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Droop Control in DFIG-Based Wind Turbines Implementation and its Analysis and Impacts on Microgrid Stability

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ABSTRACT: Wind Energy is going to be a large a part of power generation, 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 microgrid operation, even as droop-control is recommended via many researchers to remedy these problems, special analysis of droop-controlled DFIG units in microgrids 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 microgrids, and affects of pitch-attitude 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. 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. Today, doubly-fed induction generators are commonly used by the wind turbine industry (year 2005) 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 generation could result in problems which could not be observed and even discussed in conventional dispatchable distributed generation (DG) units. The paper also shows that the simple yet effective method 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 microgrid to enhance supply reliability and increasing utilization of inertia-less types of generation in power grids, it becomes essential 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. Significant part of research efforts is devoted to the use of wind turbine rotating mass, whereas several proposals are made to provide this energy by deviating from maximum power extraction point. Interestingly, the use of frequency deviation, i.e., frequency droop method, instead of frequency derivative, conventional inertia emulation, or at least a combination of both is proposed. It is reported that this method has more advantages, however, detailed analysis was not provided to prove these arguments. It may be worthy to mention that in all of these works, a secondary, usually dispatchable, source of energy was employed to restore the frequency to its nominal value. While almost all of the proposed methods for long-term participation of wind in frequency/power regulation agreed on deloading and using 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. On the other hand, the pitch-angle is used to deviate from optimum power extraction, whereas the DFIG torque control and over-speeding are used, it is reported that pitch-angle control is fast enough for deloading; however, comparative results among other techniques reveal its slower behavior. It is also suggested that similar to the conventional wind control, pitch-angel could be utilized for high wind speed whereas torque could be used for under-rated speeds. Despite its advantages, this approach needs wind speed measurement for switching between both control methods. Using both methods simultaneously based on a fuzzy control is proposed, however, similar to all discussed references, detailed stability analysis is not presented. In addition, none of mentioned papers, except a recently published article, allude to the stand-alone operation of DFIG-wind generators in the absence of any dispatchable sources. However, the work in existing paper does not also include any stability analysis. Further, it only considers constant wind speed with always excessive generation and instead of 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 generation could result in problems which could not be observed and even discussed in conventional dispatchable distributed generation (DG) units.

The contributions of this paper to the research field 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 microgrid frequency stability by eigen-values studies, and comparing the impact of wind-droop to real inertia;

3) providing a systematic approach to coordinate wind-droop with other energy sources available in a typical microgrid system (e.g., inverter- and turbine-based generators);

4) examining stand-alone operation of wind generation (without any dispatchable sources) in a microgrid with real wind speed pattern.

IMPLEMENTATION

DROOP IMPLEMENTATION IN DFIG

DFIG-based wind power generator with interactive control for stiff-grid-connected and weak/microgrid operation modes is shown in fig 1. The DFIG system is not required to contribute to voltage regulation when the generator is connected to a stiff grid. In this mode, the DFIG is controlled to work at unity power factor. On the contrary, in

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islanding or weak grid mode the DFIG is forced to control its terminal voltage via the rotor-side converter (RSC) whereas the grid-side converter is controlled to operate at unity power factor to minimize the converter rating. The terminal voltage controller generates the reference reactive current component. During connection to a stiff grid, a DFIG is controlled to extract the maximum available power/torque, and it does not incorporate in frequency/active power regulation. On the contrary, in the islanding/weak grid mode, it switches to droop control, which can be realized by torque-droop or power-droop. The reference torque is used to generate the reference active current component. Conventional proportional-integral (PI) controllers are used to control the RSC currents. To incorporate wind in microgrid frequency regulation and implement droop, enough reserve power should be considered in wind power generation.

