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Implementation of Droop Control in Doubly Fed Induction Generator Based Wind Turbines

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ABSTRACT: Wind Energy is going to be a large part of power generation, However in addition to its intermittent nature that might lead to fundamental difficulties for Energy system reliability and stability, the conventional manage applied to wind turbines and their turbines, generally Doubly-fed induction mills (DFIGs), does now not enable them to take part in frequency regulation, whether short or long run. Furthermore, using wind turbines for autonomous frequency legislation is fitting an most important goal in power grids with lowered inertia and remoted micro-grid operation, even as Droop-control is recommended via many researchers to remedy these problems, special analysis of droop-controlled DFIG units in micro-grids has no longer been mentioned. To fill-out this gap, this paper presents torque- and power-droop implementations in DFIG-founded models by using some simple changes within the traditional manage and then, by way of small-signal modeling and Eigen-value reviews, suggests how both tactics have an impact on frequency stability. Sensitivity reviews, with appreciate to the presence of turbine- and inverter-based turbines in micro-grids, and affects of pitch-angle controller, wind velocity version and remoted mode operation with simplest wind-turbines, are carried out.

I. INTRODUCTION

The grid interaction and impacts of the wind turbines have been the focus of research over the years. There have been concerned about the intermittence nature of the power generated from wind turbines. These concerns are also the limiting factors to further increase the integration of wind power.

Wind turbines (WTs) can either operate at fixed speed or variable speed. For a fixed-speed wind turbine the generator is directly connected to the electrical grid. For a variable-speed wind turbine the generator is controlled by power electronic equipment. There are several reasons for using variable-speed operation of wind turbines; among those are possibilities to reduce stresses of the mechanical structure, acoustic noise reduction and the possibility to control active and reactive power. Most of the major wind turbine manufactures are developing new larger wind turbines in the 3-to-5-MW range [4]. These large wind turbines are all based on variable-speed operation with pitch control using a direct-driven synchronous generator (without gearbox) or a doubly-fed induction generator (DFIG). Fixed-speed induction generators with stall control are regarded as unfeasible for these large wind turbines [7]. Today, doubly-fed induction generators are commonly used by the wind turbine industry for larger wind turbines.

The major advantage of the doubly-fed induction generator, which has made it popular, is that the power electronic equipment only has to handle a fraction (20–30%) of the total system power. This means that the losses in the power electronic equipment can be reduced in comparison to power electronic equipment that has to handle the total system power as for a direct-driven synchronous generator, apart from the cost saving of using a smaller converter.

In this paper, it is shown that the employment of conventional power-droop in non-dispatchable wind power generationcould result in problems which could not be observed and evendiscussed in conventional dispatchable distributed generation(DG) units. The paper also shows that the simple yet effectivemethod of torque-

Droop could solve these problems. On the contrary, such a method could not be applied to conventional inverter-based dispatchable DG units.

II. EXISTING SYSYEM

Recently, and especially after introducing the concept of micro-grid to enhance supply reliability and increasing utilizationof inertia-less types of generation in power grids, it becomesessential for wind turbines to participate in frequency regulation. Even in the grid-connected mode, many grid codes have changed to allow or even force wind power generation to participate in primary frequency regulation [4]. Significant part of research efforts is devoted to the use of wind turbine rotating mass [7], whereas several proposals are made to provide this energy by deviating from maximum power extraction point [8], [9]. Interestingly, the use of frequency deviation, i.e., frequencydroop method, instead of frequency derivative, conventional inertia emulation, or at least a combination of both [4], is proposed. It is reported that this method has more advantages , however, detailed analysis was not provided to provethese arguments. It may be worthy to mention that in all of theseworks, a secondary, usually dispatchable, source of energy wasemployed to restore the frequency to its nominal value. Whilealmost all of the proposed methods for long-term participationof wind in frequency/power regulation agreed on deloading andusing droop control method, the adopted approaches are different. Many of these methods use wind speed for deloading; however, its accurate measurement does not seem easy [5]. Onthe other hand, the pitch-angle is used to deviate from optimum power extraction in [2] and [6], whereas the DFIG torque control and over-speeding [5] are used. In [11] it is reported that pitch-angle control is fast enough for deloading; however,comparative results among other techniques reveal its slowerbehavior. It is also suggested that similar to the conventionalwind control, pitch-angel could be utilized for high wind speedwhereas torque could be used for under-rated speeds [5]. Despite its advantages, this approach needs wind speed measurement for switching between both control methods. Usingboth methods simultaneously based on a fuzzy control is proposed in [8], however, similar to all discussed references, detailed stability analysis is not presented. In addition, none of mentioned papers, except a recently published Article [9], allude to the stand-alone operation of DFIG-wind generators inthe absence of any dispatchable sources. However, the work in [9] existing paper does not also include any stability analysis. Further, it onlyconsiders constant wind speed with always excessive generationand insteadof modifying the widely-accepted conventional control method, it proposes a completely new and relatively complicated method.

