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Chapter 6

Design of FUZZY-(1+PD)-FOPID Controller for Hybrid Two-Area Power System

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Summary

Approach of the fuzzy logic control (FLC) has been one of the most vibrant and productive fields for study in the use of fuzzy set theories during the past couple of decades. Zadeh's influential publications on the linguistic methodology and analysis of the system based on the idea of fuzzy sets served as the inspiration for Mamdani and his coworkers' revolutionary study on FLC. The fundamental tenet of this strategy was to develop the controller while taking into account the "learning" of a human process of operations. A control algorithm is built from a collection of linguistic rules that characterize the operator's controlling approach, with the words described as fuzzy sets. To triumph over the LFC in all two-area power systems, a hybrid FUZZY-(1+PD)-FOPID controller is introduced in this study as a novel expert control approach. The proposed controller settings such as K_{P1} , K_{P2} , K_{D1} , K_{D2} , and K_{I2} as well as additional parameters, such as the integrator-exponential (λ) and differentiator-exponential (μ), are optimized using a recently published population-based, nature-inspired algorithm named tree-seed algorithm (TSA) while using the integral of squared error (ISE) criteria. The recommended FUZZY-(1+PD)-FOPID controller has been suggested to be utilized for controlling a two-area power system that includes thermal and nuclear units along with non-conventional energy sources (NCEs) like solar and ocean thermal. The whole system with the proposed controller is sketched and tested in the MATLAB simulation platform. The simulation results are analyzed using the acquired time-domain parameters such as settling time (ST), overshoot (OS), and undershoot (US). The suggested controller outperforms competing controllers found in the literature, as evidenced by the comparison of the major performance indices and the

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Kristov , L. , The Bottom-Up (R)Evolution of the
Energy Mag. , **17** , 2 , 42 – 49 , March-April 2019 .

[Google Scholar](#)

Xu , S. , Xue , Y. , Chang , L. , Review of power s
algorithms, and trends . *IEEE Open J. Power Ele*

[Google Scholar](#)

Shakibjoo , A.D. , Moradzadeh , M. , Din , S.U. , Mohammadzadeh , A. , Mosavi , A.H. , Vandevælde , L. , Optimized Type-2 Fuzzy Frequency Control for Multi-Area Power Systems . *IEEE Access* , **10** , 6989 – 7002 , 2022 , doi: [10.1109/ACCESS.2021.3139259](https://doi.org/10.1109/ACCESS.2021.3139259) .

[Google Scholar](#)

Hidalgo , D. , Castillo , O. , Melin , P. , Type-1 and type-2 fuzzy inference systems as integration methods in modular neural networks for multimodal biometry and its optimization with genetic algorithms . *Inf. Sci.* , **179** , 13 , 2123 – 2145 , 2009 .

[Google Scholar](#)

Zribi , M. , Al-Rashed , M. , Alrifai , M. , Adaptive decentralized load frequency control of multi-area power systems . *Int. J. Electr. Power Energy Syst.* , **27** , 8 , 575 – 583 , 2005 .

[Web of Science®](#) | [Google Scholar](#)

Panda , G. , Panda , S. , Ardil , C. , Hybrid neuro
. *Int. J. Comput. Intell.* , **5** , 1 , 80 – 84 , 2009 .

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Rodríguez-Abreo , O. , *et al.* , Self-tuning neural network based

[Google Scholar](#)

Vrdoljak , K. , Perić , N. , Petrović , I. , Sliding mode based load-frequency control in power systems . *Electr. Power Syst. Res.* , **80** , 5 , 514 – 527 , 2010 .

[Web of Science®](#) | [Google Scholar](#)

Dahiya , P. , Sharma , V. , Naresh , R. , Optimal sliding mode control for frequency regulation in deregulated power systems with DFIG-based wind turbine and TCSC–SMES . *Neural Comput. Appl.* , **31** , 7 , 3039 – 3056 , 2019 .

[Web of Science®](#) | [Google Scholar](#)

Rosaline , A.D. and Somarajan , U. , Structured H-Infinity controller for an uncertain deregulated power system . *IEEE Trans. Ind. Appl.* , **55** , 1 , 892 – 906 , 2018 .

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Sondhi , S. and Hote , Y.V. , Fractional order PID controller for load frequency control . *Energy Convers. Manage.* , **85** , 343 – 353 , 2014 .

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generating systems . *Swarm Evol. Comput.* , 32

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frequency control with governor saturation cc

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Kumar , N. , Kumar , V. , Tyagi , B. , Multi area AGC scheme using imperialist competition algorithm in restructured power system . *Appl. Soft Comput.* , 48 , 160 – 168 , 2016 .

[Web of Science®](#) | [Google Scholar](#)

Ebrahim , M.A. , Becherif , M. , Abdelaziz , A.Y. , PID-/FOPID-based frequency control of zero-carbon multisources-based interconnected power systems under deregulated scenarios . *Int. Trans. Electr. Energy Syst.* , 31 , 2 , e12712 , 2021 .

[Web of Science®](#) | [Google Scholar](#)

Arya , Y. , *et al.* , AGC performance amelioration in multi-area interconnected thermal and thermal-hydro-gas power systems using a novel controller . *Eng. Sci. Technol. Int. J.* , 24 , 2 , 384 – 396 , 2021 .

[Web of Science®](#) | [Google Scholar](#)

Arya , Y. , *et al.* , Cascade- λ D μ N controller des
sources . *IET Renewable Power Gener.* , 15 , 3 , 5

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Saikia , L.C. , *et al.* , Automatic generation control of a power system . *Int. J. Electr. Power Energy Syst.* , **33** , 4 , 1101 – 1108 , 2011 .

[Web of Science®](#) | [Google Scholar](#)

Khuntia , S.R. and Panda , S. , Simulation study of a power system . *Soft Comput.* , **12** , 1 , 333 – 341 , 2012 .

[Web of Science®](#) | [Google Scholar](#)

Fathy , A. and Kassem , A.M. , Antlion optimizer-ANFIS load frequency control for multi-interconnected plants comprising photovoltaic and wind turbine . *ISA Trans.* , **87** , 282 – 296 , 2019 .

[PubMed](#) | [Web of Science®](#) | [Google Scholar](#)

Sharma , D. and Mishra , S. , Non-linear disturbance observer-based improved frequency and tie-line power control of modern interconnected power systems . *IET Gener. Transm. Distrib.* , **13** , 16 , 3564 – 3573 , 2019 .

[Web of Science®](#) | [Google Scholar](#)

Guha , D. , Roy , P.K. , Banerjee , S. , Disturbance observer aided optimised fractional-order three-degree-of-freedom tilt-integral-derivative controller for load frequency control of power systems . *IET Gener. Transm. Distrib.* , **15** , 4 , 716 – 736 , 2021 .

[Web of Science®](#) | [Google Scholar](#)

Sahu , B.K. , *et al.* , A novel hybrid LUS–TLBO based load frequency control of a power system . *Electr. Power Energy Syst.* , **74** , 58 – 69 , 2016 .

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Nayak , J.R. , Shaw , B. , Sahu , B.K. , Application filter for automatic generation control of an ir

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Haroun , Gomaa , A.H. , Li , Y.-Y. , A novel optir system with physical constraints and boiler dy

[PubMed](#) | [Web of Science®](#) | [Google Scholar](#)

Fathy , A. , Kassem , A.M. , Abdelaziz , A.Y. , Optimal design of fuzzy PID controller for deregulated LFC of multi-area power system via mine blast algorithm . *Neural Comput. Appl.* , 32 , 4531 – 4551 , 2020 .

[Web of Science®](#) | [Google Scholar](#)

Nayak , N. , *et al.* , Application of modified sine cosine algorithm to optimally design PID/fuzzy-PID controllers to deal with AGC issues in deregulated power system . *IET Gener. Transm. Distrib.* , 13 , 12 , 2474 – 2487 , 2019 .

[Web of Science®](#) | [Google Scholar](#)

Nayak , P.C. , *et al.* , Performance analysis of hydrogen aqua equaliser fuel-cell on AGC of wind-hydro-thermal power systems with sunflower algorithm optimised fuzzy-PDFPI controller . *Int. J. Ambient Energy* , 43 , 1 , 3454 – 3467 , 2022 .

[CAS](#) | [Google Scholar](#)

Arya , Y. , A new optimized fuzzy FOPI-FOPD co , 5611 – 5629 , 2019 .

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Sudha , K.R. and Vijaya Santhi , R. , Robust decoupled control using type-2 fuzzy approach . *Int. J. Elec. Power Energy Syst.* , **41** , 1077 – 1084 , 2019 .

[Web of Science®](#) | [Google Scholar](#)

Kocaarslan , I. , Akalin , G. , Erfidan , T.A.R.I.K. , et al . , Robust control of interconnected power system . *European Control Conference (ECC)* , IEEE , 1999 .

[Google Scholar](#)

Chandran , K. , et al . , Modified cascade controller design for unstable processes with large dead time . *IEEE Access* , **8** , 157022 – 157036 , 2020 .

[Google Scholar](#)

Sanki , P. and Basu , M. , New approach in two-area interconnected AGC including various renewable energy sources using PSO . *Turk. J. Electr. Eng. Comput. Sci.* , **26** , 3 , 1491 – 1504 , 2018 .

[Web of Science®](#) | [Google Scholar](#)

Chaine , S. and Tripathy , M. , Performance of CSA optimized controllers of DFIGs and AGC to improve frequency regulation of a wind integrated hydrothermal power system . *Alexandria Eng. J.* , **58** , 2 , 579 – 590 , 2019 .

[Web of Science®](#) | [Google Scholar](#)

Hakimuddin , N. , Nasiruddin , I. , Bhatti , T.S. , et al . , Robust control of interconnected power system using bacterial foraging algorithm . *Eng. Rep.* , **2** , 8 , 1077 – 1084 , 2019 .

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Biswas , S. , Roy , P.K. , Chatterjee , K. , Renewa
algorithm . *IETE J. Res.* , **69** , 3 , 1 – 19 , 2021 .

[Google Scholar](#)

Hernández-Romero , I.M. , *et al.* , Optimal design of the ocean thermal energy conversion systems involving weather and energy demand variations . *Chem. Eng. Process.-Process Intensif.* , **157** , 108114 , 2020 .

[CAS](#) | [Google Scholar](#)

Hasan , N. and Farooq , S. , Real time simulation of automatic generation control for interconnected power system . *Int. J. Electr. Eng. Inform.* , **4** , 1 , 40 , 2012 .

[Google Scholar](#)

Gupta , N. and Garg , R. , Tuning of asymmetrical fuzzy logic control algorithm for SPV system connected to grid . *Int. J. Hydrogen Energy* , **42** , 26 , 16375 – 16385 , 2017 .

[CAS](#) | [Web of Science®](#) | [Google Scholar](#)

Kapoor , S. , Chaturvedi , M. , Juneja , P.K. , Design of fractional order PID controller for a SOPDTprocess model . *2017 Fourth International Conference on Image Information Processing (ICIIP)*

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Abraham , A. , *et al.* , Design of fractional orde
conference on Genetic and evolutionary comput

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Zamani , M. , *et al.* , Design of a fractional order PID controller for an AVR using particle swarm optimization . *Control Eng. Pract.* , **17** , 12 ,
1380 – 1387 , 2009 .

[Web of Science®](#) | [Google Scholar](#)

Monje , C.A. , *et al.* , On fractional PI λ controllers: some tuning rules for robustness to plant uncertainties . *Nonlinear Dyn.* , **38** , 369 – 381 ,
2004 .

[Web of Science®](#) | [Google Scholar](#)

Barbosa , R.S. , Tenreiro Machado , J.A. , Ferreira , I.M. , Tuning of PID controllers based on Bode's ideal transfer function . *Nonlinear Dyn.* ,
38 , 305 – 321 , 2004 .

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Controller Design for Industrial Applications is essential for anyone looking to master the advanced techniques of intelligent controller design, enabling you to effectively tackle the complexities of modern industrial processes and optimize performance in an ever-evolving landscape.

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