International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** II **Month of publication:** February 2020

DOI: http://doi.org/10.22214/ijraset.2020.2022

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 8 Issue II Feb 2020- Available at www.ijraset.com

Frequency Fluctuations Challenge in a Wind Integrated Large Power System

Md. Amzad Hossain[1], Md. Nazir Hossain[2], Jannat Ul Raihan[3]
[1, 2, 3]*Department of Electrical and Electronic Engineering, Jashore University of Science and Technology, Jashore 7408, Bangladesh*

Abstract:** We discussed the technical challenges and power system frequency fluctuations due to high wind power penetration. The simulation analyses using a multi-machine power system model using PSCAD/EMTDC have been performed to investigate the performance of the power system frequency with the increased wind power penetration using real wind speed data. The real wind data was measured in Hokkaido Island, Japan. It was observed the power system frequency is fluctuating, and the thermal governor can minimize power system frequency more than the hydro governor. The frequency deviations are maintained within ± 0.24 [Hz] for thermal governor model and from 49.60 Hz to 50.50 Hz for both hydro governor model. It was also found that, the wind farm output voltage, the wind farm output power and the SG output power was also fluctuating for both thermal and hydro governor model. Comparing with the hydro governor, the thermal governor can maintain up to certain capacity.
***Keywords:** PSCAD Simulation, Renewable energy, Governor model, Frequency fluctuations, Grid code*

I. INTRODUCTION

The renewable energy technology to meet the energy demands has been steadily increasing for the past few decades due to the limitations of the fossil fuels and their harmful effects on the environment [1-4]. The wind energy is one of the promising renewable energy sources all over the world [4-5]. The promoting wind power is considered as an important strategy to attain CO_2 emission reduction, environmental protection, energy savings, and energy security [5-10]. However, the important drawbacks associated with renewable energy systems are their inability to guarantee reliability and their spare nature [1]. Nowadays, it is well-known that the renewable energy industry is accelerating quickly and intensively rising concerns about natural resources exhaustion and climate change [11-20]. The renewable energy is seen by many researchers as part of the appropriate response to these concerns. Few national governments have taken programs in place to support the wide use of sustainable energy systems [21-25]. Therefore, these lead to a rapid boost in demand for renewable energy specialists who are able to design, install as well as maintain such power systems [26-33]. In this work, we discussed the problems associated with conventional IG machines used in wind integrated power systems. We investigated power system frequency fluctuations with high wind power penetration. The effects of the governor control system models of SG and conventional pitch control model on hybrid power system frequency fluctuations were discussed in detail. In section II, effects of hydro governor in conventional IG are explained in detail. In section III, the AVR and LFC model is discussed briefly. In section IV, the results obtained are summarized.

II. EFFECT OF HYDRO AND THERMAL GOVERNOR MODEL

To represent the impacts of governor, the model system used in the simulation analyses is shown in Fig. 1. One synchronous generator of SG [100 MVA] and one Induction generator of IG [10 MVA] acting as a wind farm are used with the network. The Q_{WF} and Q_{Load} are capacitor banks. The Q_{WF} is used at the terminal of IG to compensate the reactive power demand of wind generator at steady state. The value of the capacitor is chosen so that the p.f. becomes unity, when the wind generator operated in the rated condition [24]. The Q_{Load} is used at the terminal of load to compensate the voltage drop by the impedance of transmission lines. The core saturation of induction generator and synchronous generators are not considered for simplicity. Figure 2 and 3 shows the hydro and thermal governor model used in the simulation analysis, respectively. When the generator load is constant, the turbine is operated at a constant rotational speed. However, when the load changes, balance between the generator output and the load is not maintained, and the rotational speed changes [28]. When the load is removed, the governor detects the increase of the rotational speed, and then, the valve is closed rapidly so that an abnormal speed increase of the generator is prevented [24]. The power system model is shown in Fig. 1. in which the initial values of 65M and 77M for thermal generators are shown in Table 1 [23-24]. Where Sg: the revolution speed deviation [pu]; 65M: the initial output [pu]; 77M: the load limit (65M + rated MW output × PLM [%]); PLM: the spare governor operation [%]; Pm: the turbine output [pu]. In the simulation analysis, the conventional pitch controller is modeled with a first order delay system with a time constant, T_D.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 8 Issue II Feb 2020- Available at www.ijraset.com

Table 1
Initial values of 77M and 65M

Synchronous Generator (Thermal)		
Frequency control	77M	65M
PLM%	10	5
	IG: 10MVA	IG: 5MVA
GF	0.84	0.8
77M [pu]	0.82	0.84
65M [pu]	0.72	0.75

In the simulation analysis, the conventional pitch controller is modeled with a first order delay system with a time constant, T_D. The purpose of using the pitch controller is to maintain the output power of the wind generator at rated level by controlling the blade pitch angle of turbine blade when the wind speed is over the rated speed. Generally, the blade pitch operation system is complicated, but this paper simulates the pitch operation system by using a first order time delay system with time constant T_D.

