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Control and Analysis of Microgrid Frequency Droop with Fuzzy based WECS with EV

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***Abstract*— This paper presents an innovative technique in modern power grids that is to operate the combination of wind generators and plug-in hybrid electric vehicles (PHEVs) for alleviating the difficulties. In spite of all their benefits, these two kinds of sources are restricted by some physical constraints thus, both of these sources are incapable to work efficiently for regulating the primary frequency in grids with alleviated inertia. Nevertheless, the combination of wind generator and PHEVs are protecting the frequency during various circumstance over individual source. In this work, small signal system with fuzzy has suggested to examine the frequency regulation approach. Furthermore, the centralized and distributed control schemes are investigated in the presence of cooperation sources and does not occur any violation. The suggested approach shown the better performance over other conventional control techniques.**

***Keywords*— wind generator, plug-in hybrid electric vehicles, Fuzzy, Small signal, Sources, Centralized control.**

1. INTRODUCTION

In 2015, according to figures released by Energinet.dk, Danish wind turbines generated what corresponds to 42% of Danish electricity consumption. In Jutland and on Funen, in fact, wind power supplied more electricity than the total load for 1460 hours of the year. This is the highest figure ever, and the highest proportion for any country. In 2014, the figure was 39% - also a world record, and in 2013, 32.7%. These figures illustrate that the Danish and European energy systems are undergoing huge changes, and that renewable energy will change the way the electricity systems are operated. "Hours with wind power production exceeding consumption is not in itself unusual, but the fact that we are now generating surplus power 16 % of the time in the Western Danish power grid illustrates that increasingly fluctuating electricity generation means that we can benefit from imports and exports across borders to an even greater extent.

If, for some hours, we have surplus wind energy, the producers sell it to consumers in Norway, Sweden and Germany, and, conversely, we buy hydroelectric power from Norway, solar energy from Germany and power station electricity from Sweden, when it is advantageous for Denmark", said Carsten Vittrup, an energy strategy adviser for Energinet.dk's energy analysis section. Out of the year's 8760 hours, Western Denmark had 65 hours and Eastern Denmark 36 hours with 'negative prices', ie hours with electricity generation levels so high that producers must pay to get rid of the electricity.

One of the main reasons for 2015 being a record year is that it was a very windy year compared to 2014, which, from a wind perspective, was a normal year. Conversely, two offshore wind farms, Anholt and Horns Rev 2, were out of operation for one and two months, respectively, due to cable faults. Excluding these cable faults, the wind power share would have been about 43.5%. 2015 was also a spectacular year in other areas. For the first time ever, power was supplied to the grid for a whole day without any of the country's large central power stations being in operation. This has never happened before for an entire calendar day. On 2 September, the Danes were supplied with electricity exclusively from wind turbines, solar cells, local CHP plants and via imports from neighboring countries. Denmark also experienced the highest wind power share in any hour in 2015. On the 26 July between 6 and 7 am wind power production equaled 138.7 % of total consumption [1-3].

The introduction of the distributed generation concept paved the way for accommodating more renewable energy sources and emerging solutions, such as microgrids, to overcome several power system problems. However, some other concerns arise about the increasing penetration level of wind generators. Reference [4-5] showed how high contributions of wind plants could negatively affect the frequency stability and regulation of power systems, not only by injecting fluctuating active power, but also by replacing conventional generators which are traditionally responsible for providing inertia for power systems.

Plug-in (hybrid) electric vehicles (PHEVs) can be an effective choice to complement the dynamic characteristics of wind generators and facilitate their effective participation in primary frequency regulation. PHEVs are growing rapidly because of environmental concerns, and, with proper control and coordination, they can be effectively used to enhance the power system performance [6]. However, the inherent characteristics of PHEVs limit their use as independent resources for frequency regulation. Batteries of PHEVs are intended mainly for the traction mode of vehicles, and not for enhancing the power system; therefore, they cannot be charged or discharged like energy storages owned by utilities. Some researchers addressed this problem [7]-[9], whereas others paid attention to the dispersed and distributed nature of these resources, which necessitates some communication among them [10]-[12]. Furthermore, the possibility of asymmetrical contributions to the power system was investigated [13]. Because of these limits, PHEVs are considered as part of larger solutions in many studies, such as [14]-[15].

