Frequency Stabilization of Multi Area Power System using Adaptive Neuro Fuzzy Interface System and Support Vector Machine Approach

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Abstract: ***Modern power systems include an increasing number of power electronics - based devices such as energy storage systems, solar energy systems, high voltage DC links, and so on. These devices lack the inherent inertia that traditional systems have to counteract frequency deviations caused by disturbances such as load imbalance. This paper presents a virtual inertia controller in an energy storage system to mitigate frequency instability during system disturbances. logical symbolism Control Is Proposed as an Intelligent Control Technique to Provide Adequate Inertia Response to Return the System to a Steady State During Load Disturbance. The Support Vector Control concept is also used to drive the steady state during load disruption. MATLAB/ Simulink software was used to model and analyse the system.***

Keywords: fuzzy logic control, Neural network, power systems stability, renewable energy and virtual inertia

1. Introduction

Preamble:
To meet the increased demand for electricity, multiple power producing sources must be utilised. Renewable energy, which appears to be a promising answer, has received significant attention in recent decades. However, combining renewable energy technologies can considerably diminish the facility system's general inertia, making the system more susceptible to frequency and voltage variations. This shows that while addressing the challenge of renewable energy penetration, consider not just ride through capabilities but also frequency responsiveness and power control during system disturbances.

Aim:
This paper proposes the addition of HVDC links for inter - area power transmission, as well as the use of an adaptive neurofuzzy interface system and the support vector machine approach as an impact scheme used in an energy storage system to provide virtual inertia during load perturbations and wind generation variation.

Objectives:
1) to examine the current multi - area power grid.
2) to go over the Fourier transform analysis procedures.
3) to examine current FFT, adaptive neuro fuzzy interface system, and support vector machine approach analysis - based methodologies for multi - area power grid analysis and detection.

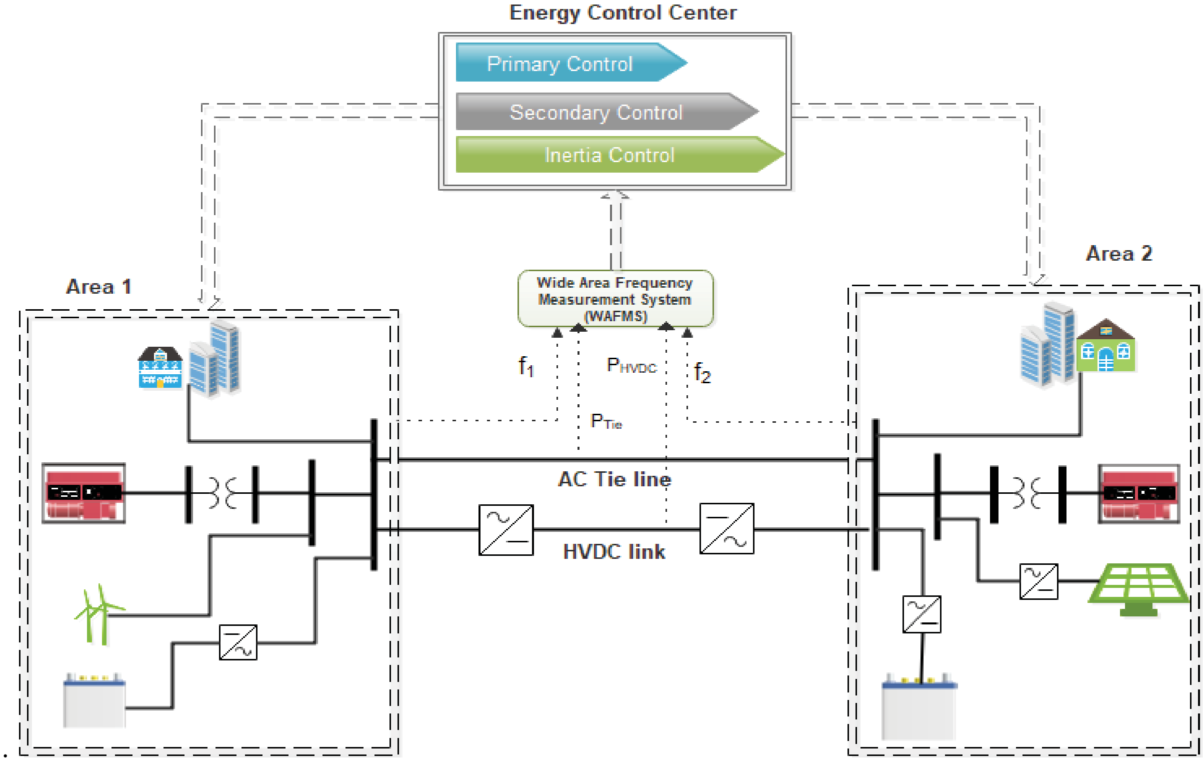

Figure 1: Pictorial diagram of a two - area interconnected system with parallel ac/ac lines

System modelling:

In conventional power systems that involve rotating masses, the kinetic energy is a function of the inertia. The overall kinetic energy present in a system is given as

$E=\frac{1}{2}mJ\hat{}2$

Where J is the moment of inertia in the system in kgm^2 and mIs the angular frequency in rad/s.