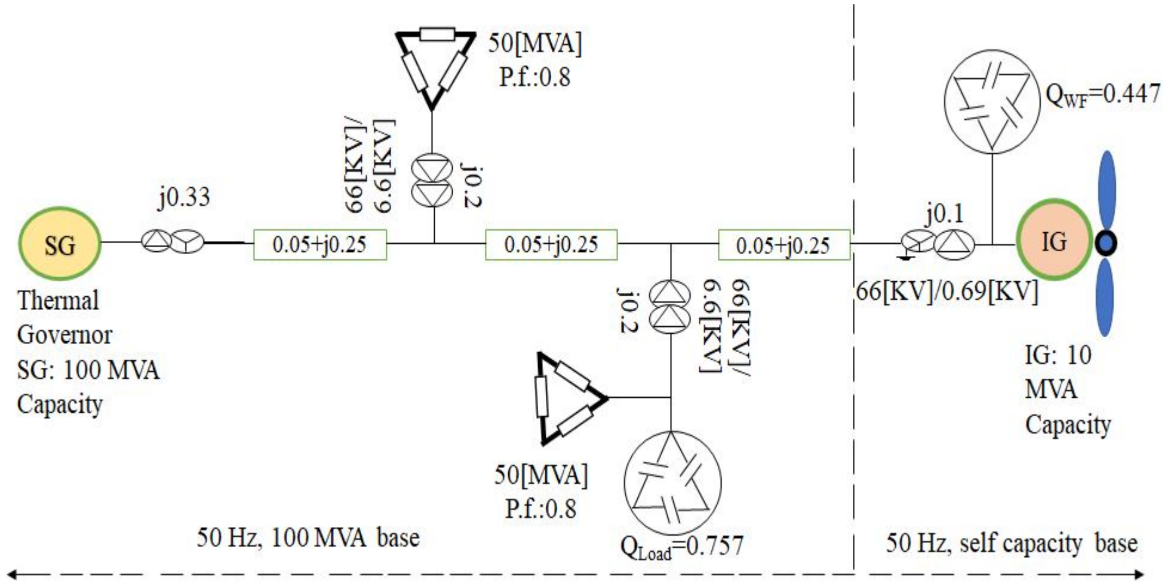


Fig. 1. Hydro governor model for simulation analysis

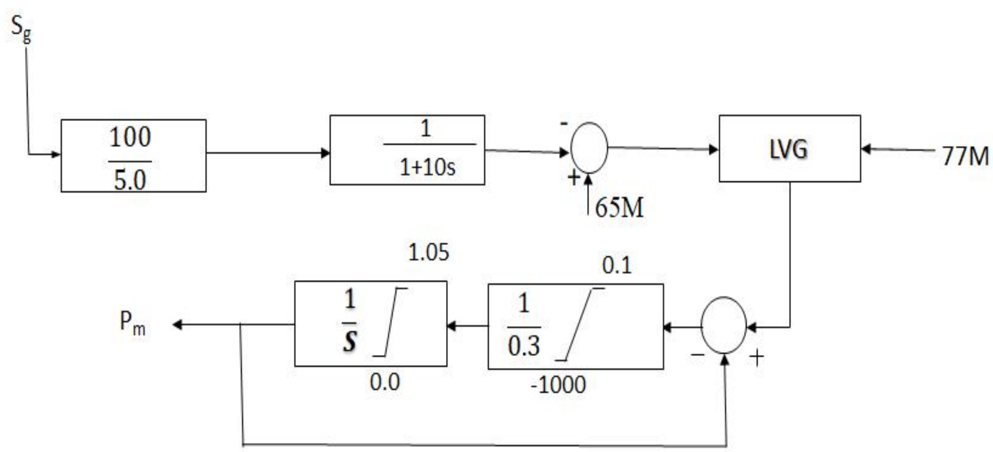


Fig. 2. Hydro governor model

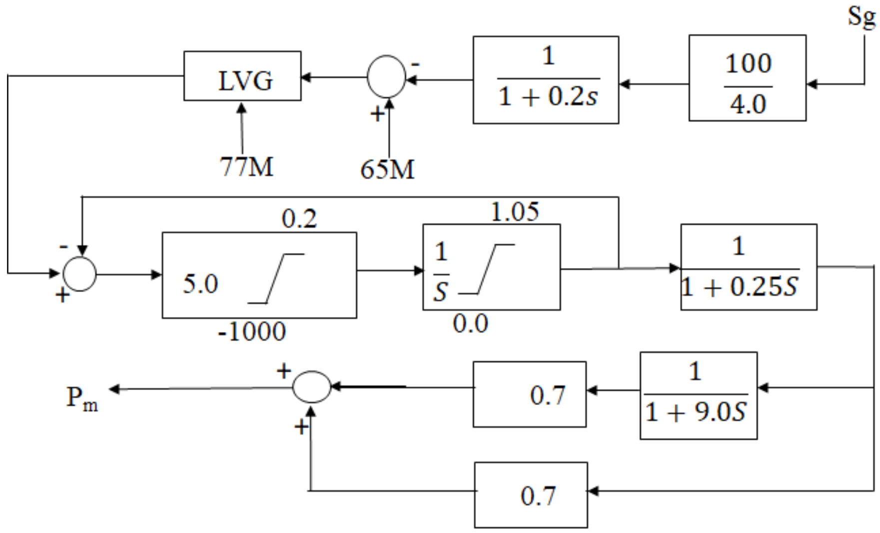


Fig. 3. Thermal Governor model

III. AVR AND LFC MODEL

In the simulation analyses, the automatic voltage regulator (AVR) model is expressed by a first order time delay, which is shown in Fig. 4 [24]. In the first place the AVR monitors the output voltage and controls the input voltage for the exciter of the generator. The AVR calculates how much voltage have to sent to the exciter numerous times a second, therefore stabilizing the output voltage to a predetermined set point. The load-frequency control (LFC) is employed to allow an area to first meet its own load demands, then to assist in returning the steady-state frequency of the system, Δf, to zero [24-25]. In the Load Frequency Control (LFC), the control output signal is sent to LFC power plant when the frequency deviation is detected in the power system [26]. Then, governor command signal and thus the output of LFC power plant is changed according to LFC signal. The frequency deviation is input into Low Pass Filter (LPF) to remove fluctuations with short period, because the LFC is used to control frequency fluctuations with a long period. The LFC model used in this study is shown in Fig. 5, where, Tc: the LFC period = 200[s]; ω_c: the LFC frequency = 1/Tc = 0.005[Hz]; ζ: the damping ratio = 1 [24].