III. PROPOSED SYSTEM

In this paper, it is shown that the employment of conventional power-droop in non-dispatchable wind power generationcould result in problems which could not be observed and evendiscussed in conventional dispatchable distributed generation(DG) units.

The contributions of this paper to the researchfield are:

1) Developing a small-signal model for wind droop methods(power- and torque-droop) in DFIG-based wind generators. The models are used for comparative analysis and sensitivity studies;
2) Investigating the impact of wind-droop on micro-grid frequency stability by Eigen-values studies, and comparingthe impact of wind-droop to real inertia;
3) Providing a systematic approach to coordinate wind-droopwith other energy sources available in a typical micro-gridsystem (e.g., inverter-based and turbine-based generators);
4) Examining stand-alone operation of wind generation
(Without any dispatchable sources) in a micro-grid with
Real wind speed pattern.

IV. IMPLEMENTATION

DROOPIMPLEMENTATION INDFIG

DFIG-based wind power generator with interactive control for stiff-grid-connected and weak/micro-grid operation modes is shown in fig 1. The DFIG system is not required to contributeto voltage regulation when the generator is connected to a stiffgrid. In this mode, the DFIG is controlled to work at unity powerfactor. On the contrary, in islanding or weak grid mode the DFIGis forced to control its terminal voltage via the rotor-side converter (RSC) whereas the grid-side converter is controlled tooperate at unity power factor to Minimize the converter rating. The terminal voltage controller generates the reference reactive current component. More details on DFIG control structures can be found in [4]. During connection to a stiff grid, a DFIG is controlled to extract the maximum available power/torque, and it does not incorporatein frequency/active power regulation. On the contrary, in theislanding/weak grid mode, it switches to Droop control, whichcan be realized by torque-droop or power-droop. The referencetorque is used to generate the reference active current component. Conventional proportional-integral (PI) controllers areused to control the RSC currents. To incorporate wind in micro-grid frequency regulation and implement droop, enough reservepower should be considered in wind power generation.

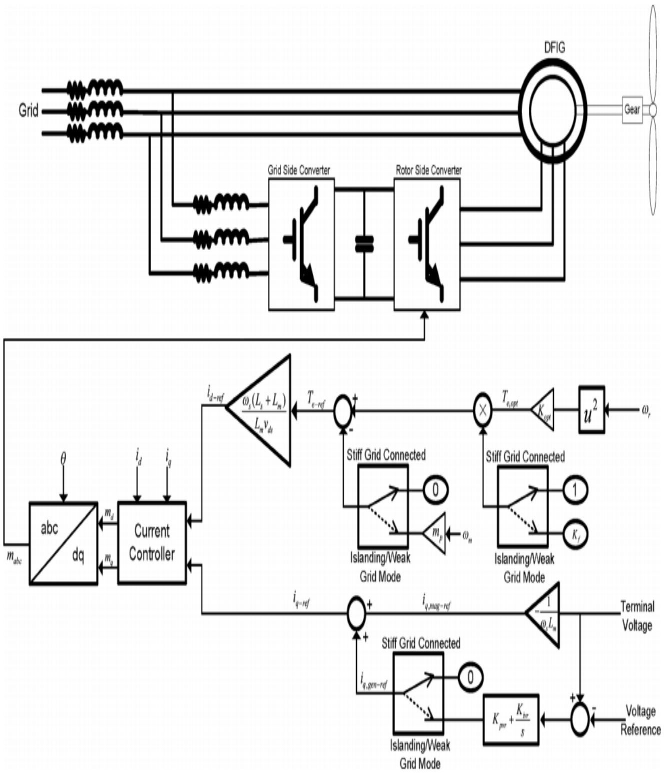


Fig.1. DFIG-based wind power generator with interactive control for stiff-grid connected and weak/micro-grid operation modes.