For a rotating mass, the rate of change of angular frequency of the rotor depends on the differencein mechanical and electrical torque (TNandTe). The torque equation commonly referred to as "swing equation".

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Fuzzy Logic Control

A fuzzy logic control (FLC) system is an intelligent control system that has found applications in many sectors of science and engineering [21]. Figure 3 depicts the basic framework of an FLC system. It comprises of a fuzzification process in which the crisp input is changed to a fuzzy input, an inference engine that uses the rule base system to decide the fuzzy output, and a defuzzification process in which the system transforms the fuzzy output back to the crisp output. The rules in an FLC are determined by the IF - THEN statements [22].

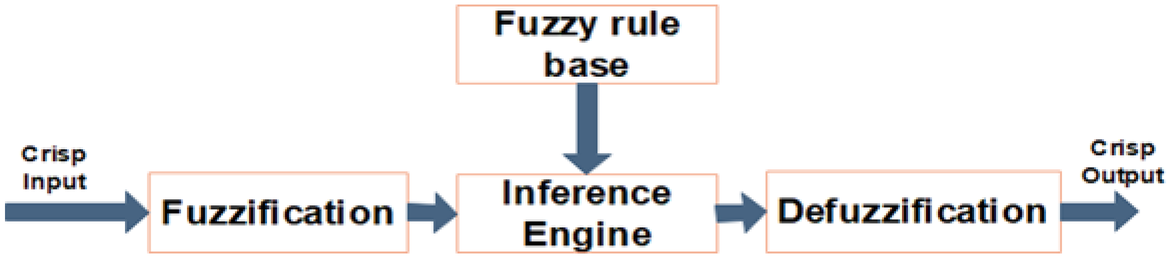


Figure 2: Basic structure of a FLC system.

As illustrated in Fig.4, the FLC system in this work has two inputs (frequency deviation and frequency deviation derivation) and one output (inertia gain). The controller's output controls the gain for the ESS to efficiently provide the required power to minimise the frequency variation. The FLC system's rules are outlined in Table.

The performance of the designed fuzzy controller is evaluated with a conventional integral controller.

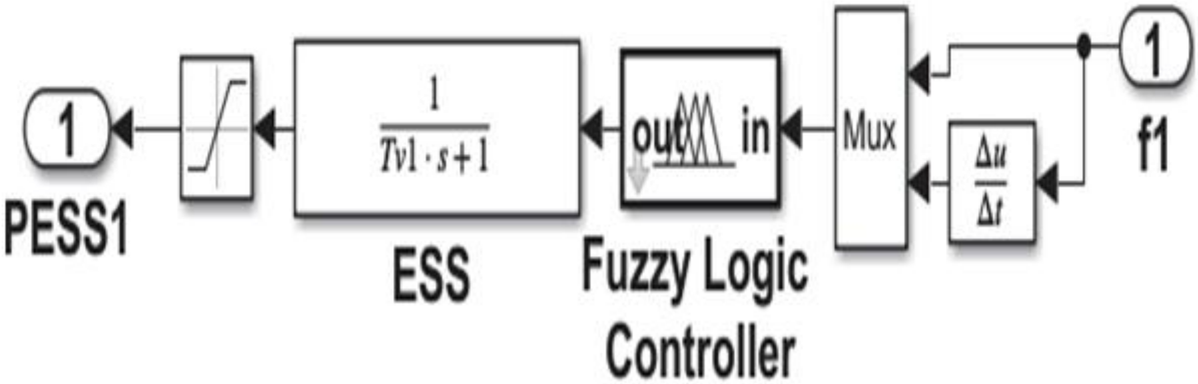


Figure 3: Energy storage system with fuzzy logic controller

2. Literature Review

1] A. Ibrahim, P. Kumar, and S. Khatoon 2006.

This article presents the operational and control problems of complex power systems. Keeping in view the time hierarchy of power system operational and control problems, the control strategies employed at different control levels are discussed and reviewed. Recent advances in control strategies, like applications of artificial neural networks and fuzzy logic concepts in power systems, are considered. [1]

2] A. Ibraheem and P. Kumar, 2004

This paper investigates the load frequency control problem for a multi - area power system taking into consideration system parameter variations. This paper proposes an intelligent control scheme for load frequency control (LFC) of interconnected power systems. A fuzzy logic based integral controller is proposed for two area power system interconnected via parallel ac/dc transmission link. The simulation studies are carried out for a two - area interconnected power system with reheat steam turbine for simplicity and without loss of generality. Suitable solution for load frequency control problem of two areas electrical power system is obtained by means of improving dynamic performance of power system under study. Robustness of controller is also checked by varying parameters. Simulation results indicate that the proposed control scheme work well when compared with others. [2]

3] A. Ibraheem and P. Kumar 2003.