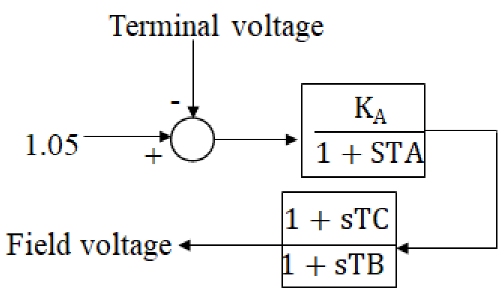


Fig. 4. Automatic Voltage Regulator model

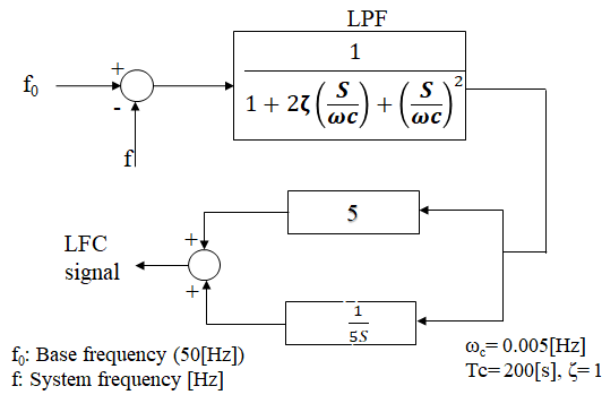


Fig. 5. Load frequency control model

IV. SIMULATION ANALYSIS

The simulation analyses have been carried out to investigate the performance of the power system frequency with the increased wind power penetration using real wind speed data. The wind speed data used in the analysis is the real data, which is measured in Hokkaido Island, Japan. The wind speed data applied to the wind generator is shown in Fig. 6. Figure 7 shows the wind farm output voltage, and wind farm output power is presented in Fig. 8. The Synchronous generator output power is shown in Fig. 9.

Figure 10, 11, and 12 show the wind farm output voltage, and wind farm output power and synchronous generator output power for thermal governor model, respectively. The power system frequency for hydro governor model and thermal governor model is shown in Fig. 13. It was observed from Fig. 13, the power system frequency is fluctuating and it fluctuates from 49.60 Hz to 50.50Hz for Hydro governor but thermal governor can minimize power system frequency than hydro governor.