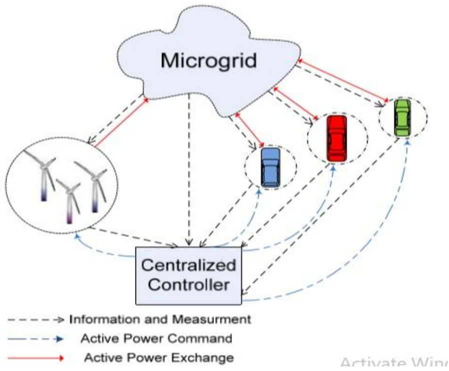


Fig.1 The structure of the centralized controller.

This paper presents an innovative technique in modern power grids that is to operate the combination of wind generators and plug-in hybrid electric vehicles (PHEVs) for alleviating the difficulties. In spite of all their benefits, these two kinds of sources are restricted by some physical constraints thus, both of these sources are incapable to work efficiently for regulating the primary frequency in grids with alleviated inertia. Nevertheless, the combination of wind generator and PHEVs are protecting the frequency during various circumstance over individual source. In this work, small signal system with fuzzy has suggested to examine the frequency regulation approach. Furthermore, the centralized and distributed control schemes are investigated in the presence of cooperation sources and does not occur any violation.

2. CENTRAL CONTROLLER

The PHEVs are fast power sources; however, their available energy for frequency regulation is limited on the other hand, wind generators are rich sources of energy, but fast interactions can result in their fatigue. These characteristics make these two sources great choices to complement each other. Therefore, the droop or the virtual inertia can be used by a centralized controller to decide how much power is needed to regulate the power system frequency, and then, the same control center can divide the power between these two sources based on their individual characteristics. The structure of the centralized controller is depicted in Fig.1. The controller gathers information from the microgrid, PHEVs and wind generator and sends back commands to the sources. As discussed, a low-pass filter (LPF) can be employed to share the power, but the coordination in practice is not straightforward because the energy storages units of the PHEVs are distributed and dispersed.

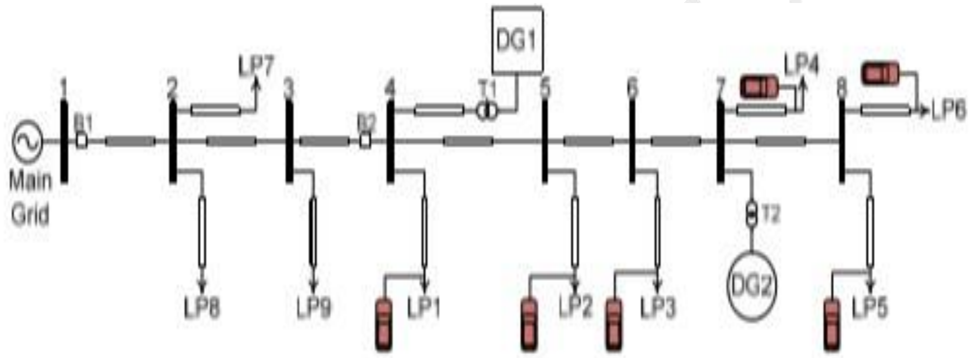


Fig.2 Studied system.

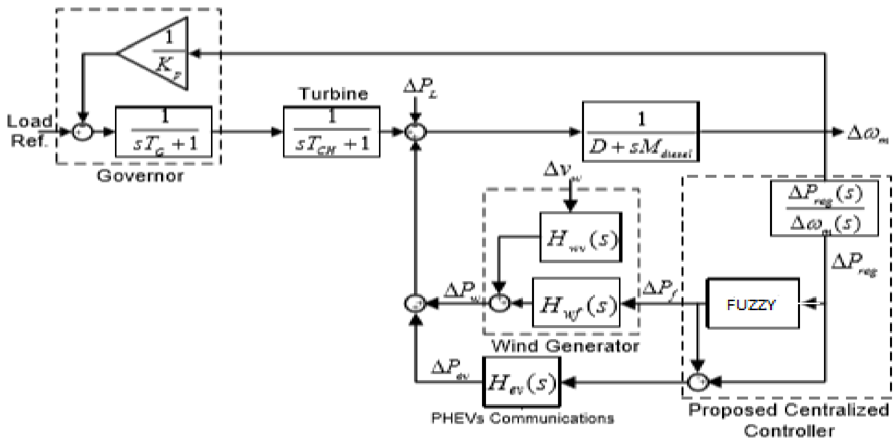


Fig.3 Proposed centralized controller.