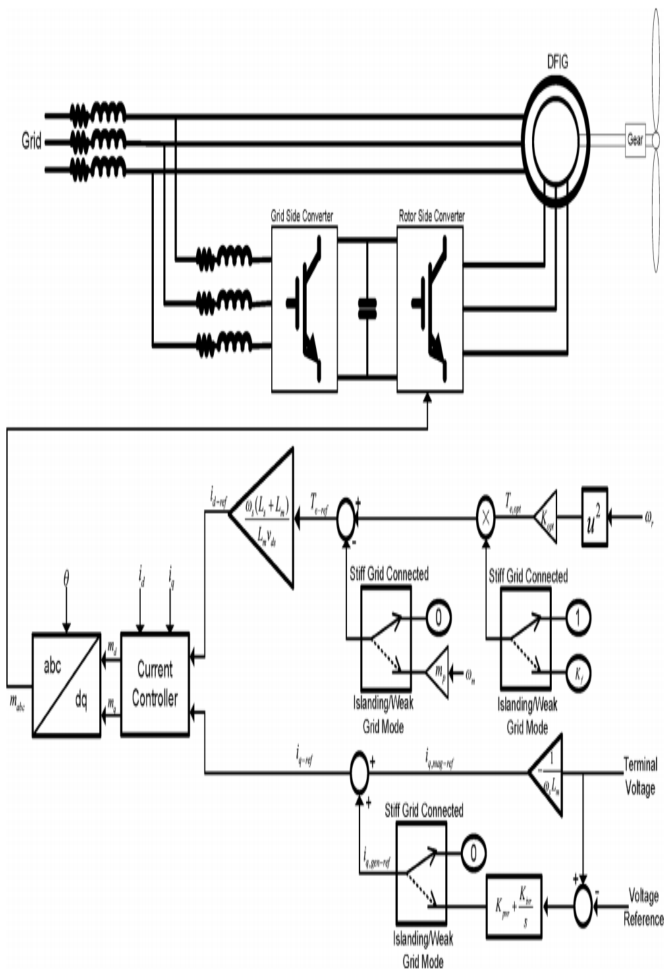

Fig.1. DFIG-based wind power generator with interactive control for stiff-grid connected and weak/microgrid operation modes.

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V. SIMULATION RESULTS

Two different scenarios are investigated. Thefirst deals with the case of both wind and gas turbine generators, whereas the second uses only wind power generation. Each scenario consists of different cases.

A. Gas Turbine Plus Wind

1) Constant Wind Speed:

a) Under-Rated Speed:

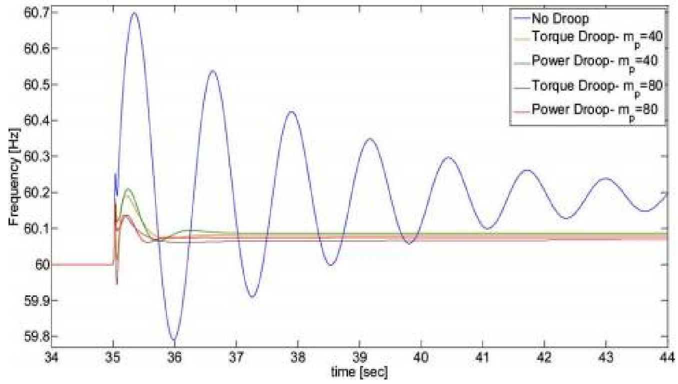

Fig: 2. Frequency response when wind speed is 13 m/sec and K_f = 0.5

b) Under-Speeding:

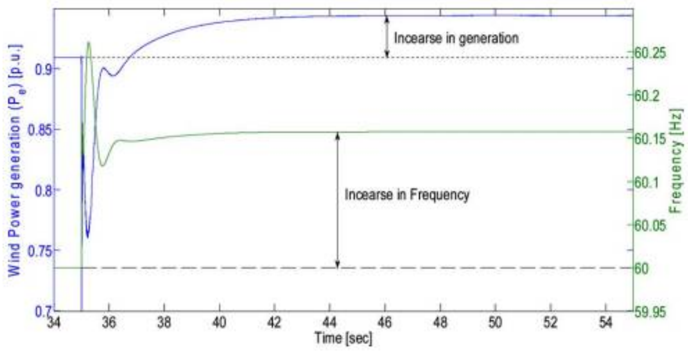

Fig:3. Frequency and wind power generation response when speed is constant at 13m/sec and K_f = 1.5, m_p = 40.

c) Inverter Interaction:

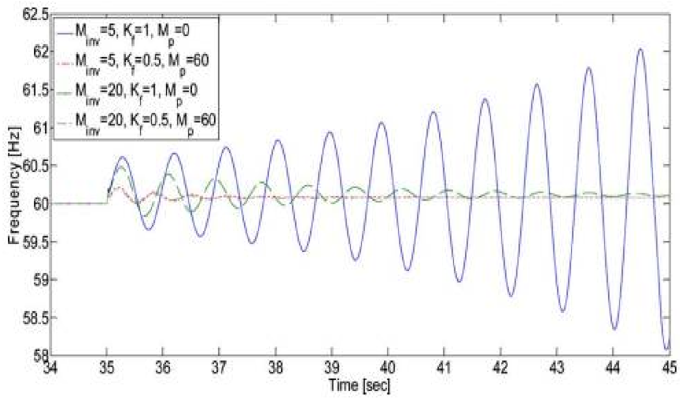

Fig:4. Frequency and wind power generation response when speed is constant at 13m/sec and K_f = 1.5, m_p = 40.

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2) Variable Wind Speed:

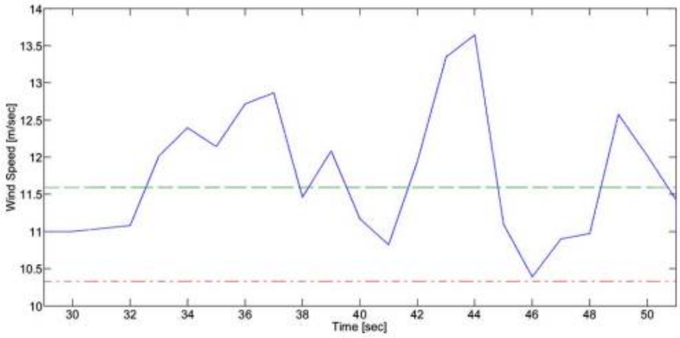

Fig. 5. Real wind speed pattern

a) Wind Droop:

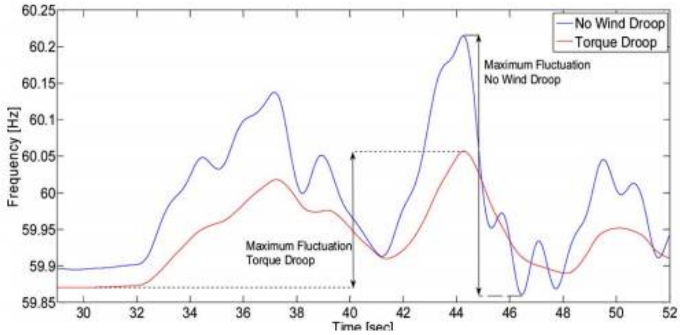

Fig. 6. Frequency responses when wind speed is varying. Islanding had taken place long enough before wind speed starts to change.

b) Turbine Droop Factor

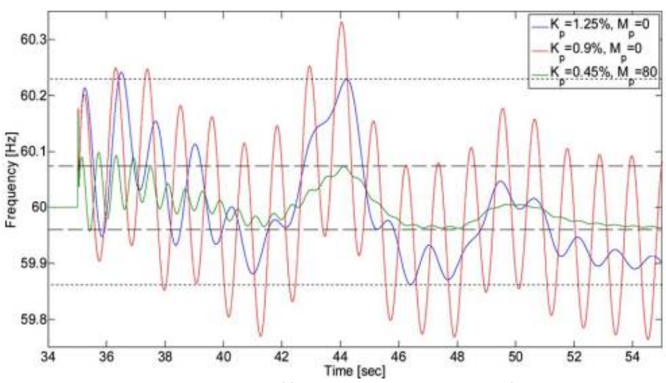

Fig. 7. Frequency response when different turbine droop factors, Kp, are adopted.