The comparison of power system frequency for hydro governor control and thermal governor control are presented in Fig. 13. The system frequency becomes more severe for IG capacity 10% of total capacity or more. It is investigated that synchronous generator (SG) operate with thermal governor model can maintain better frequency control with respect hydro governor model. Moreover, the wind farm output voltage and output power are fluctuating in intolerable limit, which concerns power system company.

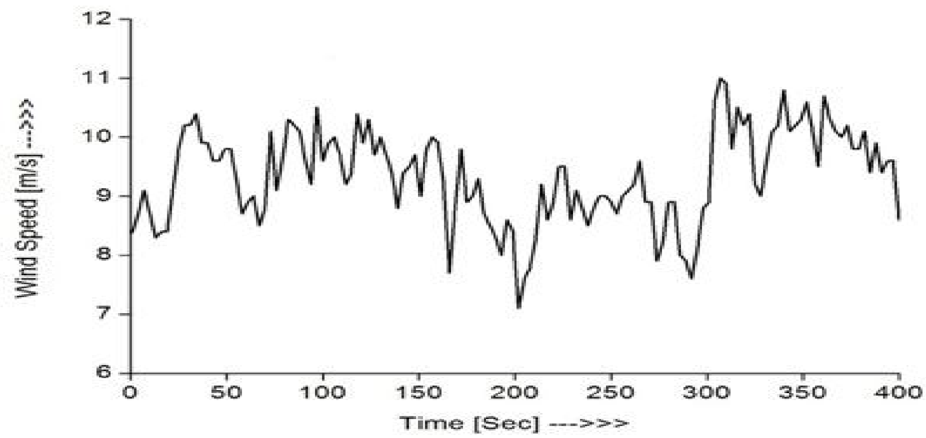


Fig. 6. Profile of natural wind data