For a meaningful analysis, a detailed model is needed. The system depicted in Fig. 2 is adopted in this paper. The system is a typical medium-voltage rural distribution system, a real system in Ontario, Canada.

connected to a 2.5 MVA PMSG with a full-scale converter. DG2 is a 2.5 MVA synchronous generator with droop and excitation control systems.The stability analysis can be extended to either larger microgrids or weak grids.

$$\Delta \dot{x}_w = A_w \Delta x_w + B_{wv} \Delta v_w + B_{wf} \Delta P_f .$$
$$\Delta P_w = C_w \Delta x_w + D_{wv} \Delta v_w + D_{wf} \Delta P_f .$$
$$\Delta H_{wv} = C_w (sI - A_w)^{-1} B_{wv} + D_{wv} .$$
$$\Delta H_{wf} = C_w (sI - A_w)^{-1} B_{wf} + D_{wf} .$$

3. DISTRIBUTED CO-OPERATIVE CONTROL

The generated reference power needed for the frequency regulation goesthrough an fuzzy or a high-pass filter (HPF) before reaching the wind and the PHEVs parking lots, respectively. Ideally, the system acts exactly like the perfect centralized controller. However, achieving such an ideal situation in reality is, if not impossible, rare. First of all, a delay could still exist. However,thanks to the distributed controller, the delays can be reduced dramatically with local measurements. Our studies showedthat delays of less than 20 ms had no significant impact even in the case of high contributions from the wind generator and PHEVs. Smart parking lots or aggregators in dense areas can easily communicate with their vehicles with such small delays via low-cost local networks, which already exist for billing and monitoring. However, as discussed in the following subsection, the distributed coordination scheme issubject to some other unique threats and opportunities. Because the power system is subject to continuous changes and no immediate direct communication occurs between the PHEVs and the wind generator, the proposed controller must be robust against miss coordination and provide accessible control leverages. These concerns are discussed in the following subsections.

WIND SPEED:

Anemometers are often attached to wind turbines to control the start-up mechanism of wind turbines in low wind speeds, and also the shutting down of wind turbines in dangerously strong winds. Wind speed is a contributing factor to the energy output potential of a wind turbine. The greater the wind speed, the greater the energy output, assuming everything else is kept unchanged. Wind speed has an approximately cubic relationship with energy output. So, for example, if you were to double the wind speed, you would increase the power output by 8 times, it is easy to see this relationship in the graph provided below. Notice from the graph that at very low wind speeds the power output is near zero. This is because all wind turbines have a distinct start-up speed and a cut-in speed.

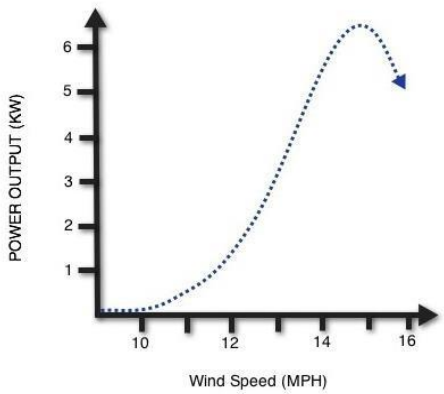


Fig.4 Power output based on wind speed.

The **start-up speed** is the minimum wind speed needed for the rotor and the blades to begin spinning, this low rotational speed will not provide any usable electric power. The more important, **cut-in speed**, is the wind speed at which the turbine generator will begin to produce electricity. This is a crucial piece of information to understand about wind turbine generators. Just because the rotor and the blades are spinning, it does not mean that the generator is producing power. At low wind and rotational speeds, the turbine generator will produce no power until the wind speeds reach the required cut-in speed for that particular wind turbine.

VARIOUS CUT-OFF FREQUENCIES

The energy injected by PHEVs may be increased by reducing the LPF cut-off frequency in some cases, flpf has no significant influence on the PHEVs power injection, as shown Maximum allowable HPF cutoff frequency, (b) The maximum frequency deviation at different LPF cut-off frequency. Impact of LPF cutoff frequency on (a) the maximum torque, (b) the maximum derivative of the torque of the shaft of the wind generator. Impact of LPF cutoff frequency on (a) the maximum energy, (b) the maximum power injected by PHEVs for the frequency regulation has shown. Because the PHEVs are used as the power sources, not energy, this almost constant power contribution means that the same number of the PHEVs is needed. In fact, separating the HPF and LPF in distributed coordination has resulted in this desired feature. In the centralized droop, the power injection of the PHEVs is highly dependent on the LPF cutoff frequency. In addition, the wind generator, and consequently the LPF, is more accessible to the system operator than the dispersed PHEVs HPF parameters. Without any need to change the control parameters of the dispersed vehicles, the mechanical tensions of the wind generator can be controlled without either significant changing in the system frequency behavior or involving more PHEVs in frequency regulation.

4. FUZZY DESIGN

The term fuzzy mean things which are not very clear or vague. In real life, we may come across a situation where we can't decide whether the statement is true or false. At that time, fuzzy logic offers very valuable flexibility for reasoning. We can also consider the uncertainties of any situation.

Fuzzy logic algorithm helps to solve a problem after considering all available data. Then it takes the best possible decision for the given the input. The FL method imitates the way of decision making in a human which consider all the possibilities between digital values Tand F.

It contains all the rules and the if- then conditions offered by the experts to control the decision-making system. The recent update in fuzzy theory provides various methods for the design and tuning of fuzzy controllers. This updatessignificantly reduce the number of the fuzzy set of rules.

Fuzzification:

Fuzzification step helps to convert inputs. It allows you to convert, crisp numbers into fuzzy sets. Crisp inputs measured by sensors and passed into the control system for further processing. Like Room temperature, pressure, etc.

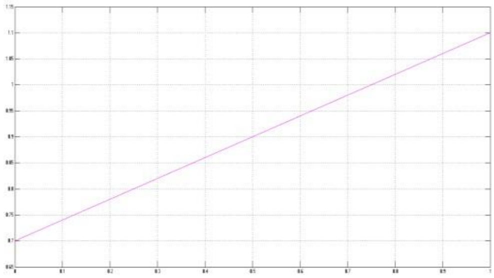
Inference Engine:

It helps you to determines the degree of match between fuzzy input and the rules. Based on the % match, it determines which rules need implement according to the given input field. After this, the applied rules are combined to develop the control actions.

Defuzzification:

At last the Defuzzification process is performed to convert the fuzzy sets into a crisp value. There are many types of techniques available, so you need to select it which is best suited when it is used with an expert system.

5. SIMULATION OUTCOMES



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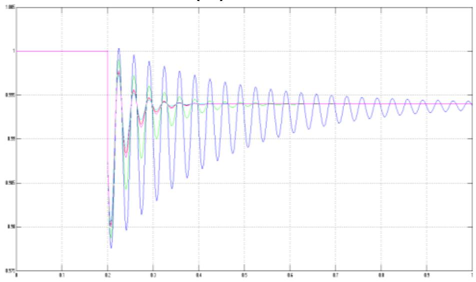
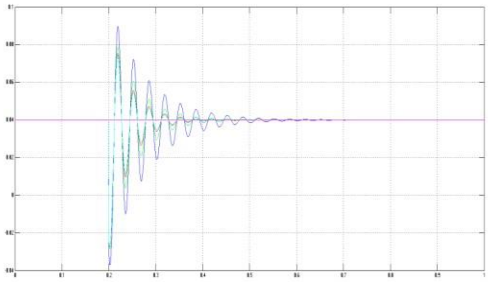
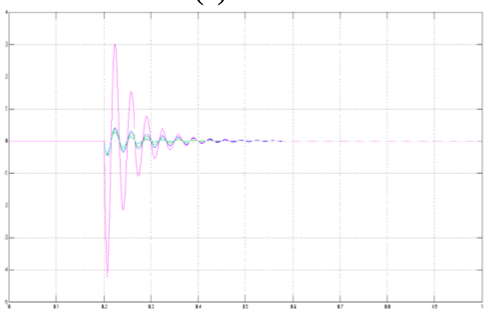


