because the information on the maximum available active and reactive powers of each wind generators are not taken into consideration [19]. The second Algorithms are based on optimization of the objective function, which is used for the optimal active and reactive powers references distribution on the wind generators [1][16][18]. This function must formulate objectives, it is optimized by a mathematical equation which takes account of several parameters [19], it needs optimization methods like: genetic algorithm [12], neurons networks [6],[11], particles swarm optimization [3][7], and methods which combines the latter with fuzzy logic [1][17]. The last supervision Algorithms which are based on proportional distribution, were developed to distribute the power references in proportional way. From a safety point of view, these algorithms ensure that each wind generator works always far from its limits defined by the (P,Q) diagram[8][9][19]. They determine the references of the active and reactive powers of each wind generators P_{WG_ref} , Q_{WG_ref} from the global active and reactive power references required by the network system operator P_{WF_ref} . Q_{WF_ref} [13] [14] [10]. Nevertheless, the implementation of this strategy is a little bit complex since it needs information on the available aerodynamic power of all the wind generators [14].

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First, this paper describes briefly the studies carried out in order to develop a complete wind farm model made up with DFIM type generators. Then, a simple control algorithm -based on Proportional integral **[PI]** regulators algorithm for wind farm active and reactive power regulation is presented. The dynamic performance of the developed wind farm model together with its reactive power controller is simulated using MATLAB/SIMULINK. The simulation results illustrate good performance of this supervision.

II.POWER SYSTEM CONFIGURATION

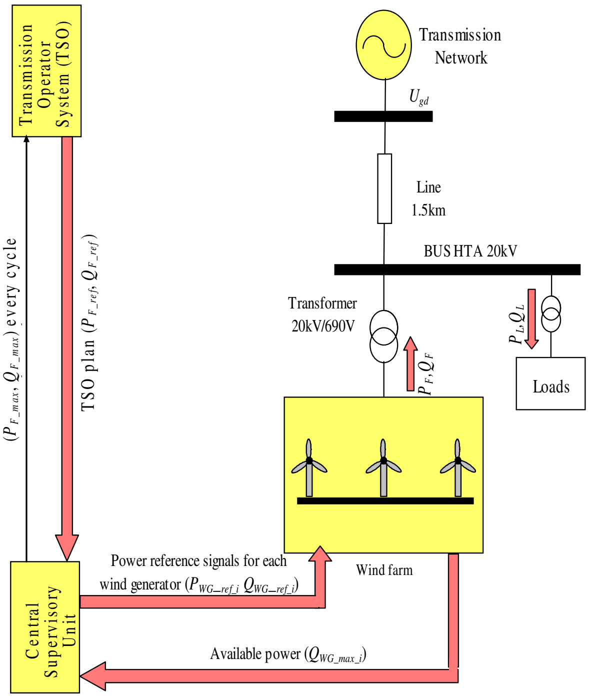

Fig.1 Power System Configuration [21]

The total diagram of an inter-connected electrical network which has several electrical devices is presented on fig.1, the wind farm is connected to HTA 20KV buses through a transformer of 20KV/690V.Differents fixed and variables loads are connected to the same bus with another transformer. A central unit of wind farm supervision is installed in order to control the exchanges (P_{WF} , Q_{WF}) powers with the electrical network [19].

The objective of this unit is a management of the total active and reactive powers of the wind farm according to a plan of production required by the system operator. On the hand, A central supervisory control level decides the active and reactive power references (P_{WF-ref} Q_{WF-ref}) for each wind generators local control level, based on received production orders (maximum production or power regulation ($P_{WF-\max}$, $Q_{WF-\max}$) from the system operator in other hand.

III. PI ALGORITHM FOR WIND FARM SUPERVISION

II.1.Principal of Operation

Generally, the reference value of the active power that a DFIG should generate is established through *optimum generation curves*, which provide the active power or the electromagnetic torque to be demanded to the generator as a function of its rotational speed. Such curves are derived as a result of thorough analysis of the wind turbine aerodynamics, and define the maximum mechanical power the DFIG can extract from the wind at any angular speed(fig.2). A considerable amount of references covering this topic in detail can be found throughout the bibliography[8] [19].

