



Robust Controller for Hydro-Plants to Mitigate Frequency Deviations with Wind Power Penetration in the Grid

A. Yuva Kishore¹, G.Ravindra²

PG Student, Department of EEE, SVEC, Tirupati, India¹

M.Tech, Asst. Prof, Department of EEE, SVEC, Tirupati, India²

ABSTRACT: This paper exhibits a robust control configuration to incorporate hydro generators to address expanded frequency deviations in power frameworks with high wind control entrance. A Robust control plan system for hydro governors is proposed so as to especially handle with unsettling influences from wind control variance. In the first place, by consolidating state conditions of hydro, thermal, and wind generators through the power stream conditions of system, a state space model of the whole power framework is determined for the control plan of hydro generators. Specifically, the attributes of wind power varieties and the water powered framework flow of hydroelectric power plants are executed in the framework demonstrate. At that point, the H_{∞} -based vigorous controller is integrated by diminishing the request of the framework model and utilizing the direct network disparity strategy. At long last, the IEEE 39-transport test framework is utilized to check the execution of the planned strong controller with 10–40% wind entrance levels. Reenactment results are contrasted and a conventional PID controller. Inquire about discoveries show that the proposed robust controller fundamentally lessens framework frequency deviations and empowers hydro generators to be more receptive to wind control variety in essential frequency direction of energy frameworks.

KEYWORDS: Frequency control, hydroelectric power generation, robust control, wind power.

I. INTRODUCTION

The frequency of power systems, which indicates the real power imbalance between generation and demand, must be confined to a narrow range around its nominal value [1]. By adjusting real power injections on generation side, the system frequency can be regulated in a hierarchical fashion, comprising three different layers at different timescales. In this regulation mechanism, the primary frequency control provides the most rapid adjustment to system frequency deviation by the local speed governor on each generator, while the secondary frequency control drives the frequency back to its nominal value and tie-line power flows to scheduled values by adjusting economic dispatch, schedules the outputs of online generators and power flows using optimization methods [2], [3]. Load variations are usually taken as the main disturbances in the frequency control loop in traditional power systems [4]. With significant wind power penetration, variabilities and uncertainties are introduced into power systems as wind power outputs are highly fluctuating and their prediction accuracy is much lower than the accuracy of load forecasts [5], [6]. This results in large mismatch between the power supply and the demand for electricity, leading to the increase in frequency deviations from the nominal value [7]. In addition, as most of modern wind generators are connected to power grids by power electronic converters, they contribute no inertial response to power systems [8]. In the near future, with more synchronous generators displaced by wind generators, the frequency of power systems will be more sensitive to the imbalance between generation and demand as the inertia of the whole system is decreasing. Hydro power generators have long been the primary actor in frequency regulation of power systems due to their fast responses to short-term demand variation [9]. In the meantime, due to the smoothing effect of clustered wind generators in the system, the whole fluctuation rate of wind power will be smaller than that of any single wind generator, making it possible for hydro generators to adjust wind power [10], [11]. With the increasing penetration of wind power, hydro power plays a more important role in frequency regulation especially for primary frequency control [12]. However, the existing



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control framework of hydro governors is designed based on parameters of the hydro generation system itself, ignoring the dynamics of other power system components [13]. These controllers therefore cannot adjust other disturbance sources in power systems, leading to larger system frequency deviations.

This limitation may restrict the frequency control performance of hydro generators in power systems with high wind penetration. Furthermore, hydroelectric power plants have special behaviors heavy water columns are presented inside penstocks when water flow control valves operate during the regulation process [14]. Due to the higher wind power penetration, more frequent and rapid regulation actions will be required for hydroelectric power control.