(b) Frequency

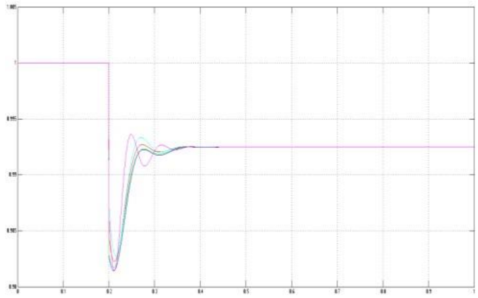


(c) Pev

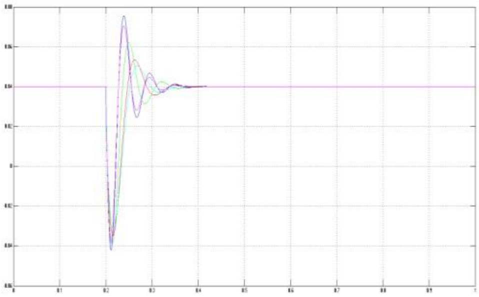


(d) ROCOTs

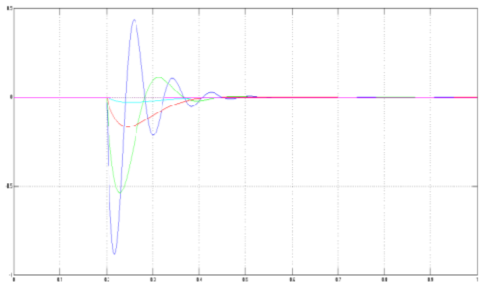
Fig. 20. Centralized control performance with *mp*=80 pu and *flpf*=0.25 Hz.



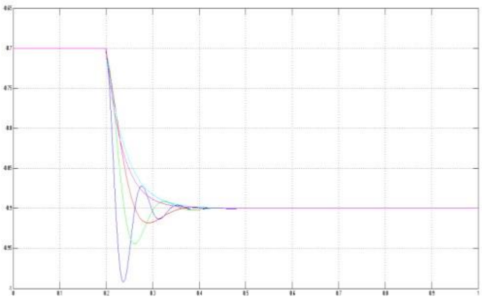
(a) Frequency



(b) Pev



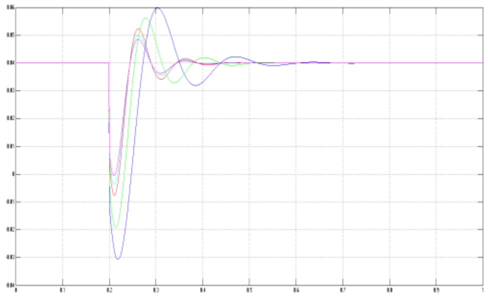
(c) ROCOTs



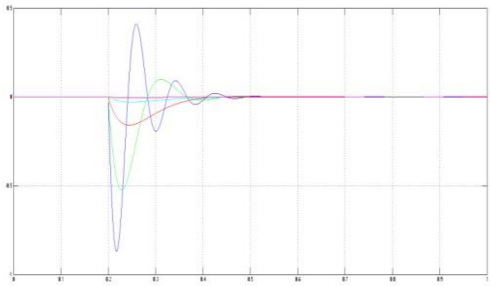
(d) Ts

Fig. Impact of the LPF cutoff frequency in distributed coordination.

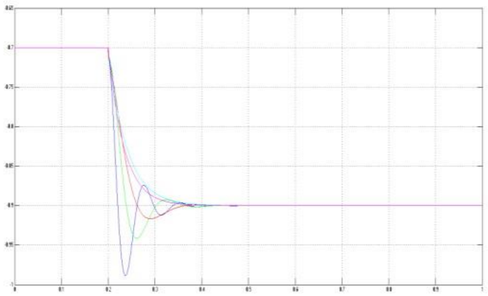
(a) y



(b) Pev



(c) ROCOTs



(d) Ts

Fig. . Impact of unequal droop gains when *mp,wind*=40pu, *flpf*=0.25Hz.