We consider a simple distribution of the active and reactive powers which consist on giving the same reference for each wind generator ($P_{WG-réf-i}$, $Q_{WG-réf-i}$). However, it is not immediate to determine the value of this reference but according to the power reference requested for the wind farm manager, by a control of the active and reactive powers at the level of the PCC (point of common coupling) the wind farm around a reference powers (Q_{WF-ref} , P_{WF-ref}). The Fig.3 shows the principle of this control; a PI regulator is used for Correct the error in power and gives the power reference in order to satisfy the request of Operator system. This algorithm of supervision generates the reference which will be distributed between the wind generators in identical way [8][4][5].

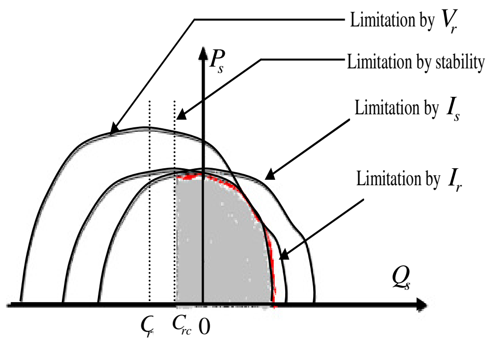

Fig.2: P-Q thermal limit curve for DFIM

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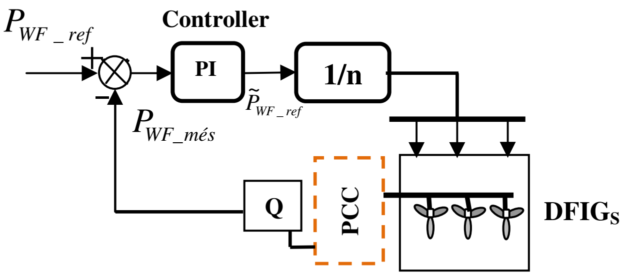
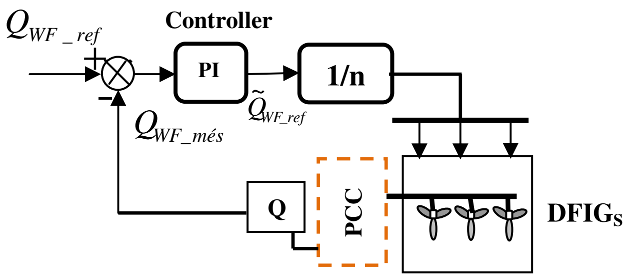


(a) Active power control



(b) Reactive power control

fig.3: Flow chart of control of the active and reactive powers in a wind farm

III.2 PI Algorithm Implementation

As is shown in Fig. 3, the PI controller receives from the transmission system operator **TSO** a reference of maximum active and reactive power (or voltage reference in some cases) that must not exceed the limit to guarantee the reliability on the grid. The control system consists of two control loops of active and reactive power, respectively. The active control loop receives active power reference, P_{WF_ref} , from the TSO and this value is compared with the active power measured in the interconnection point(PCC), $P_{WF\_més}$, the error is computed and a power reference for each wind turbine, P_{WG_ref-i} (i = 1:N_{WG} number of wind generators) is set up, through a dispatch function block. As for reactive power, the base value used in per unit representation is the same. The maximum possible reactive power demands, Q_{WF_ref} , from the TSO depends on the P-Q thermal limit curve capability of wind generators and compensating devices added to supply or absorb reactive power. This value defines the limits for the reactive power controller (see Fig. 2).
There are different ways to design the dispatch function Wind generators,(P_{WG_ref-i}, Q_{WG_ref-i}).The simplest strategy is considering that these references are directly the controller outputs, and the same for all wind generators. Note that if the power reference is increased when one or more wind generators have reached the limits, in the next controller computation, the rest of wind farms will automatically assume the load.