Traditionally, the PID control law is widely implemented in a hydro governing system [15], but with more control challenges brought about by wind power fluctuation, new control methods need to be developed to improve the frequency control performance of hydro generators to mitigate high wind penetration challenges. For the property of guaranteeing the robustness and stability in dynamic systems with bounded uncertainties and disturbances, the H_∞ -based robust control method has been increasingly applied in regulating power system frequency recently [3], [4], [16]. Hence, considering wind power fluctuations a source of disturbance, implementing a robust control method on hydro generators will help damp system frequency deviations and improve the performance of hydro governing systems. In this paper, the primary frequency control problem introduced by wind power is studied by deriving a state space model of the entire power system including the characteristics of wind power variation as well as the dynamics of hydroelectric power plants. Based on this model, the challenge of wind power fluctuation causing frequency deviations in power systems can be addressed by applying the H_∞ -based robust control method on hydro generators.

This paper is organized as follows: In Section II, the frequency regulation problem is formulated and state space models used for studying this problem are presented. Section III describes details of the proposed H_∞ -based robust control method for primary frequency control. Simulations and analysis on the IEEE 39-bus test system are discussed in Section IV to illustrate the performance of the proposed controller. Finally, conclusions and future work are addressed in Section V.

II. THE GENERALIZED MODEL OF POWER SYSTEMS

This paper focuses on the primary frequency control problem due to the continuous wind power fluctuation in the timescale of seconds to a few minutes. In this section, a common state space representation of an interconnected power system including hydro generation, thermal generation, wind generation and power flows is derived. Later a robust controller is designed and added into the frequency control loop of hydro generators based on this state space model. As this work focuses on frequency control problems, an emphasis is placed on the real power and frequency aspects and the detail of voltage dynamic is omitted. Particularly, more details are considered in the modeling of hydro power plant and characteristics of wind power in order to get a more effective hydro controller to mitigate system frequency deviations caused by wind power fluctuation. In order to simplify the frequency control problem, loads are assumed to be constant as their variations are small enough compared to wind power variation in the considered timescale [3] and all models in this paper are linearized around the equilibrium point. Units of each model are in the per unit system with respect to their rated base values.

A. Hydro Generation Model

The exact model of hydro generation system requires solutions to partial differential equations representing hydraulic transients in hydro turbines and penstocks [17]. These partial differential equations are usually simplified into ordinary differential equations, and these kinds of simplifications have been proved to be accurate enough with small disturbances [13]. In addition, hydro governor tuning studies are classically deployed on single turbine-governor models [18], [19]. In this work, dynamics of a hydroelectric power plant and its primary frequency

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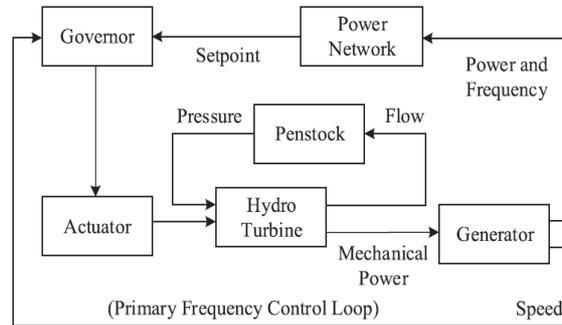


Fig. 1. Primary frequency control loop of hydro generation.

control loop are modeled based on an equivalent single turbine system as shown in Fig. 1. The discharge flow q and mechanical power P_{hm} of hydro turbine are usually represented by the functions of pressure h at the inlet of turbine, opening value Y of the water flow control valve and rotating speed ω , which is known as the hydro turbine characteristic curve [20]. Linearized functions can be expressed in (1). Parameters a_{11} to a_{23} are obtained by linearizing turbine characteristic curve around the equilibrium point.

$$\Delta Q = a_{11}\Delta H + a_{12}\Delta Y + a_{13}\Delta\omega$$

$$\Delta P_m^h = a_{21}\Delta H + a_{22}\Delta Y + a_{23}\Delta\omega \quad \text{----- (1)}$$

$$a_{11}, a_{12}, a_{13}, a_{21}, a_{22}, a_{23} = f(H, Q, \omega, Y) \text{----- (2)}$$