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B. Stand-Alone Wind

1) Single Wind Generation Unit:

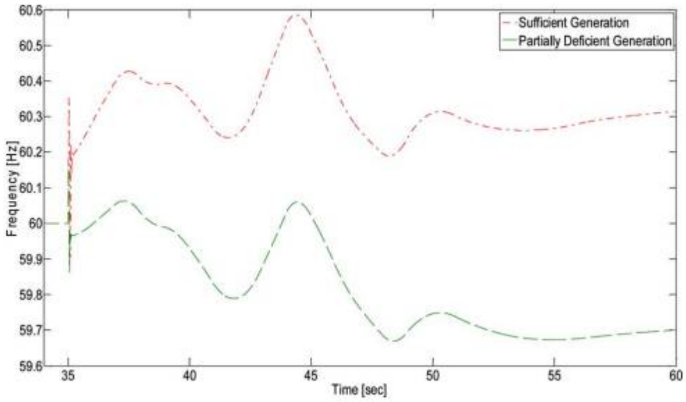
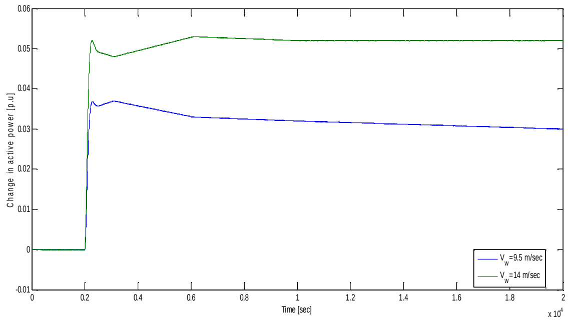


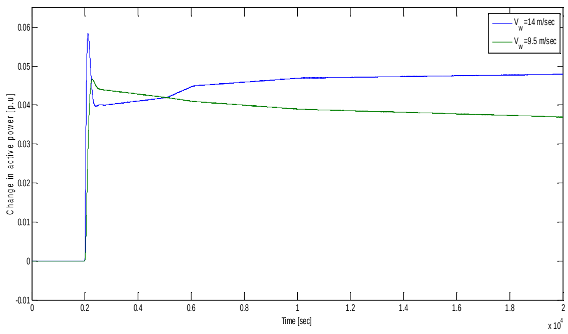
Fig. 8. Frequency response for stand-alone wind power generation.

2) Multiple Wind-Power Generators:

a) Constant Wind Speed:



(a)



(b)

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

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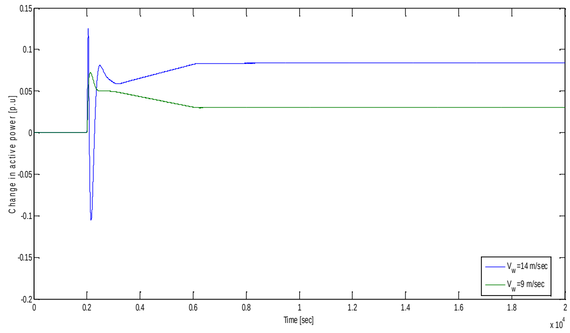
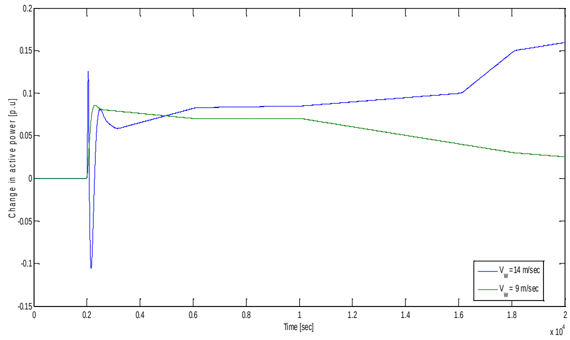


(a)



(b)

Fig. 10. Changes in active power output of stand-alone wind power generations with different wind speeds, Vm , when droop is implemented in (a) torque and (b) power.

b) Variable Wind Speed:
Similar Wind Speed Patterns

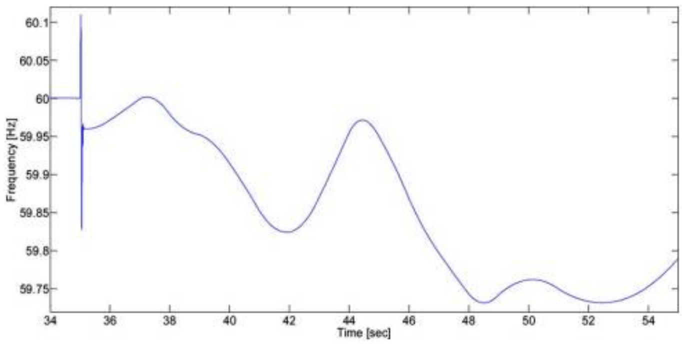


Fig. 11. Frequency versus time when two stand-alone wind generators with identical wind speeds regulating the microgrid frequency.