IV. SIMULATION RESULTS AND DISCUSSION

The validation of this type of supervision was made on the model of a wind farm of three wind generators situated in different wind profiles. In order to observe the behavior of this regulation we applied to our system different level of active and reactive powers.
The scenarios of simulation used an identical distribution of the active and reactive powers references for wind generators of wind farm [Fig.4, Fig.5].
Based on PSO for the application of the PI tuning we get the PI tuning parameters for the model as

Kp(active) = 0.5 Ki (active)=3.0
Kp(reactive) = 0.4 Ki (reactive)= 1.00

IV.1. Results obtained by PI controller for different wind generators

The simulation results show a good performance of the control system. The specified references both for the active and reactive power are achieved properly [Fig.4 Fig.5]
.

V. CONCLUSION

Even though the control algorithm based on the PI controller proposed in this paper is really robust under wind speed sudden changes, as it does not distribute the demanded reactive power among the DFIGs proportionally, in certain cases it might cause some of the wind generators to work just on their (P-Q) limits, saturated, while others would still be able to generate or absorb much more reactive power.
It can be concluded that wind farm supervision simulation results match, and evidence that active and reactive powers regulation in wind farms based on doubly fed induction generators may be accomplished robust and efficiently by means of the control algorithm suggested in this paper.

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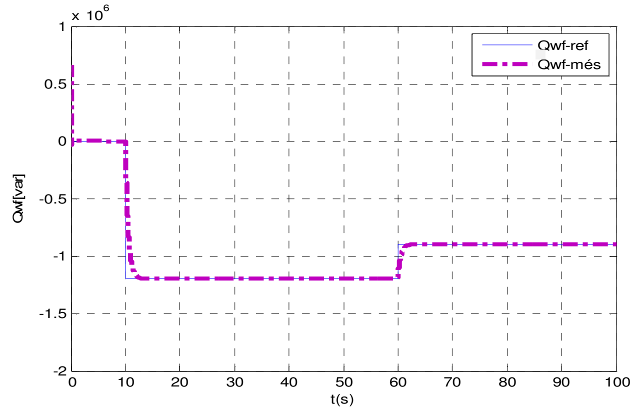
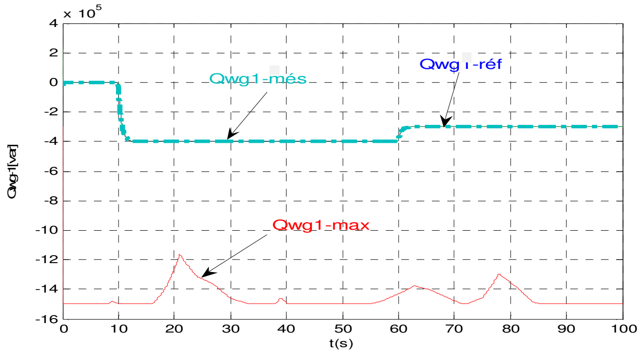
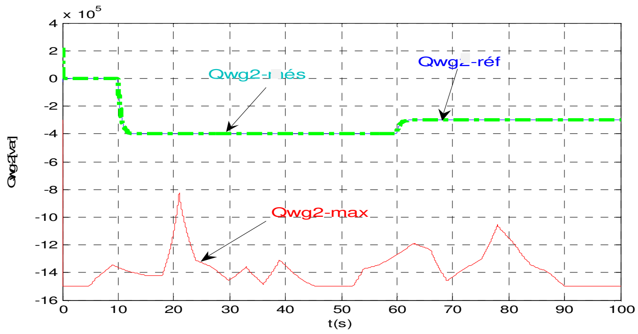