As for the water passage system, an equivalent penstock is used for representation. The linearized model of penstock is shown in (3), where T_w is the water time constant of the penstock

$$\Delta \dot{Q} = \frac{-1}{T_w} \Delta H \quad \text{----- (3)}$$

Equation (3) represents an important characteristic of a hydroelectric power plant which has been analyzed in detail by Kundur in [1]. He indicated that if back pressure is applied at the end of the penstock by closing the control valve, the water in the penstock will decelerate. However, the flow will not change immediately due to water inertia, causing the power output of hydro turbine to increase. With a dynamic response determined by T_w , the water flow decelerates until it reaches a new steady value which establishes the new steady turbine power value. This means the initial turbine power will be opposite to the direction of the change in the valve gate position, which makes the hydro generation system a non-minimum phase system [1, Ch. 9, p. 382]. The dynamic of a servo actuator is shown in (4), where ΔU_t is the control signal, ΔY is the gate position and parameter T_y is the time constant of the actuator

$$T_y \Delta \dot{Y} + \Delta Y = \Delta U_t \text{----- (4)}$$

To analyze the frequency control process, electrical dynamic of generators may be neglected and rotational dynamic of turbine-generator can be captured by a single rotating mass with inertia H , driven by accelerating torque ΔT_{km} and decelerating torques ΔT_{ke} as shown in (5). It is assumed that

$$2H_t \Delta \dot{\omega} = \frac{\Delta P_m^h - \Delta P_e^h}{S_h} - e_g \Delta \omega \text{----- (5)}$$

$\Delta P_m^h \approx \Delta T_{hm}$, $\Delta P_e^h \approx \Delta T_{he}$ as rotating speed is usually controlled tightly around ω_0 . Parameter S_h represents the ratio of power base values between a hydro generator and the power network, and parameter e_g is the damping factor of the hydro generator. By combining the hydraulic dynamics (1), (2) and (3) together with the actuator dynamic (4) and the rotor dynamic (5), the state space model of the entire hydro generation system is shown in

$$\begin{bmatrix} \Delta \dot{\theta} \\ \Delta \dot{\omega} \\ \Delta \dot{Y} \\ \Delta \dot{Q} \end{bmatrix} = \begin{bmatrix} 0 & \omega_0 & 0 & 0 \\ 0 & \frac{-e_g + a_{23} - a_{13}a_{21}}{2H_t a_{11}} & \frac{a_{12} - a_{12}a_{21}}{2H_t a_{11}} & \frac{a_{12}}{2H_t a_{11}} \\ 0 & 0 & \frac{-1}{T_y} & 0 \\ 0 & \frac{a_{13}}{T_w a_{11}} & \frac{a_{12}}{T_w a_{11}} & \frac{-1}{T_w a_{11}} \end{bmatrix} \begin{bmatrix} \Delta \theta \\ \Delta \omega \\ \Delta Y \\ \Delta Q \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & \frac{-1}{2H_t S_h} \\ \frac{1}{T_y} & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \Delta U_t \\ \Delta P_e^h \end{bmatrix} \text{----- (6)}$$



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B. Thermal Generation Model

The model of a thermal generation system is the same as that of the hydro generation system except for prime movers and speed governors. With the first order equation (7) representing steam turbine and a standard proportional droop control (8) representing speed governors [21], the fourth order state space model for thermal generation given by (9) is adopted