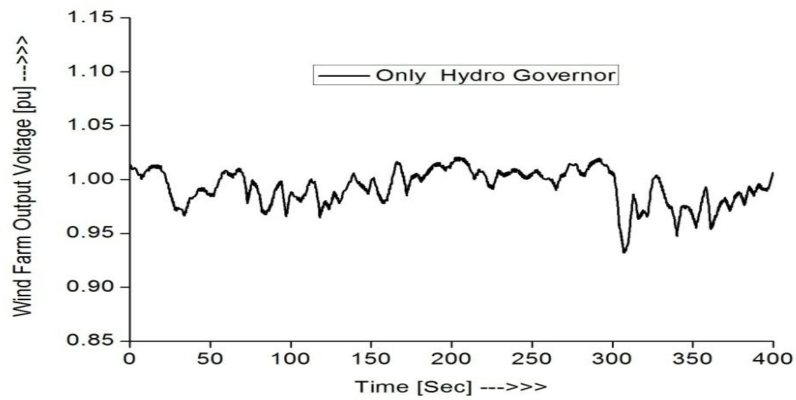


Fig. 7. Response of wind farm output voltage

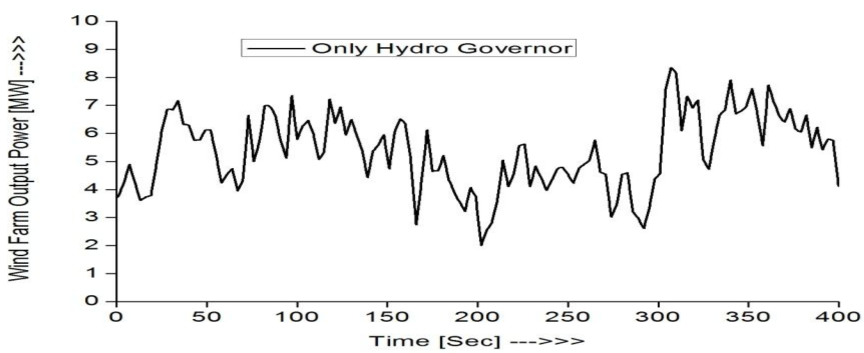


Fig. 8. Response of wind farm output power

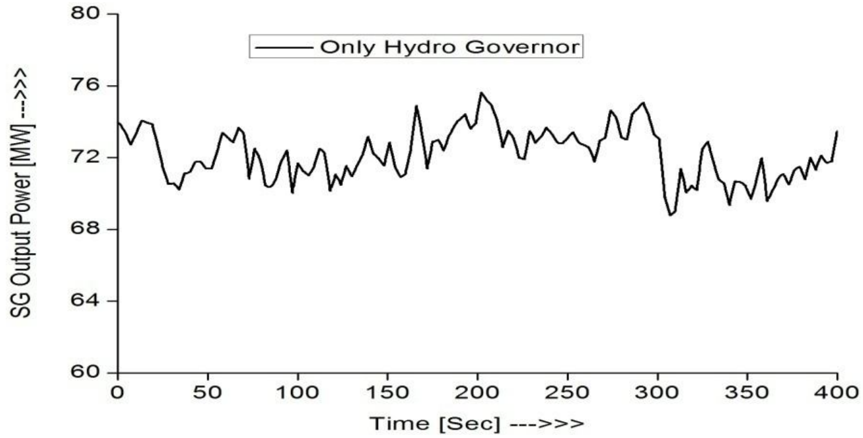


Fig. 9. Response of synchronous generator output power

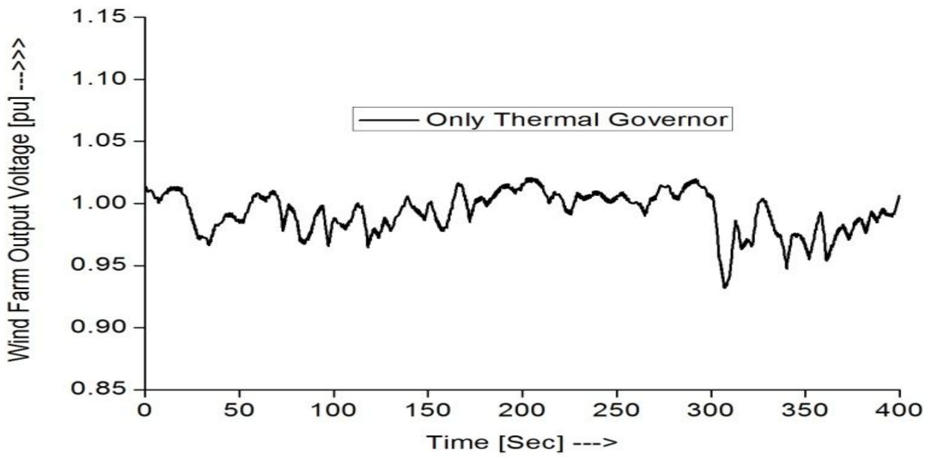


Fig. 10. Response of wind farm output voltage

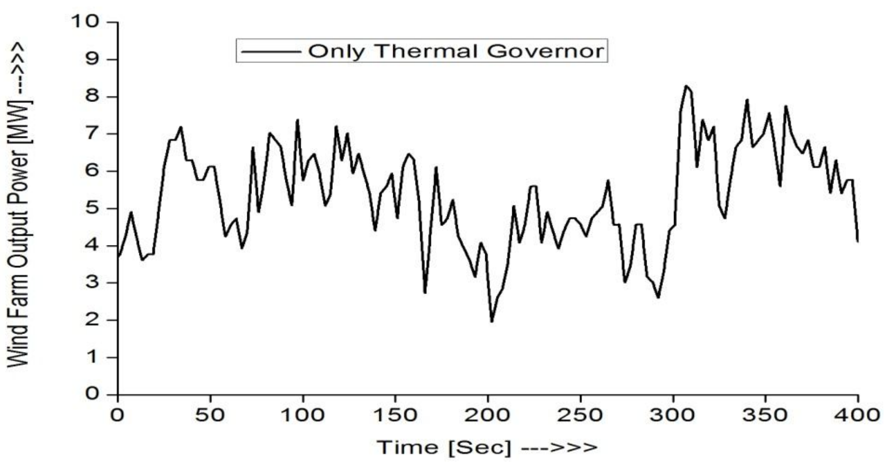


Fig. 11. Response of wind farm output power

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 8 Issue II Feb 2020- Available at www.ijraset.com