V. SIMULATION RESULTS

Two different scenarios are investigated. Thefirst deals with the case ofboth wind and gas turbine generators, whereas the second usesonly wind power generation. Eachscenario consists of differentcases.

A. Gas Turbine Plus Wind

1) Constant Wind Speed:

a) Under-Rated Speed:

Here the system frequencys shown Fig. 2 without wind-droop and with wind-droop implemented as Power-droop or Torque-droop at different droop gains.

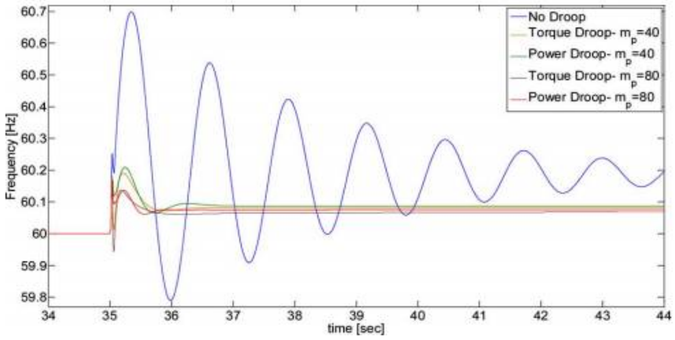


Fig: 2. Frequency response when wind speed is 13 m/sec and K_f = 0.5

b) Under-Speeding:

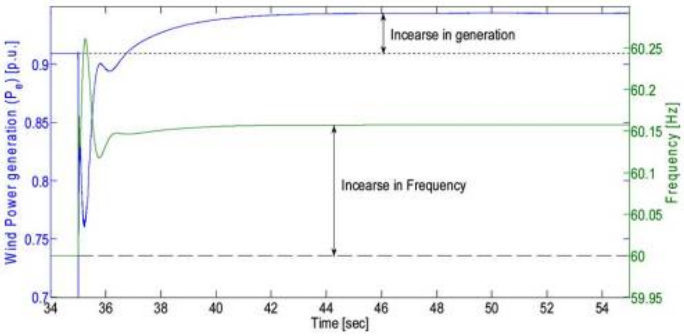


Fig:3. Frequency and wind power generation response when speed is constant at 13m/sec and K_f = 1.5, m_p= 40.

Here we observe that the wind generator output when K_f = 1.5, The system has excessive generation and also frequency has increased after islanding.

c) Inverter Interaction:

Fig. 4 shows the system frequency in several scenarios. While decreasing the inverter droop factor has worsen both the steady-state and the dynamic behaviours, the presence of wind-droop improves the system stability.

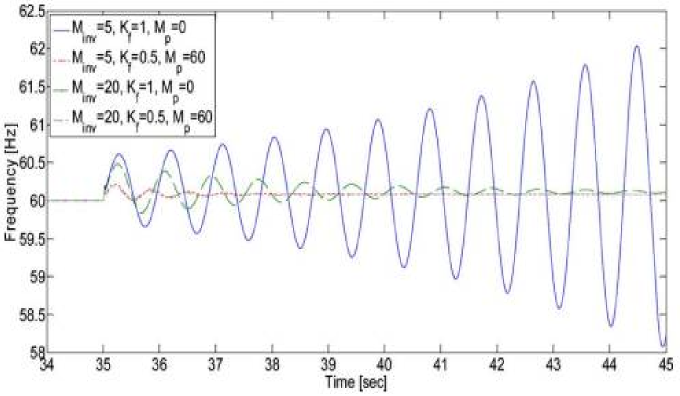


Fig:4. Frequency and wind power generation response when speed is constant at 13m/sec and K_f = 1.5, m_p= 40.