$$\Delta P_m^g = \frac{\Delta Y}{(sT_{ch}+1)} \text{-----(7)}$$

$$\Delta u_g = \frac{-\Delta \omega}{R} \text{-----(8)}$$

$$\begin{bmatrix} \dot{\Delta \theta} \\ \dot{\Delta \omega} \\ \dot{\Delta Y} \\ \dot{\Delta P_m^g} \end{bmatrix} = \begin{bmatrix} 0 & \omega_0 & 0 & 0 \\ 0 & \frac{-K_g}{2H_g} & \frac{1}{2H_g} & 0 \\ 0 & \frac{-1}{T_g R} & \frac{-1}{T_g} & 0 \\ 0 & 0 & \frac{1}{T_{ch}} & \frac{-1}{T_{ch}} \end{bmatrix} * \begin{bmatrix} \Delta \theta \\ \Delta \omega \\ \Delta Y \\ \Delta P_m^g \end{bmatrix} + \begin{bmatrix} 0 \\ -1 \\ 2H_g S_g \\ 0 \\ 0 \end{bmatrix} * [\Delta P_g] \text{---(9)}$$

where, ω_0 is the nominal rotating speed; H_g , K_g , S_g are the inertia constant, the damping factor and the ratio of power base between the thermal generator and the power network, respectively; T_{ch} , T_g are the time constant of a steam turbine and an actuator, respectively; and R is the speed droop coefficient of a thermal speed governor.

C. Wind Generation Model

In this work, wind generators are modeled as negative loads injecting into the power grid, and wind power outputs are therefore not affected by other components of the interconnected power network. Meanwhile, this also implies that they make no contribution to system frequency regulation [22]. Hence, variation of wind power can be regarded as disturbances to the power system in the frequency control design stage. In order to capture the characteristics of wind power variation, frequency spectrum is used for frequency domain representation of wind generation. As for this work, the Fast Fourier Transform method is applied on measured wind power data to obtain the power spectrum density (PSD) [23]. When wind speed data are available, wind power data can be calculated from wind speed data and turbine characteristics. Then, a rational transfer function (10), which is the ratio of two polynomials with real coefficients, is used to fit the PSD of wind power data. For simplicity, orders of the numerator and denominator polynomials are set to one and two, respectively

$$w(s) = \frac{a.s}{s^2+b.s+c} \text{-----(10)}$$

Parameters a , b and c in (10) are selected using a trial-and-error method. When changing each parameter, some particular regularity appear in the shape of this function's frequency response. Parameters, of which its transfer function (10) offers the best fit to the PSD of the measured data, are chosen. Then, the transfer function of wind power variation, which has a similar frequency response to the measured data, is obtained. This function is integrated into the frequency control design as discussed in Section III.

D. Power Flow Model

In order to simplify the power flow model, voltages at all buses are supposed to be controlled at nominal values as reactive power is perfectly compensated locally [4]. Real power balance is therefore the only constraint to be considered. Hence, the DC power flow model, expressed in (11) is applied to the power network model [24]. Where, ΔP represents the power variation at each bus; $\Delta \theta$ represents power angle variation; and H is the admittance matrix of the power network

$$\Delta P = H . \Delta \theta \text{-----(11)}$$

E. Entire Power System Model

For a specific interconnected power system, we can designate one or several hydro generators to mitigate the system frequency deviation caused by fluctuation in wind power output. From this perspective, control design of hydro governors should be based on the overall system model.

By stacking all state variables of hydro generators and thermal generators in (6) and (9), the following equation is attained:

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$$\dot{x} = A_0x + B_0\Delta U_t + E_0 \begin{pmatrix} \Delta p_e^g \\ \Delta p_e^h \end{pmatrix} \text{-----(12)}$$

As for wind generators, wind power outputs can be connected with electrical power of hydro and thermal generators through the DC power flow model. The corresponding admittance matrix can be partitioned as shown in (13). ΔP_e remains zero as loads are assumed to be constant in this work

$$\begin{bmatrix} \Delta P_e^h \\ \Delta P_e^g \\ \Delta P_e^w \\ \Delta P_e^l \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} \Delta \theta_h \\ \Delta \theta_g \\ \Delta \theta_w \\ \Delta \theta_l \end{bmatrix} \text{-----(13)}$$

Replacing $\Delta P_{he}, \Delta P_{ge}$ in (12) with ΔP_{we} by substituting (13) into (12), the final state space expression of the entire power system is obtained as shown in (14). This model is used for the subsequent H_∞ -based controller synthesis

$$\dot{x} = Ax + B\Delta u_t + F\Delta P_e^w \text{-----(14)}$$

III. ROBUST CONTROL FRAMEWORK

A. Proposed Control Strategy

In the traditional frequency control framework of a hydro governor, a fixed reference signal is compared with the local frequency feedback to decide the governor input, and the governor design is based on dynamics of the hydro generation system [13]. This implies that this kind of control does not consider the characteristics of system disturbances. In order to fundamentally address the frequency regulation problem introduced by wind power variation, an improved frequency feedback control framework for hydro generators is proposed by taking the whole power system as the control object, and wind power variation as the disturbance to the system. The designed controller $K(s)$ adjusts the power output of hydro turbine by adjusting the position of hydro valve based on frequency measurements. In this work, uncertainties of sensors and actuator are not considered and the control design is deployed based on the single turbine system derived in the previous section. Note that in addition to frequency, other system variables might be also considered for the feedback design, such as power and pressure outputs of the hydro turbine [25].

B. Robust Control Method

The standard H_∞ control problem can be depicted by the state space model expressed in (15), where x represent the internal states vector of the system; y, z represent the measurement vector and the performance vector, respectively; w is the exogenous inputs including disturbances, references and measurement noises; and u is the control input to be designed [26]

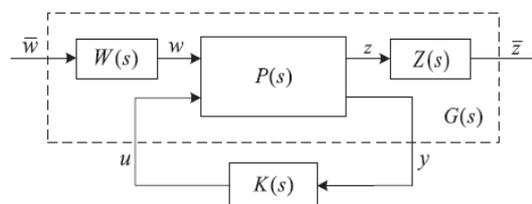


Fig. 2. Augmented G plant for robust control synthesis.

Then, the H_∞ control problem is established to seek for the optimal stabilizing controller $K(s)$ to minimize the H_∞ norm of the system closed-loop transfer function, which is represented by $T_{wz}(s)$ in this paper. This norm has several interpretations which corresponds to the peak of the maximum singular value of the complex matrix $T_{wz}(j\omega)$ in the frequency domain and the largest input/output gain in the time domain [26] as shown in

$$\begin{aligned} \dot{x} &= Ax + B_1w + B_2u \\ z &= C_2x + D_{21}w + D_{22}u \\ y &= C_1x + D_{11}w + D_{12}u \text{-----(15)} \end{aligned}$$

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$$\min \left[\|T_{WZ}\|_{\infty} = \sup_{\omega} \sigma_{\max}(T_{\omega Z}(j\omega)) = \sup_{\omega \neq 0} \frac{\|Z\|}{\|\omega\|} \right] \text{-----(16)}$$

In this way, the H_{∞} control method can be derived as an optimization problem and can be solved by Riccati-based and linear matrix inequality (LMI)-based approaches [26], [27].

C. Implementing Weighting Functions

The H_{∞} control method can also be applied to disturbance rejection problems as it guarantees the performance bound of the control system subjected to any bounded disturbance. In order to characterize the disturbance and performance signals, dynamic weighting functions are assigned to w and z as shown in Fig. 2. The standard control problem therefore changes into the following weighted H_{∞} control problem (17). Where $W(s)$ and $Z(s)$ are the weighting functions of the disturbance and performance signals, respectively

$$\min_{k(s)} \|W(S)T_{WZ}Z(S)\|_{\infty} \text{-----(17)}$$

$$\begin{aligned} \dot{x}_w &= A_w X_w + B_w \omega \\ \omega &= C_w X_w + D_w \omega \text{-----(18)} \end{aligned}$$

$$\begin{aligned} \dot{x}_z &= A_z X_z + B_z Z \\ \omega &= C_z X_z + D_z Z \text{-----(19)} \end{aligned}$$

$$\begin{bmatrix} \dot{x} \\ \dot{x}_w \\ \dot{x}_z \end{bmatrix} = \begin{bmatrix} A & B_1 C_w & 0 \\ 0 & A_w & 0 \\ B_z C_1 & 0 & A_z \end{bmatrix} \begin{bmatrix} x \\ x_w \\ x_z \end{bmatrix} + \begin{bmatrix} B_1 D_w \\ B_w \\ 0 \end{bmatrix} \bar{w} + \begin{bmatrix} B_2 \\ 0 \\ B_z D_{12} \end{bmatrix} u$$

$$\bar{z} = \begin{bmatrix} D_z C_1 & D_z D_{11} C_w & C_z \end{bmatrix} \begin{bmatrix} x \\ x_w \\ x_z \end{bmatrix} + D_z D_{11} D_w \bar{w} + D_z D_{12} u$$

$$y = \begin{bmatrix} C_2 & D_{12} C_w & 0 \end{bmatrix} \begin{bmatrix} x \\ x_w \\ x_z \end{bmatrix} + D_{21} D_w \bar{w} + D_{22} u$$

----- (20)

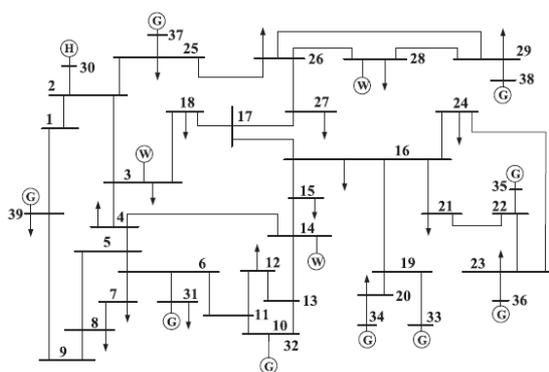


Fig. 3. IEEE New England 39-bus test power system.



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With properly selected weighting functions $W(s)$ and $Z(s)$, which can be transferred to the state space form as shown in (18) and (19), the augmented system model (20), which includes dynamic characteristics of exogenous input signals, is obtained by integrating equations (15), (18) and (19). With this augmented model, the H_∞ based robust controller accounting for the characteristics of exogenous disturbances can be synthesized by solving the standard H_∞ control problem.

D. Model Order Reduction

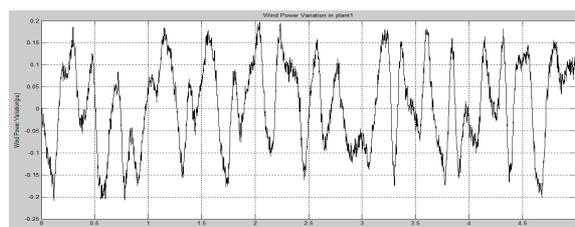
According to [26], the resulting controller by solving the H_∞ control problem (16) is of dynamic type and has the same order as the augmented plant $G(s)$. For the frequency control problem, the augmented plant $G(s)$ may have very high order. Although, modern microprocessors make the implementation of high order controllers possible, these controllers may be complex and inefficient for practical implementation. A low order controller can be obtained by reducing the order of the augmented plant prior to the controller design, or reducing the controller order in the final stage, or both. In this work, the former approach is adopted using the standard Hankel norm approximation method [26].

IV. MATLAB SIMULATION RESULTS

The control design approach proposed in the previous sections applied to the IEEE New England 39-bus test power system. The generator on Bus 30 is set to be a hydroelectric power plant with capacity of 500 MW, and wind generators are located at Bus 3, Bus 14 and Bus 28 as shown in Fig. 3. Basic parameters of this test system are taken from [28] and detailed parameters of the hydroelectric power plant are listed in Table I. Capacities of the three wind generators at Buses 3, 14 and 28 are 1.5MW, 1.5 MW and 1.5MW, respectively. System loads have been increased in proportion to the average wind power outputs to make sure that generation and load of the system is balanced, and all loads are assumed to be constant for the considered time horizon of 5 seconds. Two cases are studied and compared in this work. The base case corresponds to the situation where the hydro generator is equipped with the PID controller, whose parameters are shown in Table I. In the second case, the H_∞ -based robust controllers synthesized and implemented on the hydro generator. In both cases, all other thermal generators are equipped with proportional droop control.

Penstock					
Water time constant (T_w)		3.2			
Turbine					
a_{11}	0.5	a_{12}	1	a_{13}	0.1
a_{22}	1	a_{22}	1.5	a_{23}	0.1
Governor					
K_p	5	K_d	0.5	K_i	0.1

Table I: Hydroelectric power plant parameters



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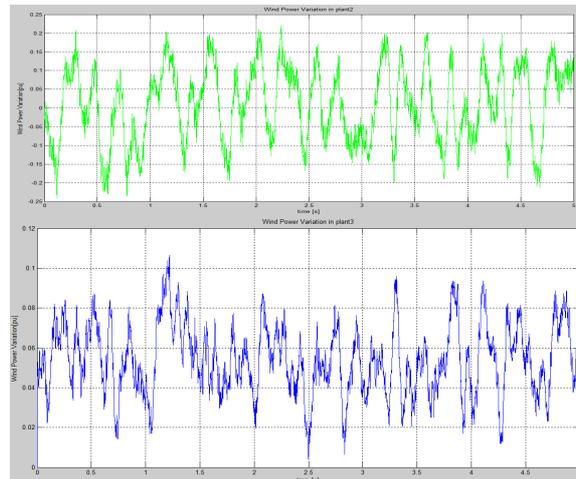


Fig. 4. Wind power variations in three wind farms.

the controller to tackle with wind power fluctuation. With this kind of control design, the robust controller is expected to provide better control performances than a typical PID controller in power system frequency regulation. Note that wind generators are modeled as negative loads in this work. As supplementary control may be applied on wind generators to make them dispatch able [30], it is still possible to apply similar robust controllers on hydro generators to damp the system frequency deviations by implementing new models of wind generators into modified system model, but the damping effects of the controller may be less significant when wind generators are dispatch able.

C. Time Domain Simulation Results

In order to provide further illustrations on the performance of the synthesized controller, time domain simulations of both PID control and robust control with wind penetration are carried out. By solving the closed-loop transfer functions of the entire system with the PID controller and the designed robust controller in time domain, which is also accomplished with MATLAB, system frequency responses under specific wind power disturbances are obtained. Wind power profiles of three wind generators in the test system are shown in Fig. 4, which have a time horizon of 5 seconds. Variation of wind power is represented by deviation values around the mean value within this time horizon of 5 seconds, and the system is assumed to be in

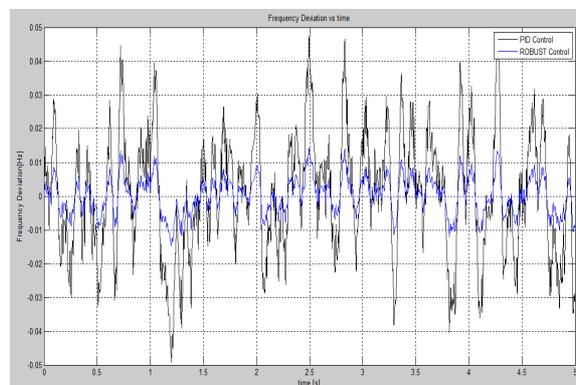


Fig. 5. System frequency response to wind power variation

with a typical PID control and with the proposed robust control and the system I assumed to be in the equilibrium state at the beginning time of simulation. System frequency responses to these wind variations are shown in Fig. 8. Here, the PID control case has more than ± 0.05 Hz deviation in frequency response, while the robust controller shows a much

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superior control result. Simulations are also carried out at different wind penetration levels in the test system, with capacities of other generators keep the same. As variance, which is a descriptor in statistics, can measure how far a set of numbers is spread out [31], it issued to represent the frequency deviation level. These frequency response simulation results prove that the designed robust controller has effectively reduced system frequency deviation and delivers a satisfactory control performance under a wide range of wind penetration levels.

D. Control Actions Analysis

It is necessary to indicate how the robust hydro controller can be more effective than the PID controller in frequencyRegulation. Hence, the control action, (i.e., the corresponding mechanical power output of the prime mover), is analyzed for both cases. With 20% wind penetration in the test power system, the mechanical power deviations of the hydro generator in the PID control case and the robust control case are displayed in Fig. 6. For the hydro generator, the mechanical power deviations inthe robust control case obviously increase compared with thatof the PID case.

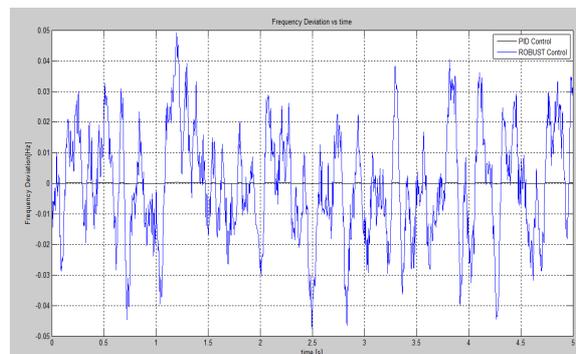


Fig. 6. Mechanical power deviation of the hydro generator with the PID control and with the robust control.

This change in control actions makes the hydro generator more responsive during the frequency regulation. On the other hand, the mechanical power deviations of all thermal generators. These reductions imply that thermal generators can have more stable outputs, and thus suffer less influence brought about by wind power variations. These simulation results imply that the responsibility to adjust wind power variation is more concentrated on hydro generators in the robust control case. This is because in the PID control case, hydro generators only correspond to frequency deviations locally. This is a kind of indirect adjustment to wind power variation. The robust controller, on the other hand, is synthesized based on the whole system. This makes the hydro generators correspond to wind power variation directly. This improvement can also prevent the rest of the power system from being affected by wind power variation.

V. CONCLUSION

A H_{∞} -based robust control outline structure for hydro generators is proposed to lessen robust deviations presented by wind control changeability. This control issue is figured as an unsettling influence dismissal issue, and the controller is incorporated in view of the whole framework demonstrate including the qualities of wind power. Under this control structure, wind control change is straightforwardly handled and remunerated by hydro generators to relieve the framework robust deviation. Recreation ponders on the IEEE 39-transport test framework exhibit that the proposed vigorous controller has fulfilling control execution and the entire framework accomplished substantially littler robust deviation. Likewise, with hydro generators assuming greater liability for robust direction, different generators are less influenced from the impact of wind power variance. Later on work, more muddled generator-senator models considering other damping impacts, for example, PSS, are to be incorporated into the power framework model to enhance the practicability of the planned robust controller.



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BIOGRAPHY



Mr. A. Yuva Kishore has pursuing her Master of Technology in Power Systems, EEE Department, Sree Vidyanikethan Engineering college, Tirupati, Andhra Pradesh, India. He completed his graduation in JNTUA college of Engineering Pulivendula, Andhra Pradesh. His areas of interests includes Power system stability, Renewable energy sources and Power electronic convertors.



Mr. G. Ravindra is currently working as an Assistant Professor in EEE department, Sree Vidyanikethan Engineering college, Tirupati. He received his post graduation from Madanapalle Institute of Technology and Sciences, Madanapalle, Andhra Pradesh. His areas of interest include Network Theory Electrical Machines and Power systems. He has 11 years of teaching experience.