Proportional Distribution Algorithm for Wind Farm Supervision

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***Abstract* -- Nowadays, the research related to the wind farms is oriented to the development of improved supervision algorithm to manage the active and reactive powers as well as to provide an ancillary system. This paper proposes an PD (proportional distribution controller) algorithm for wind farm supervision. This paper presents a centralized supervision of the active and reactive powers control for a wind farm. A weighting distribution strategy has been used in order to determine the reactive power reference for each wind generator. The performance of the proposed algorithm is verified through simulation results considering a wind farm of three generators (1.5 MW).**

***Key-Words* -- wind farm supervision, PD (proportional distribution controller).MPPT.MADA**

I. 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][13][16][25] 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 [8]. Two algorithms can be distinguished; the first uses this regulator to regulate the power-factor [15][21], while the second one regulates the active and reactive power directly [1] [16] [27], 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 [8]. 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 [13][23][25]. This function must formulate objectives, it is optimized by a mathematical equation which takes account of several parameters [8], it needs optimization methods like: genetic algorithm [18], neurons networks [10],[17], particles swarm optimization [4][11], and methods which combines the latter with fuzzy logic [13][24]. 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[1][2][8]. 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} [8] [19] [20] [6]. 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 [20].

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The paper is organised as follows. First, the power system configuration is briefly presented. Then, the supervision algorithm in the wind farm is explained., the performance of the control strategy, when a given power demand is required from the system operator, is assessed and discussed by means of normal operation simulations of the wind farm. Simulation results are illustrated both at the wind farm level and at each individual wind turbine level.

II. POWER SYSTEM CONFIGURATION

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 [8].

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.

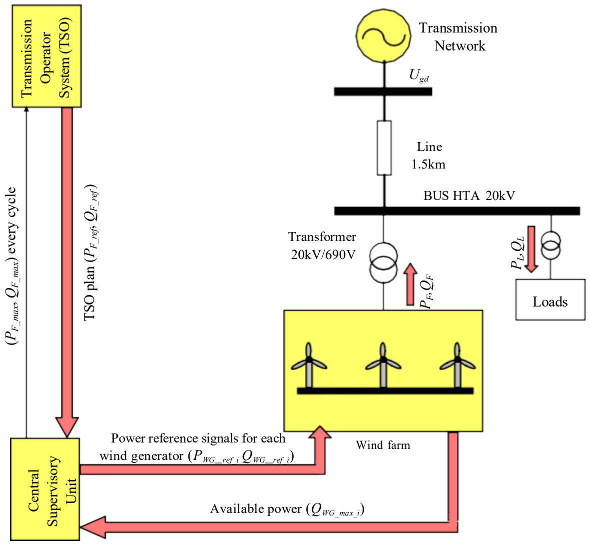

Fig.1. Power System Configuration [28]

III. PROPORTIONAL DISTRIBUTION(PD) ALGORITHM FOR WIND FARM SUPERVISION

As the wind farm active power generation is closely related to the wind speed, it is important to maintain the active power levels while ensuring are active power generation absorption. In consequence, it is important maintain the necessary power factor to achieve the correct electric parameters of the electric grid that the farm is connected to. Once the active and reactive power set points are defined, it is necessary to develop the control-law that will guide the system. There are different ways to design the control-law but the one presented in this paper is based on a proportional distribution of the active and reactive powers that the farm must generate, taking into account that the generated active power must be always the maximum obtained in each moment from the wind.

The designed control-law takes into account the machine operating limits and tries to follow the set point defined for the farm. This law appears in (1)(2).

$$P_{WG\_ref\_i} = \frac{P_{WF\_ref}}{P_{WF\_\max}} P_{WG\_\max\_i} \tag{1}$$

$$Q_{WG\_ref\_i} = \frac{Q_{WF\_ref}}{Q_{WF\_\max}} Q_{WG\_\max\_i} \tag{2}$$

Where, $P_{WG\_ref\_i}$ $Q_{WG\_ref\_i}$, are the active and reactive powers that each (i) machine must generate; $P_{WG\_\max\_i}$, $Q_{WG\_\max\_i}$, are the maximum active and reactive power that each machine can generate in one specific moment and P_{WF_ref} , Q_{WF_ref} , are the active and reactive power set point for the farm.

The procedure followed to implement the control law is described below:

1. Measurement of the active and active power produced in the farm
2. Read of the active and reactive power needed to maintain the electric parameters of the grid, (P_{WF_ref}, Q_{WF_ref} ,).
3. Measurement of the active power generated by each machine and its reactive power limit ($P_{WG\_\max\_i}$, $Q_{WG\_\max\_i}$)
4. Apply (1) (2) to calculate the active and reactive power that each machine ($P_{WG\_ref\_i}$ $Q_{WG\_ref\_i}$) must generate and send it to the machine as the active and reactive power sets points to follow.
5. Measurement of the active and reactive power generated by the overall farm.
6. Comparison between the sets points (P_{WF_ref} , Q_{WF_ref} ,) and the obtained active, reactive power and return to 2.