2) Variable Wind Speed:

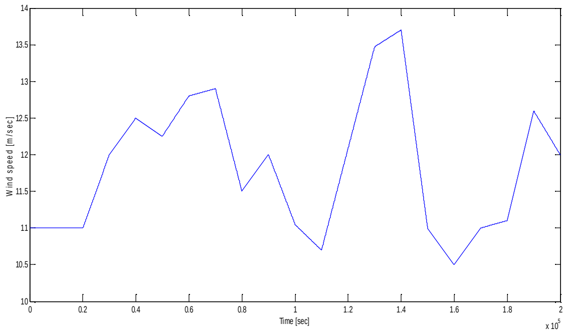


Fig.5. Real wind speed pattern

Here we discussed a real wind speed pattern, which is derived from real measured wind speed in wind turbine is used, and it is shown in Fig. 5.

a) Wind Droop:

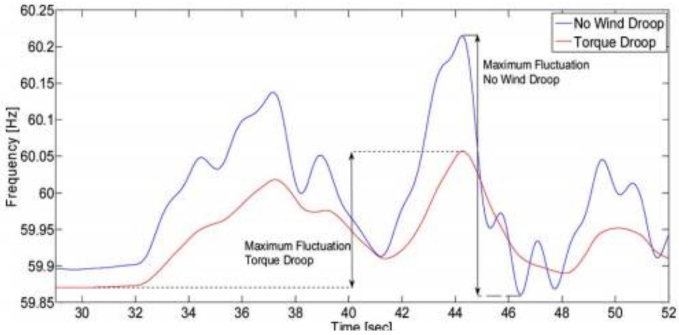


Fig.6. Frequency responses when wind speed is varying. Islanding had taken place long enough before wind speed starts to change.

Fig. 6 shows how wind droop has made the frequency smoother with less fluctuation. It reveals how the proposed method reduces the fluctuations in dispatchable source output.

b) Turbine Droop Factor

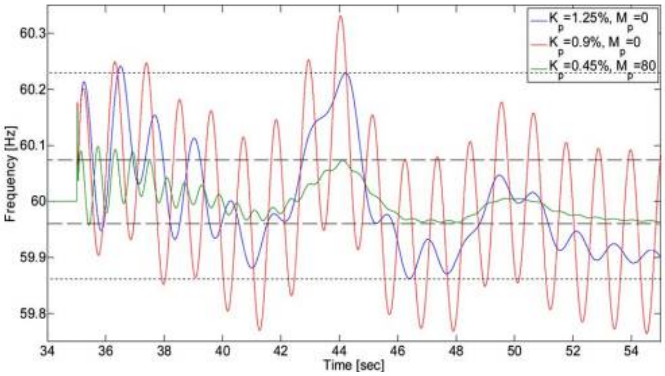


Fig.7. Frequency response when different turbine droop factors,K_p,are adopted.

Fig. 7 shows the presented analysis predicted that lowering, despite its positive impact on steady-state frequency deviation, may result in instability. It also verifies that the presence of wind-droop allows turbine to experience lower without facing stability problems.

B. Stand-Alone Wind

1) Single Wind Generation Unit:

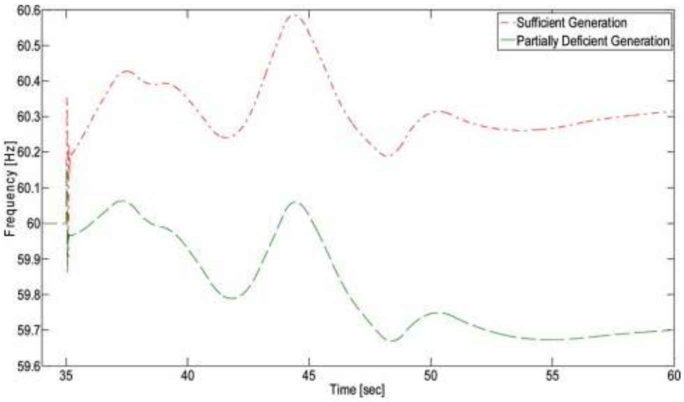


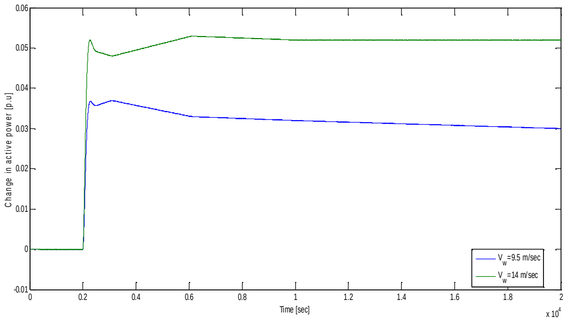
Fig.8. Frequency response for stand-alone wind power generation.

Fig. 8 depicts the frequency in both cases, which are stable. This experiment reveals that short-term deficiency in available wind power could be afforded due the kinetic energy provided by the rotating mass.