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Different Wind Speed Patterns

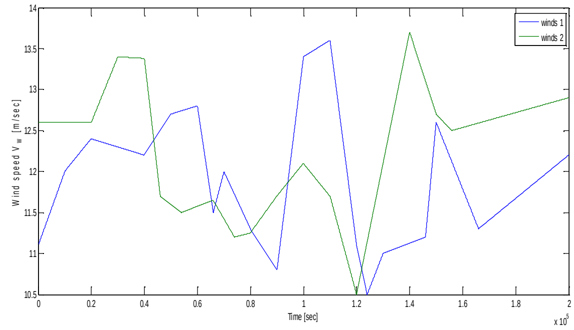

Fig. 12. Real wind speed pattern.

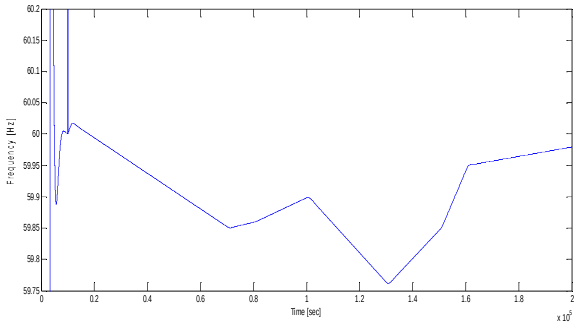

Fig. 13. Microgrid frequency response with different variable wind speed patterns.

(3) Compatibility Between Torque- and Power-Droops
A question may arise about the compatibility between the power and torque-droop as two possible droop methods. With wind speed patterns are exactly the same, one of DG units is equipped with torque-droop whereas the other unit adopts power-droop.

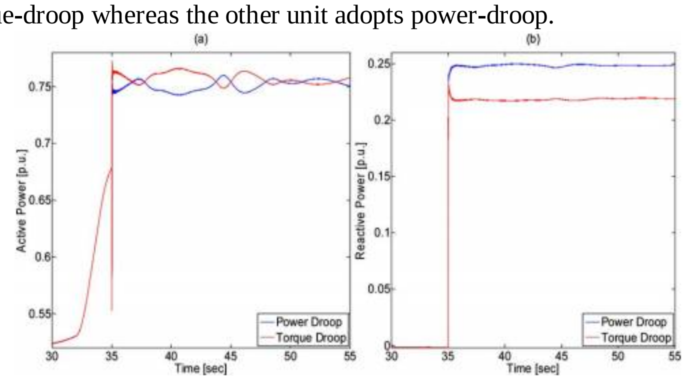

Fig. 14. Wind (a) active power and (b) reactive power generation responses.

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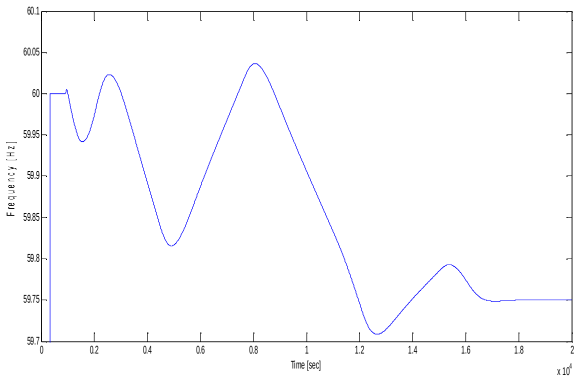

Fig. 15. Microgrid frequency response

VI. CONCLUSION

The torque- and power-droop, as two easily-achievable methods to implement droop-control in DFIG-based wind power generation units, were analyzed and compared 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 microgrid in the medium-frequency range; and 3) showed the positive influence of wind-droop on turbine governor and inverter droop functions. Time-domain simulations verified all analytical results and discussions; and showed that wind power generation with autonomous frequency regulation has the ability to stabilize the frequency in an isolated microgrid. Load sharing and coordination of two wind power generation in presence of real wind speed patterns and different wind-droop method were examined.

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