The main of supervision algorithem controller is shown in figure 2.

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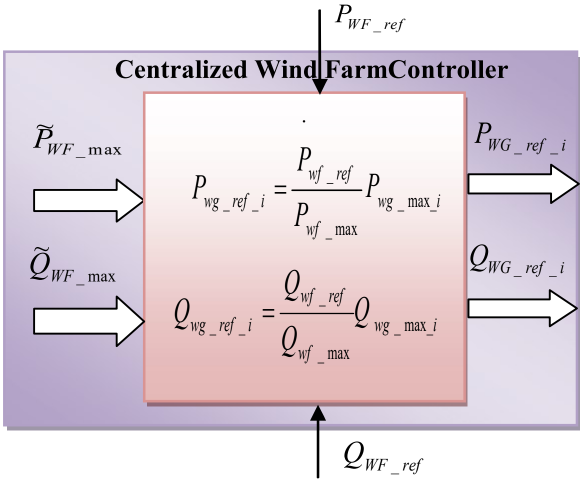

Fig.2 Wind farm control level.

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. Supposing that the wind generators of the wind farm are worked in "MPPT".

- simulation scenario : with the distribution of different references in Active and reactive powers we take into account the disconnection of each wind generators during the defects (saturation, short-circuits,). Figures [Fig.3, Fig.4] Show the dynamics of this control.

In order to demonstrate the performance of the wind farm Controller, it is considered that at the moments of [40 s .Fig.3] for the active power and [50 s .Fig.4] for the reactive power the first wind generator is disconnected from the farm, being thus unable to contribute with both active and reactive power, I.e.

Fig.3(a),Fig.4(a)illustrates both the available active power, actual active and reactive powers at the wind farm level, namely in the PCC of the wind farm. The disconnection of the first wind generator is illustrated as a step to another level of the available power. Noticed that the wind farm controller manage to keep the required 2 MW actual active power and 0.8 Mvar actual reactive power, in both cases before and after the disconnection of the first wind generator.

- **Fig.3 (b, c, d), Fig. 4 (b ,c ,d)** illustrates the Simulation results at the wind generators control level. At the moment of disconnection of the first wind generator, its active and reactive power reference signals becomes zero. The dispatch function block fig.2 recomputed then the references for the remaining two wind generators in order to maintain the 2 MW active power and the 0.8 MVar reactive power in the PCC. Noticing that the wind farm keeps the required 2 MW active power very smoothly (see Fig. 3.a), although the active power varies at the individual wind generators (see Fig.4 (b, c, d)). Noticing that the production of the active power and the absorption of reactive power from the two remaining wind generators increase to compensate the disconnected a first wind generator.

V. CONCLUSION

In this paper, the attention is mainly drawn to the capability of a wind farm controller to regulate the wind farm's production. The goal is to design a central controller, which, according to different control task imposed by the system operator, can control the active and reactive power injected by the whole wind farm into the grid. Central supervisory algorithms are implemented and tested by simulation, under Matlab-Simulink software, on a wind farm of three wind generators. The simulation results illustrate good performance of this modification.

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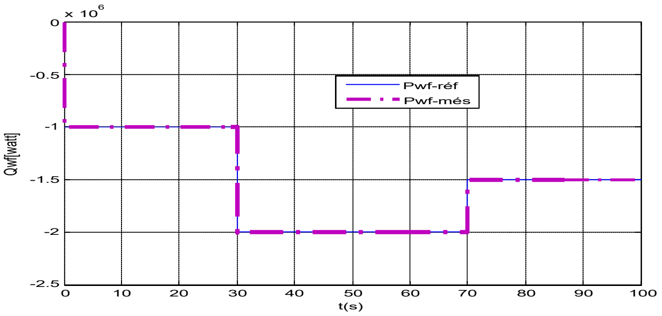
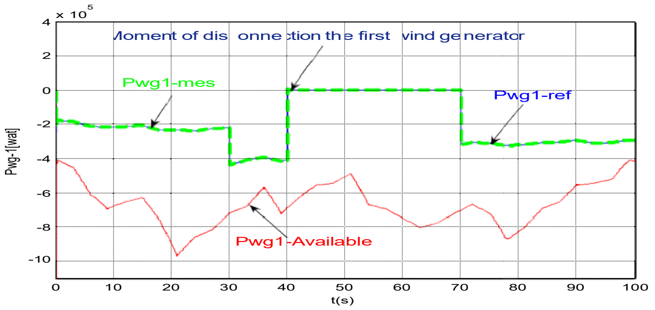
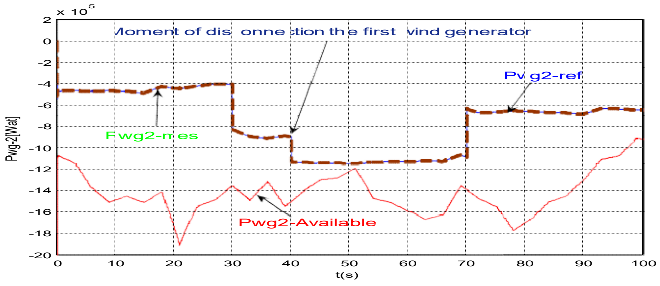