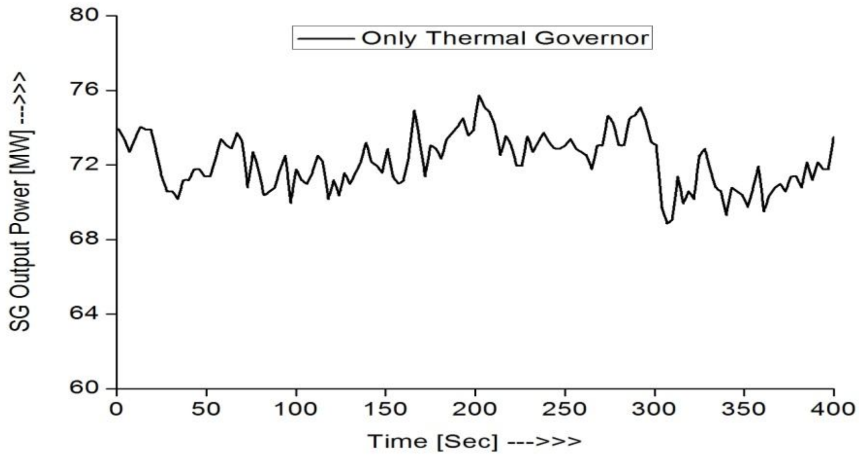


Fig. 12. Response of synchronous generator output power

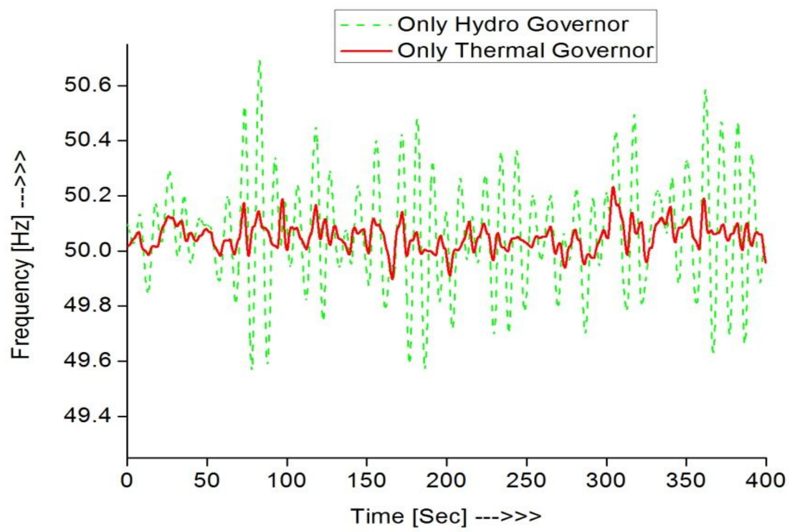


Fig. 13. Comparison of power system frequency

V. CONCLUSIONS

The output responses of wind generators affect the power system frequency due to wind speed variations. This study focuses on power system frequency fluctuations with high wind power penetration. The effects of the governor control system models of SG and conventional pitch control model on frequency fluctuations are evaluated and presented. However, from the results presented, it is predicted that the fluctuations of system frequency are high as the power capacity of wind power penetration are become large. Therefore, to improve the reliability and quality of electric power, some preventive measurements must be taken by the power grid companies. It was observed that the frequency deviations are more than ± 0.2 [Hz]. The thermal governor showed better performance than hydro governor. The conventional pitch control system and governor control system can be used to minimize the output fluctuation up to a certain degree but with many limitations. The wind farm output voltage, the wind farm output power and the SG output power response are almost same numerically.

VI. ACKNOWLEDGMENT

The authors would like to thank Professor Dr. Md. Rafiqul Islam Sheikh, Department of Electrical and Electronic Engineering, Rajshahi University of Engineering and Technology, Bangladesh for his valuable suggestions and guidelines. Moreover, Dr. Hossain extends his gratitude to Mr. Biplob Hossain, Department of Electrical and Electronic Engineering, Jashore University of Science and Technology, Bangladesh for his comments and assistance.

REFERENCES

[1] M. H. Nehrir, C. Wang, K. Strunz, H. Aki, R. Ramakumar, J. Bing, Z. Miao, and Z. Salameh, "A Review of Hybrid Renewable/Alternative Energy Systems for Electric Power Generation: Configurations, Control, and Applications", IEEE Transaction on Sustainable Energy, vol. 2, no. 4, 392–403, October 2011.

[2] Boqiang Lin, Yufang Chen, "Impacts of policies on innovation in wind power technologies in China", Applied Energy, vol. 247 (2019) 682–691.

[3] Junxia Liu, "The past, present and potential of hydrogen as a multifunctional storage application for wind power", Renewable and Sustainable Energy Reviews, vol. 99, pp. 212–219, 2019.

[4] Dimitrios Apostolou, Peter Enevoldsen, "The past, present and potential of hydrogen as a multifunctional storage application for wind power", Renewable and Sustainable Energy Reviews, vol. 112 (2019) 917–929.

[5] Juchuan Dai, Xin Yang, Li Wen, "Development of wind power industry in China: A comprehensive assessment", Renewable and Sustainable Energy Reviews, vol. 97 (2018) 156–164.

[6] P. K. Halder, N. Paul, M. U. H. Joardder, M. Sarker, "Energy scarcity and potential of renewable energy in Bangladesh", Renewable and Sustainable Energy Reviews, vol. 51 (2015) 1636–1649

[7] P. K. Halder, N. Paul b, M. U. H. Joardder, M. Z. H. Khan, M. Sarker, "Feasibility analysis of implementing anaerobic digestion as a potential energy source in Bangladesh", Renewable and Sustainable Energy Reviews, vol. 65 (2016) 124–134.

[8] C. Fant, C.A. Schlosser, K. Strzepek, The impact of climate change on wind and solar resources in southern Africa, Appl. Energy, vol. 161 (2016) 556–564.