6. CONCLUSION

The coordination control of wind generator and PHEVs can compensate for each other's drawbacks and effectively participate in the primary frequency regulation of microgrids. The combination of both sources is coordinated each other at every perturbation and enhanced the system dynamic performance. As per the simulation outcomes, the virtual inertia does not appropriate to the frequency regulation tool for coordinated control. Furthermore, centralized coordinate control approach is rather suitable for a small contribution of wind and PHEVs in the presence of rapid communication system. The suggested approach shown the better performance over other conventional control techniques.

References

[1] "Global wind energy outlook," 2014 [Online]. Available: www.gwec.net.

[2] "Wind by Numbers: Economic Benefits of Wind Energy" from Canadian Wind Energy Association [Online]. Available: http://www.canwea.ca

[3] "New record-breaking year for Danish wind power", ENERGINET official Website, 2016.

[4] H. Polinder, F. van der Pijl, G.-J. de Vilder, P. J. Tavner, "Comparison of direct-drive and geared generator concepts for wind turbines," IEEE Trans. Energy Convers, vol.21, no.3, pp.725-733, Sept. 2006.

[5] N. Nguyen et. al., "An Analysis of the Effects and Dependency of Wind Power Penetration on System Frequency Regulation," IEEE Trans. on Sustainable Energy, vol. 7, no. 1, pp. 354-363, Jan. 2016.

[6] M. Yilmaz, et. al., "Review of the Impact of Vehicle-to-Grid Technologies on Distribution Systems and Utility Interfaces," IEEE Trans. on Power Electronics, vol.28, no.12, pp.5673-5689, Dec. 2013.

[7] H. Liu, et. al., "Decentralized Vehicle-to-Grid Control for Primary Frequency Regulation Considering Charging Demands," IEEE Trans. on Power Systems, vol. 28, no. 3, pp. 3480-3489, Aug. 2013.

[8] H. Yang, C. Y. Chung, J. Zhao, "Application of Plug-In Electric Vehicles to Frequency Regulation Based on Distributed Signal Acquisition Via Limited Communication," IEEE Trans. Power Sys, vol.28, no.2, pp.1017, May 2013.

[9] T. Liu, D. J. Hill and C. Zhang, "Non-Disruptive Load-Side Control for Frequency Regulation in Power Systems," IEEE Trans. on Smart Grid, vol. 7, no. 4, pp. 2142-2153, July 2016.

[10] H. Liu, et. al., "Vehicle-to-Grid Control for Supplementary Frequency

Regulation Considering Charging Demands," IEEE Trans. on Power Systems, vol. 30, no. 6, pp. 3110-3119, Nov. 2015.

[11] T. Masuta, et. al., "Supplementary Load Frequency Control by Use of a Number of Both Electric Vehicles and Heat Pump Water Heaters," IEEE Trans. on Smart Grid, vol. 3, no. 3, pp. 1253-1262, Sept. 2012.

[12] M. F. M. Arani, Y. Mohamed, et al., "Analysis and Mitigation of the Impacts of Asymmetrical Virtual Inertia," IEEE Trans. on Power Systems, vol. 29, no. 6, pp. 2862-2874, Nov. 2014.

[13] C. Gouveia, et. al., "Coordinating Storage and Demand Response for Microgrid Emergency Operation," IEEE Trans. on Smart Grid, vol. 4, no. 4, pp. 1898-1908, Dec. 2013.

[14] S. Gao, et. al., "SMES Control for Power Grid Integrating Renewable Generation and Electric Vehicles," IEEE Trans. on Applied Superconductivity, vol. 22, no. 3, pp. 5701804-5701804, June 2012.

[15] M. Datta, et. al., "Fuzzy Control of Distributed PV Inverters/Energy Storage Systems/Electric Vehicles for Frequency Regulation in a Large Power System," IEEE Trans. on Smart Grid, vol. 4, no. 1, pp. 479-488, March 2013.