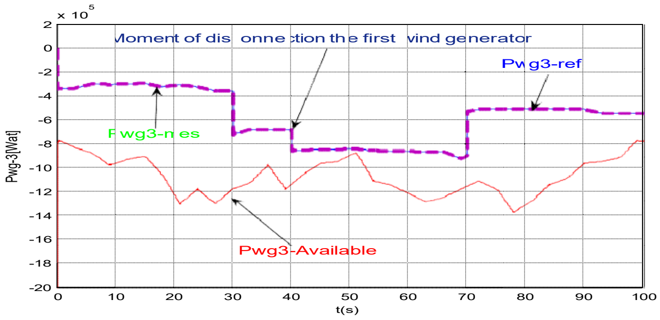
(a) active Power of the wind farm



(b) active power the first wind generator

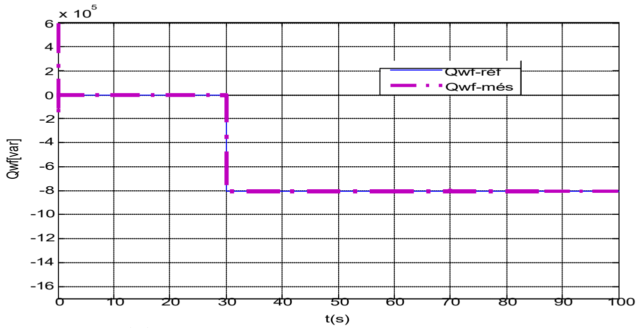


(c) active power the second wind generator

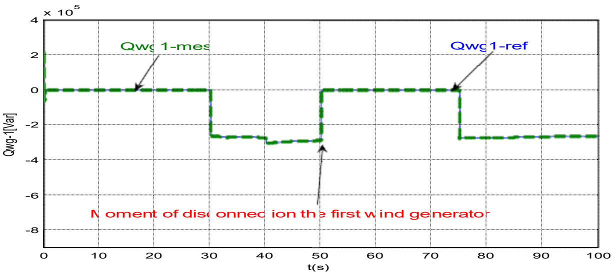


(d) active power the third wind generator

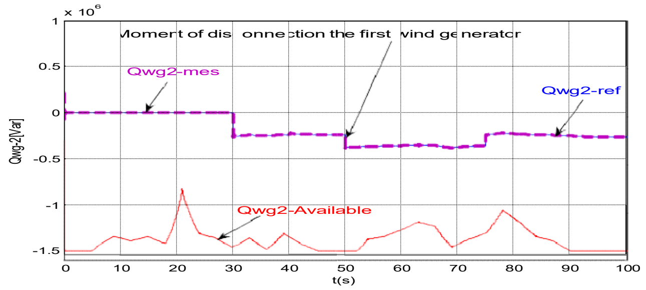
Fig.3 Simulation Results the centralized supervision of the active power [PD]: disconnection the first wind generator.



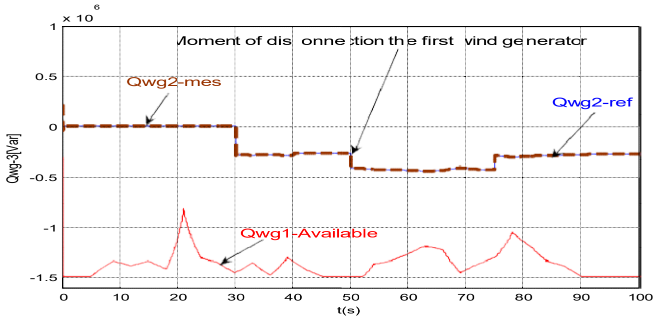
(a) reactive Power of the wind farm



(b) reactive power the first wind generator



(c) reactive power the second wind generator



(d) reactive power the third wind generator

Fig.4 Simulation Results the centralized supervision of the active power [PD]: disconnection the first wind generator.

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