[9] Reid Dorsey-Palmateer, "Effects of wind power intermittency on generation and emissions", The Electricity Journal, vol. 32 (2019) 25–30.

[10] Simon R. Sinsel, Rhea L. Riemke, Volker H. Hoffmann, "Challenges and solution technologies for the integration of variable renewable energy sources a review", Renewable Energy, vol. 145 (2020) 2271–2285.

[11] Ll. Lled, V. Torralba a, A. Soret a, J. Ramon a, F.J. Doblas-Reyes, "Seasonal forecasts of wind power generation", Renewable Energy, vol. 143 (2019) 91–100.

[12] Zhixin Fan, Caichao Zhu, "The optimization and the application for the wind turbine power-wind speed curve", Renewable Energy, vol. 140 (2019) 52–61.

[13] Tinghui Ouyang, Xiaoming Zha, Liang Qin, Yusen He, Zhenhao Tang, "Prediction of wind power ramp events based on residual correction", Renewable Energy, vol. 136 (2019) 781–792.

[14] Guorui Ren, Jie Wan, Jinfu Liu, Daren Yu, Lennart Soder, "Analysis of wind power intermittency based on historical wind power data", Energy, vol. 150 (2018) 482–492.

[15] Fabio A. Diuana, Cindy Viviescas, Roberto Schaeffer, "An analysis of the impacts of wind power penetration in the power system of southern Brazil", Energy, vol. 186 (2019) 115869.

[16] Milton M. Herreraa, Isaac Dynerb,∗, Federico Cosenz, "Assessing the effect of transmission constraints on wind power expansion in northeast Brazil", Utilities Policy, vol. 59 (2019) 100924.

[17] Soraida Aguilar Vargas, Gheisa Roberta Telles Esteves, Paula Medina Maçaira, Bruno Quaresma Bastos, Fernando Luiz Cyrino Oliveira, Reinaldo Castro Souza, "Wind power generation: A review and a research agenda", Journal of Cleaner Production, vol. 218 (2019) 850–870.

[18] D. Argüeso, S. Businger, "Wind power characteristics of Oahu, Hawaii", Renewable Energy, vol. 128 (2018) 324–336.

[19] Lin Ye, Cihang Zhang, Hui Xue, Jiachen Li, Peng Lu, Yongning Zhao, "Study of assessment on capability of wind power accommodation in regional power grids", Renewable Energy, vol. 133 (2019) 647–662.

[20] Karki R, Thapa S, Billinton R. A simplified risk-based method for short-term wind power commitment. IEEE Trans Sustain Energy, vol. 2012;3(3):498–505.

[21] Waleed K. Ahmed, "Mechanical Modelling of Wind Turbine: Comparative Study", International Journal of Renewable Energy Research, vol. 3, no.1, 2013.

[22] Gilbert M. Masters, "Renewable and Efficient Electric Power Systems", Chapter 6, John Wiley & Sons, Inc., ISBN 0-471-28060-7, 2004.

[23] M.R.I. Sheikh, Md. Mejbaul Haque, and M.A. Hossain, "Performance of Governor System on Minimizing Frequency Fluctuations with Wind Power Generation", International Journal of Electrical and Computer Engineering (IJECE), ISSN: 2088-8708, pp. 46~56, Vol. 2, No. 1, February 2012.

[24] Md. Rafiqul Islam Sheikh and J. Tamura, "Stabilization of a Grid Connected Wind Farm by Using SMES: Modeling, Control Strategy and Application", LAP LAMBERT Academic Publishing GmbH & Co. KG, Germany, 2012.

[25] P. Kundur, "Power System Stability and Control", New York, McGraw Hill, 1994.

[26] F. Giraud and Z. M. Salameh, "Steady-state performance of a gridconnected rooftop hybrid wind-photovoltaic power system with battery storage," IEEE Trans. Energy Convers., vol. 16, no. 1, pp. 1–7, Mar. 2001.

[27] "PSCAD/EMTDC Manual", Manitoba HVDC Research Center (http://www.hvdc.ca).

[28] M. Yagami, S. Shibata, T. Murata, and J. Tamura, "An Analysis of Superconducting Fault Current Limiter for Stabilization of Synchronous Generator in Multimachine System: A Two-Machine Infinite Bus System", IEEJ Transaction on Power and Energy, Vol. 123, no. 2, pp.133-142, 2003.