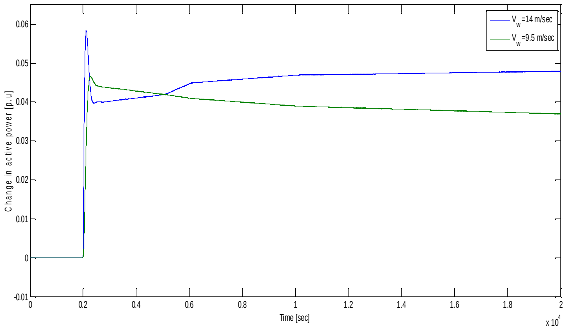
2) Multiple Wind-Power Generators:

a) Constant Wind Speed:

Fig. 9 shows the out power responses of both generators when Torque-droop and Power-droops are implemented. When torque-droop the generator with higher wind speed has higher share in power regulation. In contrast, power-droop yields almost equal power sharing. Here two generators are work. One of the generators works at 14m/s whereas the other operates at v_w = 9.5 m/s and the droop factor is the same for both.



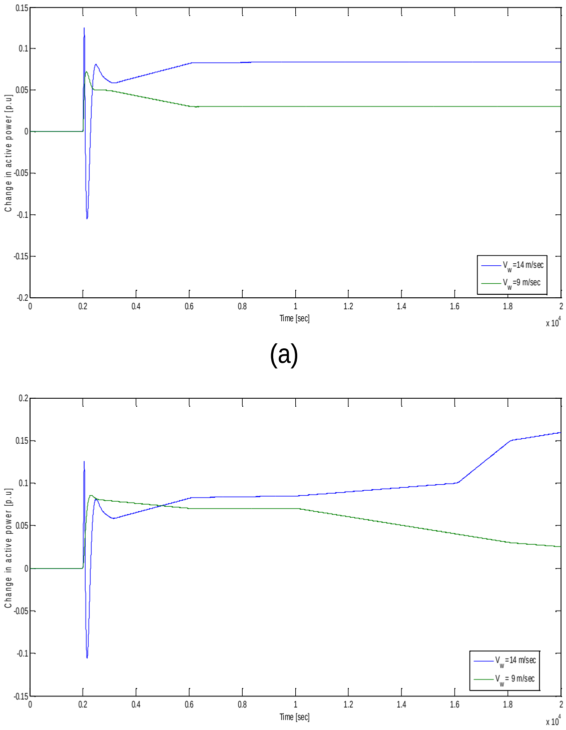
(a)



(b)

Fig.9. Changes in active power output of stand-alone wind power generations with different wind speeds,v_w, when droop is implemented in (a) Torque-Droop and(b)Power-Droop.

When compare to previous section it was reported that the almost constant effective droop factor of power-droop, while the deloaded power is not constant, could result in instability. The case of Fig. 10 confirms this argument which is similar to the case of Fig. 9 but now the lower wind speed is decreased from 9.5 to 9 m/s.



(a)

(b)

Fig. 10. Changes in active power output of stand-alone wind power generationswith different wind speeds,v_w, when droop is implemented in (a) Torque-Droop and (b)Power-Droop.

b) Variable Wind Speed:
(i) Similar Wind Speed Patterns

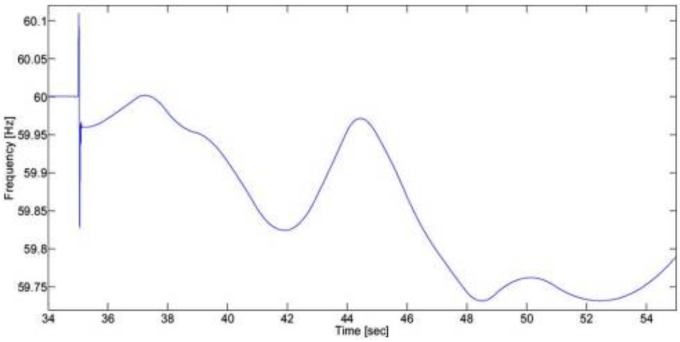


Fig.11. Frequency versus time when two stand-alone wind generators with identical wind speeds regulating the micro-grid frequency.

In this part, both wind power generators experience the same wind speed pattern shown in Fig. 5 . Figs. 11 show the frequency regulation when two stand –alone wind generators with identical wind speeds regulating the micro-grid frequency.

(ii) Different Wind Speed Patterns

A different wind speed pattern, derived from [10] and shown in Fig. 12, is used for one DG unit whereas the other unit still works with the previous wind speed pattern shown in Fig. 5 (shown by blue solid line in Fig.12).
Fig. 13 reveals the Micro-grid frequency response.

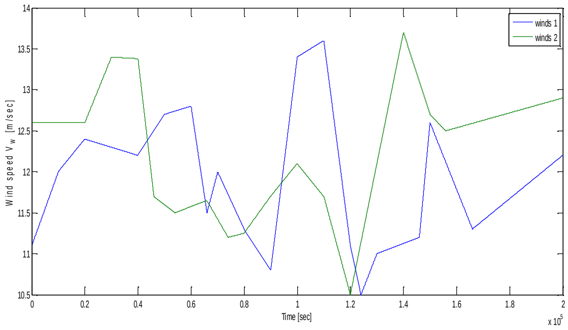


Fig. 12.Real wind speed pattern.

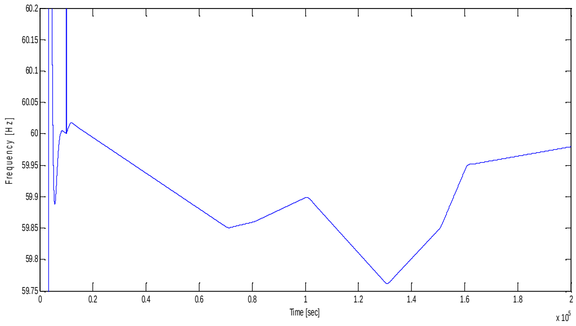


Fig.13. Micro-grid frequency response with different variable wind speed patterns.

(3) Compatibility between Torque-Droop and Power-Droops:

A question may arise about the compatibility between the Power-Droop and Torque-Droop as two possible droop methods. Withwind speed patterns are exactly the same, one of DG unitsis equipped with torque-droop whereas the other unit adoptspower-droop.

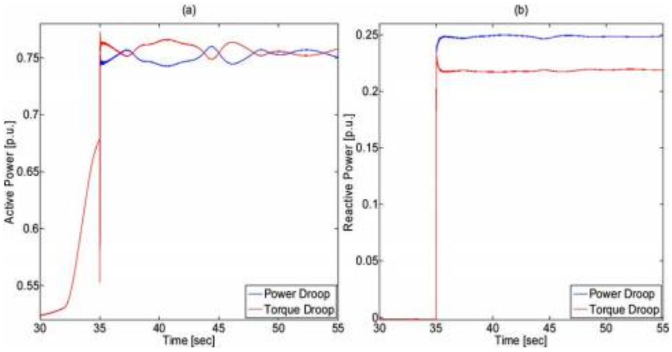


Fig.14. Wind (a) Active power and (b) Reactive power generation responses.

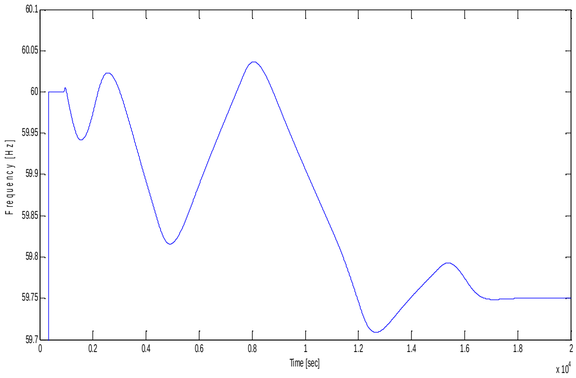


Fig.15. Micro-grid frequency response

VI. CONCLUSION

Existing method: When we are applying Conventional control method to wind turbines and their generators, then DFIG does not allow them to participate in Primary frequency regulation. And also detailed analysis not to be mentioned.

Proposed method : The Torque-Droop and Power-droop method are easily achievable methods to implement Droop-control in DFIG based wind power generation units, were analyzed and compare in this paper.

Small-signal analysis showed why under speeding should be avoided and how variance of effective Torque-droop could yield higher stability margins as compared to the Power-Droop method.

Eigen-values studies

1) proved the positive impact of wind-droop on system frequency-stability;

2) Showed that wind droop could compensate for the lack of inertia in a micro-grid in the medium-frequency range; and

3) Showed the positive influence of wind-droop on turbine governor and inverter droop functions.

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