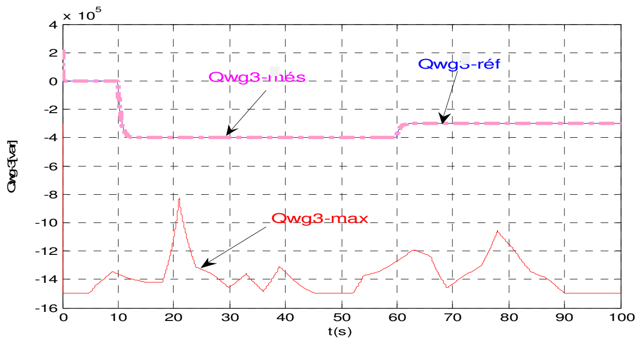
(a) reactive Power produced by the wind farm



(b) reactive produced by the first wind generator

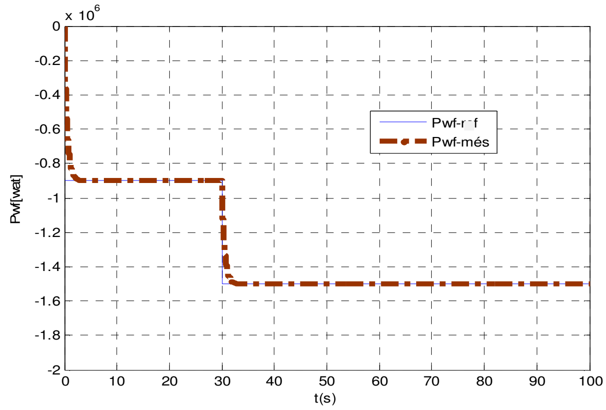


(c) reactive power produced by the second wind generator

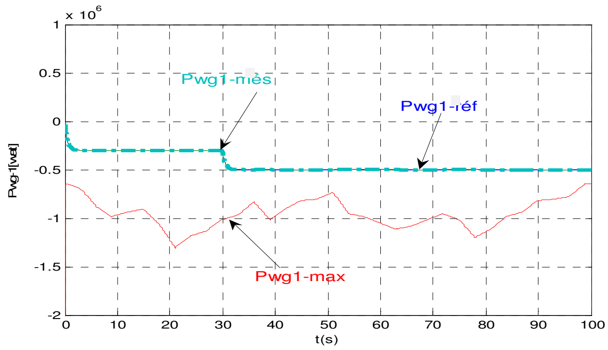


(d) reactive power produced by the third wind generator

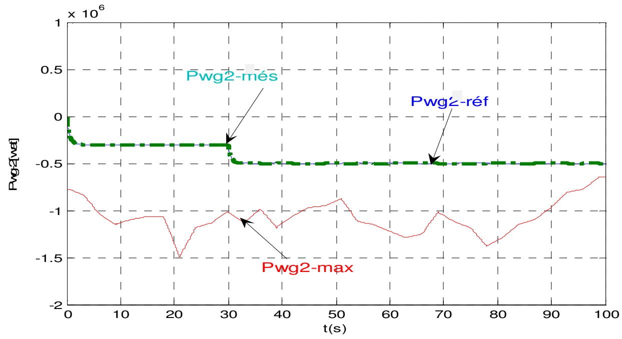
Fig.4.Simulation Results the centralized supervision of the reactive power [PI].



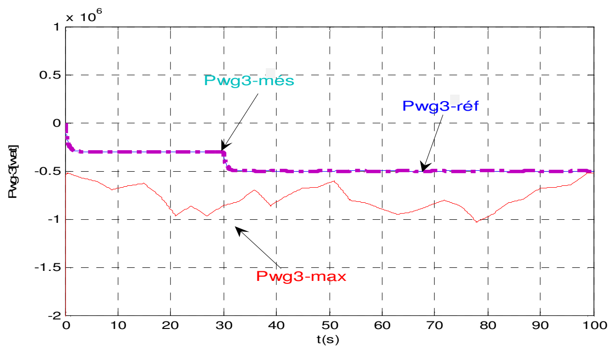
(a) active Power produced by the wind farm



(b) active power produced by the first wind generator



(c) active power produced by the second wind generator



(d) active power produced by the third wind generator

Fig.5.Simulation Results the centralized supervision of the active power [PI].

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