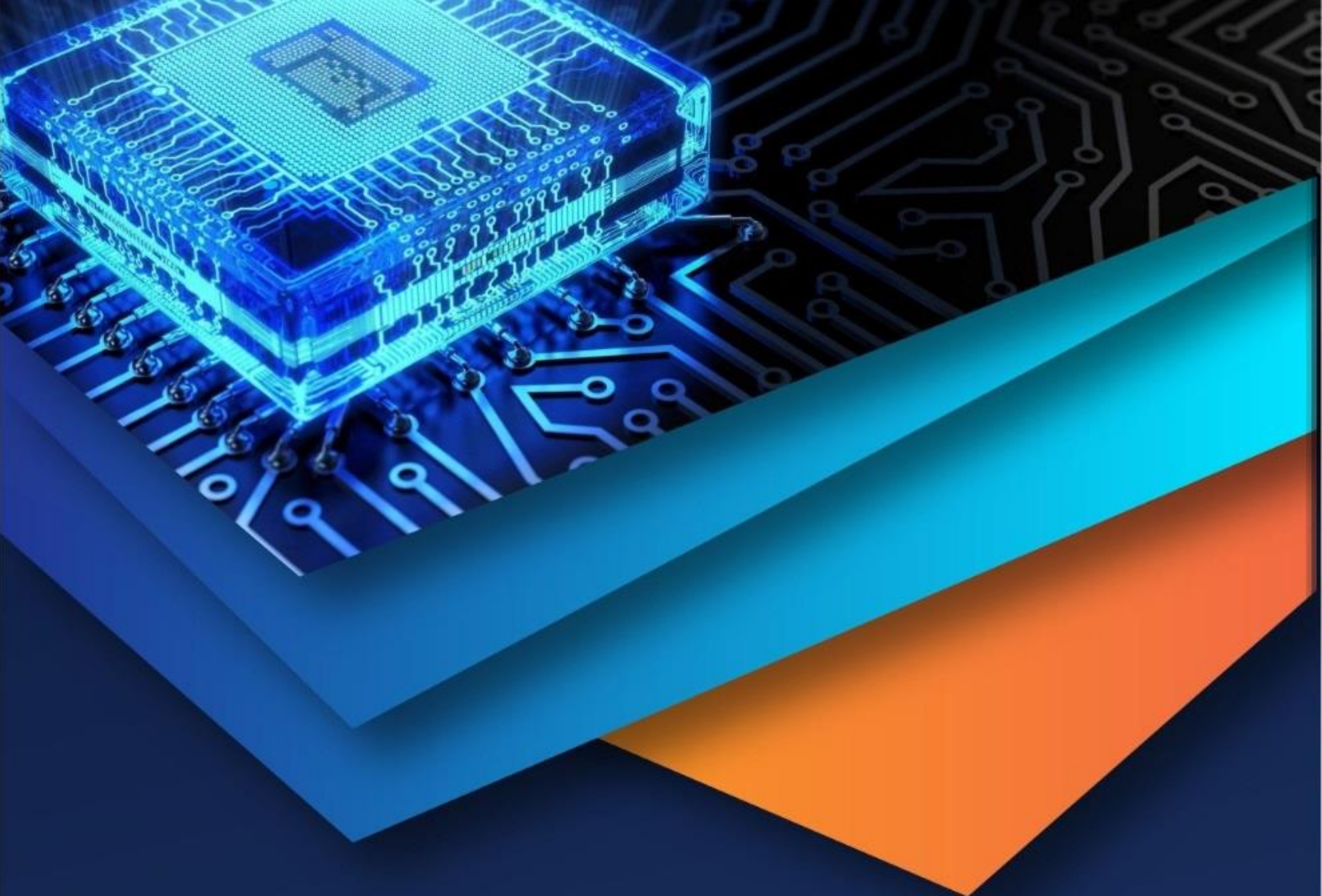
[29] C. Jauch, J. Matevosyan, "Int. Comparison of Requirements for Connection of Wind Turbines to Power Systems, Wind Energy, vol. 8. No. 3, pp. 295–306, July 2005.

[30] C. M. Colson and M. H. Nehrir, "Evaluating the benefits of a hybrid solid oxide fuel cell combined heat and power plant for energy sustainability and emissions avoidance," IEEE Trans. Energy Convers., vol. 26, no. 1, pp. 140–148, Mar. 2011.

[31] Thomas Ackermann, Wind Power in Power System, UK: John Wiley & Sons, 2005.

[32] Slootweg JG, Polinder H, and Kling WL, "Representing Wind Turbine Electrical Generating Systems in Fundamental Frequency Simulations", IEEE Transactions on Energy Conversion, vol.18. pp. 516-524, 2003.

[33] Junqiao Liu, M. Roayadi, A. Umemura, R. Takahashi, J. Tamura, "A Control Method of Permanent Magnet Wind Generators in Grid Connected Wind Farm to Damp Load Frequency Oscillation", IEEJ Transaction on Power and Energy, vol. 134, no. 5, pp. 393-398,2014.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY