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Interval Type-II Fuzzy H∞ Frequency Control for an Island Microgrid

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Abstract
Frequency control is one of the key parts for the arrangement of the performance of a microgrid (MG) system. Theoretically, model-based controllers may be the ideal control mechanisms; however, they are highly sensitive to model uncertainties and have difficulty with preserving robustness. The presence of serious disturbances, the increasing number of MG, the varying voltage supplies of MGs, and both the independent operations of MGs and their interaction with the main grid make the design of model-based frequency controllers for MGs to become inherently challenging and problematic. This paper proposes an approach that takes advantage of the interval Type-II fuzzy logic for modeling an MG system in the process of its robust H_∞ frequency control. Specifically, the main contribution of this paper is that the parameters of the MG system are modeled by interval Type-II fuzzy system (IT2FS), and simultaneously, MG deals with perturbation using the H_∞ index to control its frequency. The performance of the microgrid equipped with the proposed modeling and controller is then compared with other controllers such as H_2 and μ-synthesis during changes in the microgrid parameters and occurring perturbations. The comparison shows the superiority and effectiveness of the proposed approach in terms of robustness against uncertainties in the modeling parameters and perturbations.

Keywords: *Frequency Control, H_∞ Index, Interval Type-II Fuzzy Logic, Microgrids, Uncertainty.*

1. Introduction

Power systems are large-scale complex systems facing different uncertainties and perturbations. They challenge stability, frequency regulation, and control in cases of connected and disconnected modes. Therefore, various standards have been suggested in order to use them. In 1998, the Consortium for Electric Reliability Technology Solutions (CERTS) introduced the microgrid (MG) concept. The MG concept has been studied by different authors [1]; it integrates small scale distributed energy resources into electricity distribution networks. Today, using microgrids are being normal.

A key feature of MG is its ability to serve as a single self-controlled entity (island mode). In the island mode, MG is responsible for critical loads. More specifically, functional complexity, diversity in load, and uncertainty are the most important features of MG [2]. In the comparison of the traditional approaches of centralized grids, microgrids are expected to be more robust.

From the benefits of MGs, we can mention their increasing reliability, efficiency, and the ability to reduce costs and power distribution feeders, and transmission losses. However, it suffers from some issues such as proper power sharing among distributed generations (DGs) in a typical microgrid, frequency, and voltage fluctuation [3, 4]. The extensive use of different kinds of distributed power sources to influence the quality of the power supply within an MG power system causes many control problems, even though it also provides high reliability and flexibility in the placement of distributed generation. In [5], an approach has been suggested the primary and secondary controllers are designed in low-inertia power grids using the inverter-interfaced generation.

A number of control strategies have been proposed

for microgrid systems such as the proportional-integral, predictive deadbeat, and proportional-resonant strategies.
The important feature in the control system of MGs is frequency. A traditional method for frequency control has been proposed in [6] based on zero-crossing. Another frequency controller has been proposed based on the modified zero-crossing method [7] and smart discrete Fourier transform (DFT) [8]. In [9], the conventional proportional-integral (PI) controllers have been used to reduce the frequency oscillations. In [10], the authors have presented a mechanism for the frequency control of an island microgrid through voltage regulation. A control strategy based on the consensus algorithm has been proposed in [11]. In [12], a decentralized proportional-integral (PI) control design has been proposed for frequency control in a multi-area power system. Most of the controllers are sensitive to the system uncertainties [13]. Hence, robust controllers seem the first option to be used in control applications of power systems.
In [14], an interval Type-II fuzzy PID load frequency controller has been proposed that uses the Big-Bang-Big Crunch algorithm to tune the scaling factors. In [15], frequency fluctuation in an MG system has been examined by combining the electrolyzer system and the fuzzy PI controller. In [16], based on robust control principles, an approach for synchronizing microgrids with utility has been presented. In [17], a multi-distributed energy resource microgrid has been proposed for power-sharing in both the interconnected and island modes. In [18], a robust controller has been designed for generator excitation systems. In [19], for an island microgrid, a robust control strategy in the presence of load un-modeled dynamics has been proposed. A robust control strategy has been suggested in [20] for an island microgrid that regulates the voltage value of load in the presence of non-linear conditions. In [21], a robust optimal control has been proposed, which can provide the highest economic profit of the control schedule. In [22], a load frequency control has been proposed for a microgrid using communication networks and a robust sliding mode control strategy to overcome power unbalance.
Although robust control strategies provide many advantages, they suffer from the drawback that they focus on improving more the steady state behavior of the system such as tracking and disturbance rejection than the transient behavior. They do this by lumping all of the factors together into one block. However, the difficulty of the unmolded dynamic appears mainly in the transient response that produces fluctuations. Dealing with these fluctuations is very important in power systems due to the problem of the peak of consumption. In addition, the basic models of most systems are non-linear; the linearizing model has been suggested as a solution to reduce complication in controlling the system. Therefore, the nominal model has only quasi-steady dynamics. Indeed, two different problems emerge in controlling MG, namely the control signal dealing with perturbation and the uncertainty in modeling. Note that both problems demand the employment of numerical approaches that impose a computational burden on the system. In contrast with the alternative approaches, this paper proposes to tackle these problems separately.
In fact, the main contribution of this paper is that the interval Type-II fuzzy logic is used for handling uncertainty in MG modeling, while H_∞ frequency controller is used to handle perturbation in the control process of the MG. Modeling and controlling processes of the proposed system are done *separately* but *simultaneously* by interval Type-II fuzzy logic and H_∞ robust control, respectively. Working these parts *separately* and *simultaneously* helps balance the power generation and load demand in MGs. More specifically, the proposed approach improves not only the steady-state behavior of the system but also the transient behavior that leads to reduce frequency fluctuations and keep the microgrid stable. In the latter, we seek the uncertainty that exists in the microgrid model parameters, a necessary part for the design of model-based controllers. In the former, on the other hand, the controller is designed when the model is fed into the structure in the presence of perturbation. The control problem of MG is presented in this paper, and it is analyzed for nominal performance (NP), robust stability (RS), and robust performance (RP). The results show the robustness and adaptation ability of the proposed system.
The rest of this paper is organized as follows. After this introduction, Section 2 reviews interval Type-II fuzzy system. Section 3 discusses the proposed interval Type-II fuzzy microgrid modeling. Section 4 details the proposed controller. Simulation results are studied in Section 5. Conclusion is drawn in Section 6.

2. Preliminaries

The concept of Type II fuzzy set has been introduced by Zadeh [23] as the extension of Type I fuzzy sets. Although Type I fuzzy set is the most popular version of fuzzy logic [24], recent research works show a significant improvement in the performance using Type II fuzzy logic.
A Type II fuzzy set denoted by $\tilde{A}$ is characterized by a Type II fuzzy set as follows [25]:

$$\tilde{A} = \left\{ \left(x,u\right), \mu_{\tilde{A}}\left(x,u\right) \middle| \forall x \in X, \forall u \in J_x \in \left[0,1\right] \right\} \quad (1)$$

in which J_x is referred to as the primary memberships of x and $0 \le \mu_{\tilde{A}}(x,u) \le 1$. The uncertainty in Type II fuzzy set is called the footprint of uncertainty (FOU) that is a union of all primary membership functions. If we set $\mu_{\tilde{A}}(x,u)$ with 1 for every u, we obtain interval Type II fuzzy set (IT2FS) that can be described by an upper membership function and a lower membership function as follow:

$$\tilde{A} = \left[\underline{A}, \overline{A} \right] \quad (2)$$

and,

$$FOU\left(\tilde{A}\right) = \bigcup \left[\underline{A}, \overline{A} \right] \quad (3)$$

The structure of the interval Type II fuzzy logic system (IT2FLS) is similar to Type I. An interval Type II fuzzy logic system (IT2FLS) is described using at least one interval Type II fuzzy set. An IT2FLC is illustrated in figure1 that includes interval Type-II fuzzifier, rule-based, inference engine, and output processor containing type reduce and defuzzifier.

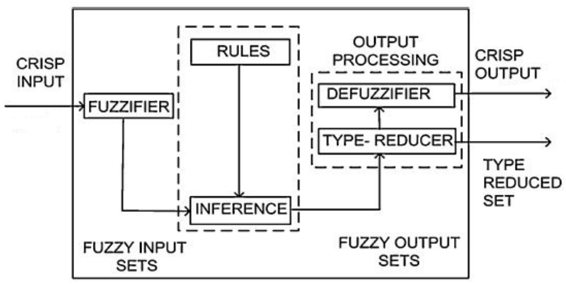


Figure 1. Block diagram of IT2FLC.

The fuzzifier maps a real-valued variable into interval-Type II fuzzy sets. In a singleton fuzzifier, the output is a single point of a unity membership grade. The knowledge of experts will be converted into a set of fuzzy IF-THEN rules. The j_{th} rule in IT2FLS can be written as below:

$$If\ x_1\ is\ \tilde{A}_1^j\ and\ x_2\ is\ \tilde{A}_2^j and \ldots and\ x_n\ is\ \tilde{A}_n^j \quad (4)$$
$$then\, output\, is\ \tilde{B}^j \qquad j = 1,..,M$$

where M is the total number of rules and x_i is the input of IT2FLS, and $\tilde{B}$ and $\tilde{A}$ are interval Type II antecedent and consequent fuzzy sets. The inference engine combines rules and gives a mapping from input IT2FSs to output IT2FSs. The firing set is generally obtained as follows:

$$If\ x_1\ is\ \tilde{A}_1^j\ and\ x_2\ is\ \tilde{A}_2^j and \ldots and\ x_n\ is\ \tilde{A}_n^j \quad (5)$$
$$then\, output\, is\ \tilde{B}^j \qquad j = 1,..,M$$

Note that the firing strength of Type II, ith rule is as follows:

$$F^i = \left[\underline{f}_i, \overline{f}_i \right] \quad (6)$$

where $\underline{f_i}, \bar{f_i}$ are the lower and upper firing degrees of rule i:

$$\overline{f}_i = \prod_{k=1}^{n} \overline{\mu}_{A_k^i}\left(x_k\right) \quad (7)$$

$$\underline{f}_i = \prod_{k=1}^{n} \underline{\mu}_{A_k^i}\left(x_k\right)$$

A type-reducer converts interval Type II fuzzy sets into Type I [26]. Most of the type reduction methods are based on computing the centroid of an IT2FS. Among different type reductions, the center of sets is widely used and obtained by iterative algorithm Karnik-Mendel [26]. In IT2FLS, the output of type reducer is an interval set. Defuzzification is achieved by obtaining the average of endpoints.

3. Proposed interval type- II fuzzy model of microgrid

In this paper, a microgrid system is comprised of a control system, diesel generator, a micro-turbine (MT), an AC load, a hydrogen tank, and renewable-energy-utilizing generators such as wind power, photovoltaic (PV), proton membrane fuel cell (FC) is considered. Wind and photovoltaic generators have the disadvantage of being unstable parts.

3.1. Uncertainty in microgrid

The microgrid model we consider here has seven inputs: loads, wind turbine generator (WTG), PV, MT (micro-turbine), FC, FES (Flywheel energy storage), and BES (Battery energy storage) and a measured output: frequency.

The main set of uncertainties about the MG model would include:

- Uncertainty in the generation, the consumption, and the distributed generation (DG) that makes deflections in energy generation
- Uncertainty in the linear approximation of the dynamic of MG due to specific non-linearity existing in the real system.

As a first approximation, this arises from the uncertainties in the wind turbine, photovoltaic coefficients, which vary with wind and solar conditions as well as uncertainty in the exact geometry of the battery.

- Uncertainty in the force.

An even more detailed view is that energy generates the forces by changing the flow in very complex ways.
Thus, there are uncertainties in the force that goes beyond the quasi-steady uncertainties implied by uncertain coefficients.

- Uncertainty in ΔP produced by the DG generated forces.

This arises from the uncertainty in the various parameters of the component power systems.

- Uncertainty due to neglected dynamics such as consumption conditions.
- Other forms of uncertainty that are less known.

In this paper, the uncertainty is modeled in this detailed manner, using IT2FS. This model approximates quasi-steady dynamics. IT2FS handles uncertainties in modeling by approximating the unknown non-linear dynamics of power systems; then these sections are lumped into one block uncertainty at the input of an 8-state the MG system.
In addition, the value of a control signal is an important aspect of the controller design. There is also uncertainty related to it in the form of perturbation, as discussed above. In this paper, H_∞ controller is used to addressing this issue.

3.2. Formulation of interval type-II fuzzy modeling

Wind and photovoltaic generators are naturally unstable; they can cause a sudden frequency fluctuation to easily occur. This type of fluctuation cannot be effectively reduced by dynamic modeling approaches; therefore, they are usually ignored by approaches. This is also true for harmonic results from power electronic devices connecting MGs to the main grids such as converters, and the fluctuations resulting from the main grid frequency fluctuations.
The system includes loads, WTG, PV, MT, FC, FES, and BES. Power electronic devices are used to invert the DC voltage to the AC voltage in charging and dispatching modes, and vice versa, for BES systems.
The structure of a total power generation source (P) is generally as [2]:

$$P_{load} = P_{load} + P_{MT} + P_{WTG} + P_{PV} + P_{FC} \pm P_{BES} \pm P_{FES} \tag{8}$$

The actual implementation requires power produced in DEG, MT, and FC to compensate for the fluctuation in $WTC, load$, and PV.
The power produced by RES (PV and WTG) depends on the environmental condition. As discussed in Sub-section 3-1, due to the uncertainties in load demand, solar radiation, and wind speed, there are deviations from the actual value. To dead with the uncertainties, the interval Type-II fuzzy model is used for WTG, DEG, FC, MT, FES, PV, BES, and load. The structure of the proposed model is depicted in figure 2. As seen, frequency fluctuation, Δf , is affected by ΔP as follows:

$$\Delta f \to 0 \qquad if \qquad \Delta P \to 0 \tag{9}$$

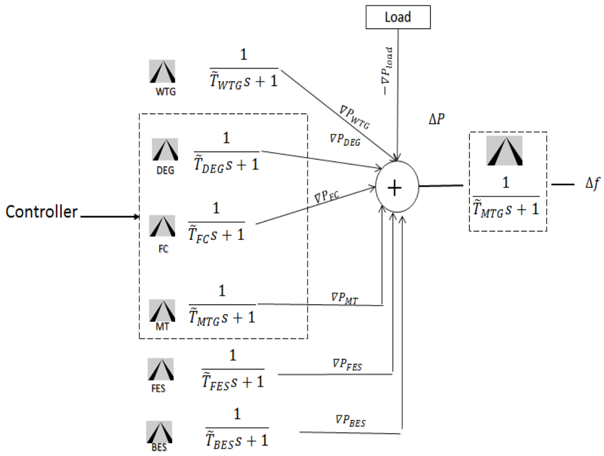


Figure 2. Proposed interval Type II fuzzy dynamical model.

The used MG model is an eight-state linear time-invariant model as follows:

$$\dot{x} = Ax + [B_2 B_1][u, w] \qquad y = Cx \tag{10}$$

and

$$x^T = [\Delta P_{WTG}, \Delta P_{PV}, \Delta P_{DEG}, \Delta P_{FC}, \Delta P_{MT}, \Delta P_{BES}, \Delta P_{FES}, \Delta f] \tag{11}$$
$$w^T = \left[\Delta P_{Wind}, \Delta P_{\varphi}, \Delta P_{Load}\right]$$
$$y = \Delta f$$

where x is the state variable vector, w is the exogenous disturbance signals, and u is the control signal input and y represents the output variable. The main source of uncertainty in the underlying framework is the uncertain parameters of the given MG leading to uncertain dynamics or more specifically, to uncertain matrices $A, B_1, B_2, C,$ and D. Therefore,

$$\dot{x} = \tilde{A}x + \left[\tilde{B}_2 \tilde{B}_1\right][u\, w] \ , \qquad y = \tilde{C}x \tag{12}$$

where,

$$\tilde{A}=\begin{bmatrix} -1/\tilde{T}_{WTG} & & & & & & & \\ 0 & -1/\tilde{T}_{PV} & & & & & & \\ 0 & 0 & -1/\tilde{T}_{DEG} & & & & & \\ 0 & 0 & 0 & -1/\tilde{T}_{FC} & & & & \\ 0 & 0 & 0 & 0 & -1/\tilde{T}_{MT} & & & \\ 0 & 0 & 0 & 0 & 0 & 0 & & 1/\tilde{T}_{BES} \\ 0 & 0 & 0 & 0 & 0 & 0 & -1/\tilde{T}_{FES} & 1/\tilde{T}_{FES} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -2\tilde{D}/\tilde{M} \end{bmatrix} \quad (13)$$

$$\tilde{B}_2=\begin{bmatrix} 1/\tilde{T}_{WTG} & & \\ 0 & 1/\tilde{T}_{PV} & \\ 0 & 0 & \\ 0 & 0 & \\ 0 & 0 & \\ 0 & 0 & \\ 0 & 0 & \\ 0 & 0 & 2/\tilde{M} \end{bmatrix}$$

$$\tilde{B}_1=\begin{bmatrix} 0 \\ 0 \\ 1/\tilde{T}_{DEG} \\ 1/\tilde{T}_{FC} \\ 1/\tilde{T}_{MT} \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\tilde{C}=\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Now, note that, as discussed in Section II, for every interval Type II fuzzy set [25], we can write:

$$\tilde{F}=\left[\underline{f},\bar{f}\right] \quad (14)$$

where $\underline{f}_i,\bar{f}_i$ are lower and upper of $\tilde{F}$. Therefore, it can be written as:

$$\dot{x}=\left[\underline{A},\bar{A}\right]x+\left[\underline{B}_2,\bar{B}_2\right]u+\left[\underline{B}_1,\bar{B}_1\right]w \quad (15)$$

$$y=\left[\underline{C},\bar{C}\right]x$$

In figure 3, the steps of fuzzifying matrices and producing lower and upper bound of matrices are shown.

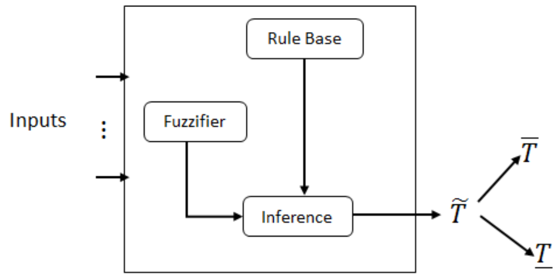


Figure 3. Fuzzifying matrices $\tilde{T}$: $\tilde{A},\tilde{B},\tilde{C}$.

As seen in figure 3, the output of each approximator is Type 1 fuzzy number $\underline{T}$, $\bar{T}$. The related transfer functions $\underline{G}$ and $\bar{G}$ can be computed as follows:

$$\underline{G}=\underline{C}\otimes\left(s\underline{I}\ominus\underline{A}\right)\otimes\underline{B} \quad (16)$$

$$\bar{G}=\bar{C}\otimes\left(s\bar{I}\ominus\bar{A}\right)\otimes\bar{B}$$

The operator $\odot$ represents $\ominus$ or $\otimes$ is defined based on the extension principle as:

$$H(h)=\sup_{h=v\odot t}\min\left(f(v),g(t)\right) \quad (17)$$
$$h,v,t\in R^3$$

Once Type II fuzzy $\tilde{G}$ is computed, it is type-reduced and defuzzified to get the crisp transfer function. Then, it is fed into the structure. We use the center of sets defuzzifier, see figure 4, then we obtain the applied transfer function $\widehat{G}$.

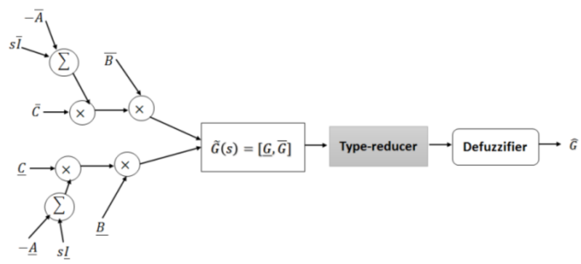


Figure 4. Applied transfer function.

4. Proposed H_∞ frequency controller

The H_∞ controller determines a feasible robust controller by minimizing the infinite-norm $\|\ \|_\infty$ as follows:

$$\|T_{zw}\|_{\infty}<1 \quad (18)$$

where T_{zw} is the transfer function matrix of the nominal closed-loop system from the disturbance input signals to the controlled output signals. The process H_∞ controller is to design controller gain K_∞ such that (18) has been satisfied. Due to internally stable of T_{zw}, robust stability and normal stability are satisfied. The nominal performance criterion for the closed-loop system can be described as follows:

$$\left\| \begin{bmatrix} W_e(I+\hat{G}K)^{-1} \\ W_pK(I+\hat{G}K)^{-1} \end{bmatrix} \right\|_\infty < 1 \quad (19)$$

where W_e and W_p are the weighting functions that are chosen to improve the nominal performance. In addition, the robust performance criterion is as follows:

$$\left\| \begin{bmatrix} W_e(I+\hat{G}P)^{-1} \\ W_pK(I+\hat{G}P)^{-1} \end{bmatrix} \right\|_\infty < 1 \quad (20)$$

We define the generalized transfer matrix includes the weighting matrices (that specify the restriction of design) and plant $\hat{G}$ as follows:

$$\begin{bmatrix} 0 & -W_p\hat{G} \\ 0 & -W_pG_dW_d \\ W_d & -\hat{G} \end{bmatrix} \quad (21)$$

The overall structure of the proposed controller is depicted in figure 5.

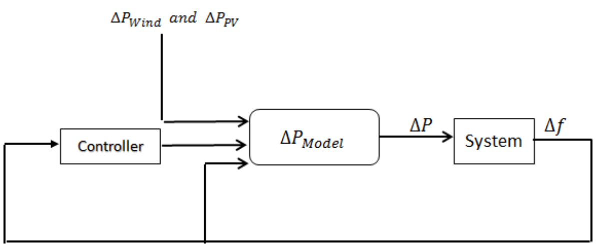


Figure 5. Proposed controller.

Figure 6 shows the system setup for robust performance. In that, z represents the desired performance signals and $y = \Delta f$ is the measured output. In addition, Δ is a diagonal matrix that represents the parametric unmolded dynamics and perturbation effects.

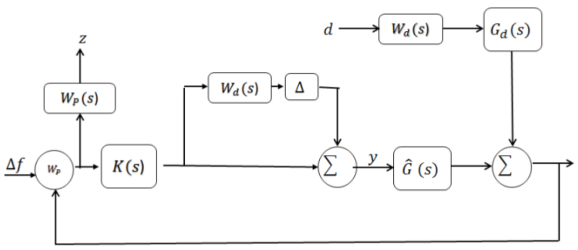


Figure 6. System setup for robust performance.

Figure 7 demonstrates the LFT framework of the proposed structure, which is based on the singleton IT2FS approximation.

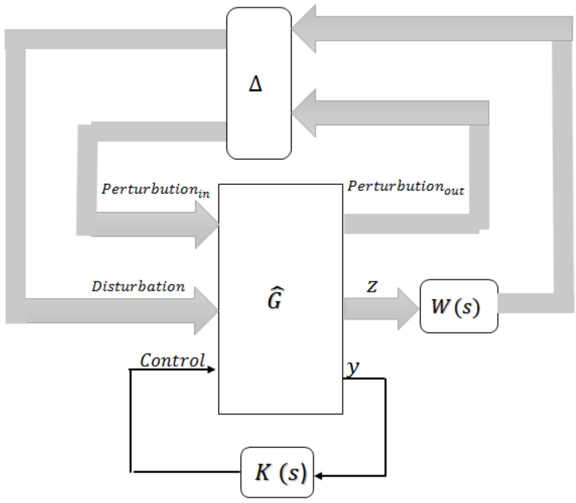


Figure 7. LFT framework of the proposed structure.

Also, we define Δ as follows:

$$\Delta = \left\{ diag\left[\delta_1 I_{r1} \quad \dots \quad \delta_k I_{rk}, \Delta_1, \dots, \Delta_f \right] \right\} \quad (22)$$
$$\delta_i \in C, \Delta_i \in C^{K_i \times K_j}$$

By this Δ, we define μ function as follows:

$$\mu_\Delta(M) = 1 / \min_\Delta \left\{ \sigma(\Delta) : |I - M\Delta| = 0,\ \Delta \in \Delta \right\} \quad (23)$$

5. Simulation results

The control objective is:

1) Maintaining frequency fluctuations bounded at a constant interval.
2) Disturbance rejection.
3) Satisfy nominal performance, robust stability, and robust performance.

Figure 8 presents the interval Type II fuzzy models for the system parameters of the given microgrid. Bode plot of the nominal and disturbance model of $\tilde{G}$ is depicted in figure 9. Singular value of nominal and disturbance model $\tilde{G}$ is depicted in figure 10.

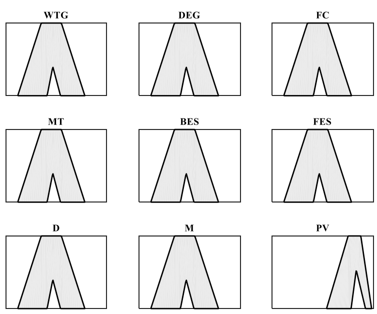


Figure 8. Interval Type II fuzzy model of microgrid's parameters.

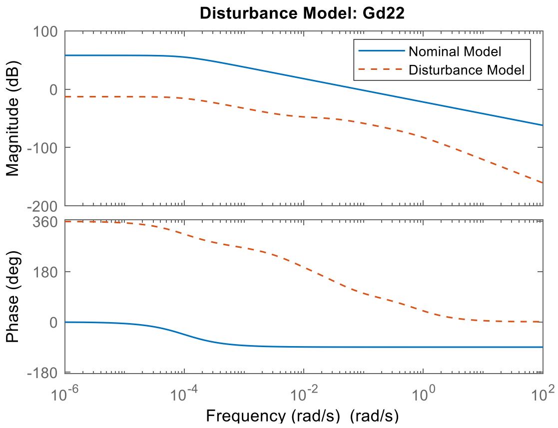


Figure 9. Bode plot of the nominal and disturbance model.

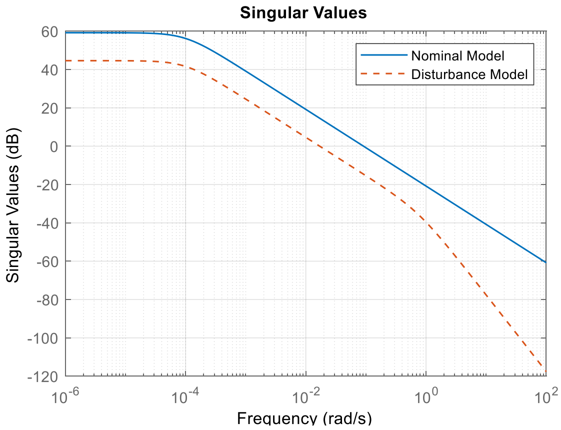
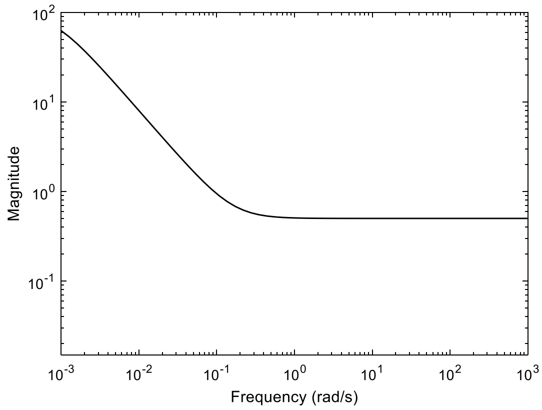


Figure 10. Singular values.

A magnitude plot of performance of weighting function W_p and uncertainty weight W_d are depicted in figure 11. Nominal performance and robust performance with H_∞ controller are depicted, respectively, in figures 12 and 13. As seen, both criteria (19-20) are satisfied and are always less than 1. Figure 14 shows the closed-loop time response and disturbance rejection with H-infinity controller when the reference signal is $\Delta f = 0$.

The simulation results of the proposed approach demonstrate a suitable performance. The comparison of the proposed approach with the alternative robust controllers is provided in table 1. This table shows the MSE (minimum square error) of the deviation of Δf from zero according to the changes in the different independent variables of ΔP_{Load}, ΔP_{Wind}, and ΔP_{φ}.



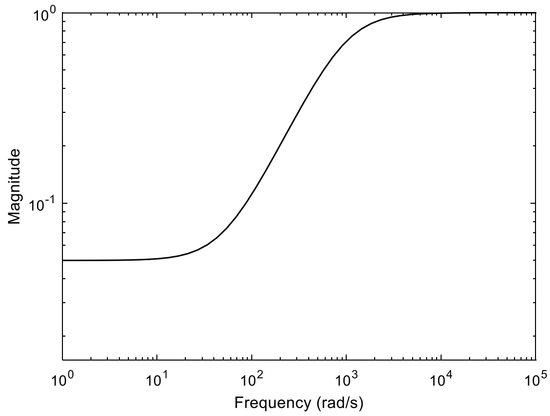


Figure 11. Uncertainty Weights (above) and Performance of weighting function (below).

It should be mentioned that these factors are independent of each other but Δf depends on all of them. We consider the changes one by one, two by two, and even all three; then we measure the deviation of Δf from zero. As shown, the proposed approach provides significantly better performance than do the cases of H_∞ controller, H_2 controller, and $\mu-$controller in terms of the MSE of frequency fluctuation with the different changes of the wind, solar, and load inputs. It is clear from the simulation results, Type II fuzzy-based parameters lead to better results. In fact, the footprint of IT2FS leads to better handling of uncertainty in modeling a microgrid that yields minimizing frequency deviations of the system against uncertainties as the results show.

In figure 15, the comparison of the bode diagram of the proposed approach with alternative approaches is shown. In the wind power, we consider a step change, as shown in figure 16 (top). The frequency response of the proposed approach and the alternative controllers of H∞ and Type 1 fuzzy H∞ are shown in figure 16 (bottom).

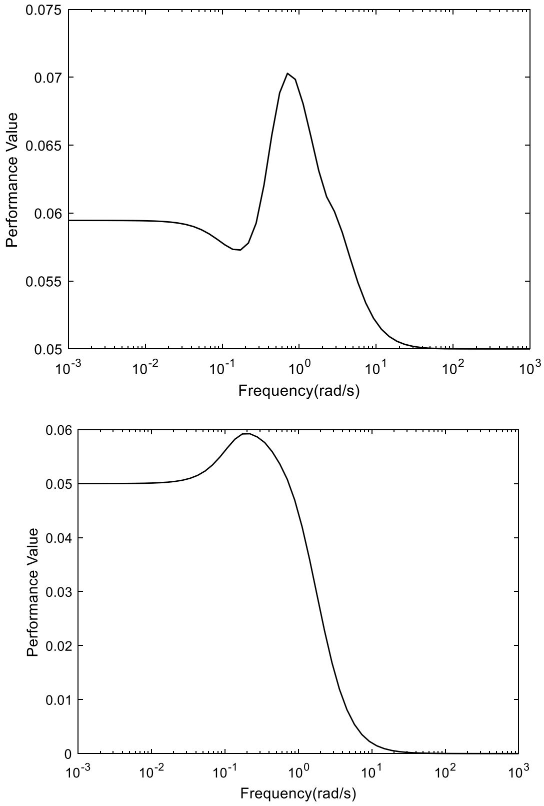


Figure 12. Nominal Performance (above) and Robust Performance (below).

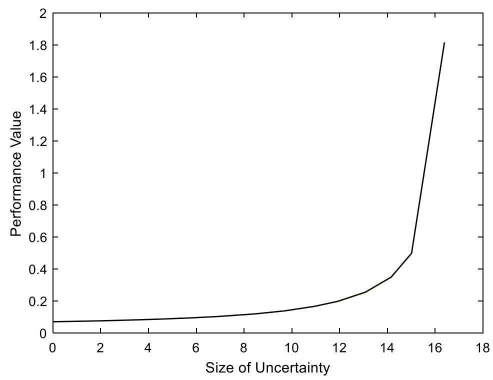


Figure 13. Worst-Case Performance with H-infinity Controller.

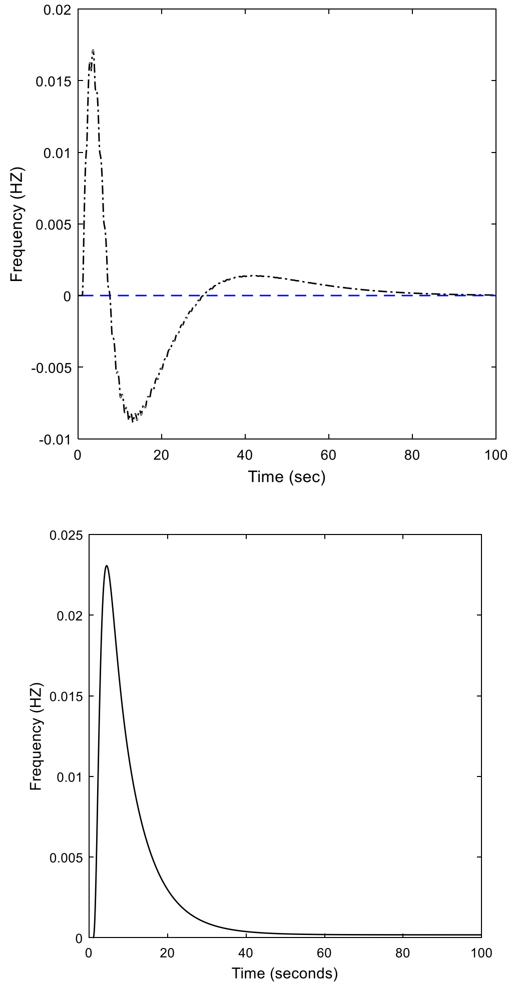


Figure 14. Closed Loop Time Response (top) and disturbance rejection (bottom).

The suggested controller indicates a suitable performance and is robust against changes in parameters values. That is the main advantage of using Type II fuzzy logic in the modeling of the microgrid for the H_∞ model-based controller. This is a valuable result in power systems.

Table 1: Comparison of the proposed and alternative approaches against changes.

Type of Controller	ΔP_{Load}	ΔP_{Wind}	ΔP_{φ}	ΔP_{Wind} ΔP_{φ}	ΔP_{Wind} ΔP_{Load}	ΔP_{Load} ΔP_{φ}	ΔP_{φ} ΔP_{Wind} ΔP_{Load}
H_∞	0.23	0.2 3	0.26	0.87	0.69	0.71	0.81
H_2	0.25	0.29	0.27	0.78	0.91	0.78	0.71
µ-synthesis	0.20	0.27	0.23	0.65	0.71	0.61	0.61
Proposed Approach	**0.15**	**0.20**	**0.17**	**0.32**	**0.25**	**0.37**	**0.32**

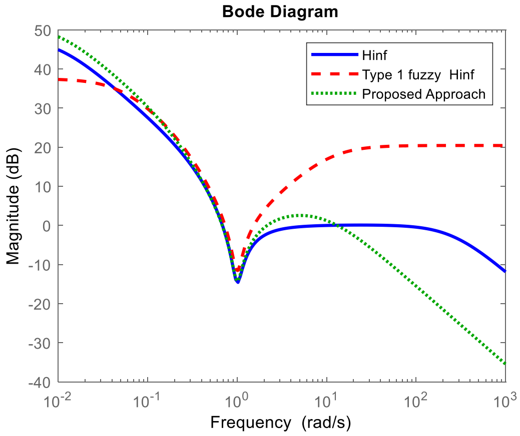


Figure 15. Comparison of alternative controllers.

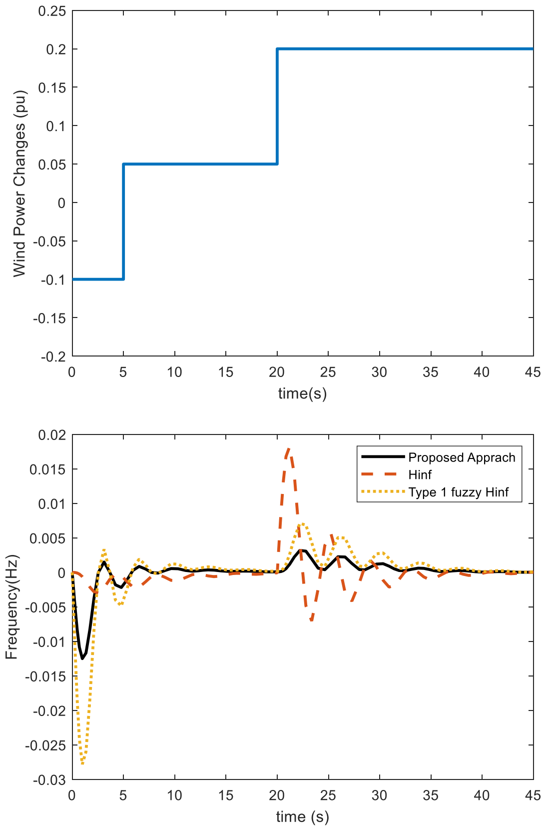


Figure 16. Comparison of the controller against wind power changes.

6. Conclusion

Microgrids will have an important role in the future electrical power system. To tolerate uncertainties existed in the microgrid model by interval Type II fuzzy system and H_∞ frequency control analysis, the proposed system presented an enhanced model and control methodology and applied to a typical microgrid. The proposed system has robustness against the effects of high-frequency non-modeled dynamics. The simulation results show that the proposed approach can reduce the frequency fluctuations and preserve the microgrid stability during changes in its parameters. The proposed approach, due to considering IT2FLS and H_∞ control helps the balance of power generation and load demand in the microgrid. Therefore, the proposed approach makes the system more reliable and efficient in the presence of uncertainties and perturbation.

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نشریه هوش مصنوعی و داده کاوی

کنترل H_∞ فرکانسی ریز شبکه جزیره‌ای برمبنای منطق فازی نوع دو بازه‌ای

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چکیده:

کنترل فرکانس یکی از بخش‌های کلیدی برای تنظیم عملکرد یک سیستم ریز شبکه (MG) است. ازلحاظ تئوری، کنترل‌کننده‌های مبتنی بر مدل مکانیسم‌های کنترل ایدئال می‌باشند. بااین‌حال, آن‌ها بسیار حساس به عدم قطعیت مدل هستند و در حفظ مقاومت و رباستنس به مشکل برمی‌خورند. حضور اختلالات جدی, افزایش تعداد ریز شبکه‌ها, منابع ولتاژ متفاوت برای MGs, و عملیات مستقل ریز شبکه‌ها و تعامل آن‌ها با شبکه اصلی باعث شده است که طراحی کنترل‌کننده فرکانس مبتنی بر مدل چالش‌برانگیز و مشکل‌ساز بشود. این مقاله یک رویکرد را پیشنهاد می‌دهد که از منطق فازی بازه‌ای نوع دوم برای مدل‌سازی یک سیستم ریز شبکه در فرایند کنترل فرکانسH_∞ استفاده شود. به‌طور مشخص، نوآوری اصلی این مقاله این است که پارامترهای سیستم MG با استفاده از سیستم فازی نوع دو بازه‌ای مدل شوند و هم‌زمان ریز شبکه با کمک شاخص H_∞ با اغتشاش مقابله کند. عملکرد ریز شبکه که مجهز به مدل‌سازی و کنترل‌کننده پیشنهادی است با عملکرد کنترل کننده‌های دیگر مانند H_2 و μ-سنتز با وجود تغییرات در پارامترهای ریز شبکه و حضور اغتشاش مقایسه شده است. این مقایسه، برتری و اثربخشی رویکرد پیشنهادی را ازنظر استحکام در برابر عدم قطعیت مدل نشان می‌دهد.

کلمات کلیدی: کنترل فرکانس، شاخص H_∞، منطق فازی نوع دو بازه‌ای،ریز شبکه، عدم قطعیت.