The present research article is devoted to discussing the dynamic performance of a two - area interconnected power system consisting of hydropower plants. It tries to establish that using an HVDC transmission system in parallel with an EHVDC transmission line as an interconnection between two areas has a favorable effect on system dynamic performance in the wake of a small load disturbance in the system. At the outset of the article, the current status of the Indian Power System is summarized, and the challenges ahead for power engineers are discussed in length. The future prospects of hydropower due to environmental considerations, merits of using HVDC transmission systems, and the upcoming interconnected structure of power systems with parallel EHVDC/HVDC transmission systems is presented. The system dynamic performance has been studied with the implementation of optimal AGC regulators in the wake of load disturbance in one of the areas. The investigations carried out justify the application of an HVDC transmission link in parallel with an EHVDC transmission line as a system interconnection. The HVDC transmission link is considered to be operating in constant current control mode. The power flow deviation through the HVDC link is modeled based on frequency deviation at the rectifier end. Two modes of an HVDC link dynamic modelas an additional control variable with turbine controllers and as an additional state variable—have been investigated. Both modes of the HVDC link dynamic model offer the better system dynamic performance as compared to that obtained without considering an HVDC link in system dynamic modeling. [3]

4] A. Ibraheem, P. Kumar, and S. Khatoon 2006
This article presents the operational and control problems of complex power systems. Keeping in view the time hierarchy of power system operational and control problems, the control strategies employed at different control levels are discussed and reviewed. Recent advances in control strategies, like applications of artificial neural networks and fuzzy logic concepts in power systems, are considered. [4]

5] E. Rakhshani and P. Rodriguez, 2014
Renewable energy sources (RES) like wind and PV are dependent on weather conditions and geographic location and as results their stochastic behavior can significantly influence power systems performance. These effects will be more relevant in case of large - scale penetration of RES. Therefore, modern power plants based on RES should both deliver power as conventional generators and contribute to support the grid services by providing ancillary services and in this way applications of advanced technology are very important to reach this goal. Active power and frequency controls are known as essential ancillary services that should be provided by generation units in large power plants. Therefore, controlling this type of grid interactive power plants is critical issue to achieve large - scale integration of RES in distributed power systems. In consequence, it is necessary to take advantages of new technologies and advanced control concepts in order to configure more intelligent and flexible generation systems, which should be able to improve the performance and stability of grid. A brief review on conventional active power/frequency control issues and complete investigation on adapted scenarios of active power/frequency control considering liberalized markets, high penetration of RES and coexistence of AC and DC networks will be explained in this chapter. [5]

6] E. Rakhshani and P. Rodriguez, 2017.
Preservation of the environment has become the main motivation to integrate more renewable energy sources (RESs) in electrical networks. However, several technical issues are prevalent at high level RES penetration. The most important technical issue is the difficulty in achieving the frequency stability of these new systems, as they contain less generation units that provide reserve power. Moreover, new power systems have small inertia constant due to the decoupling of the RESs from the AC grid using power converters. Therefore, the RESs in normal operation cannot participate with other conventional generation sources in frequency regulation. This paper reviews several inertia and frequency control techniques proposed for variable speed wind turbines and solar PV generators. Generally, the inertia and frequency regulation techniques were divided into two main groups. The first group includes the deloading technique, which allow the RESs to keep a certain amount of reserve power, while the second group includes inertia emulation, fast power reserve, and droop techniques, which is used to release the RESs reserve power at under frequency events [6]

7] Y. Han, P. M. Young, A. Jain, and D. Zimmerle 2015
In this paper, we propose a robust control strategy for reducing system frequency deviation, caused by load fluctuation and renewable sources, in a smart microgrid system with attached storage. Frequency deviations are associated with renewable energy sources because of their inherent variability. In this work, we consider a microgrid where fossil fuel generators and renewable energy sources are combined with a reasonably sized, fast acting battery - based storage system. We develop robust control strategies for frequency deviation reduction, despite the presence of significant (model) uncertainties. The advantages of our approach are illustrated by comparing system frequency deviation between the proposed system (designed via μ synthesis) and the reference system which uses governors and conventional PID control to cope with load and renewable energy source transients. All the simulations are conducted in the Matlab™ and Simulink™ environment. [7]

8] T. Inoue and H. Amano 2006
A thermal power plant model for dynamic simulation of the load frequency control (LFC) of electric power systems is presented. In the model, MW response of the thermal power plant is represented using two components. One is the slow component responding to the MW demand change from the LFC, and the other is the fast component due to the primary frequency (governor) control. For the former, demand rate limit, boiler response delay, and boiler steam sliding pressure control are considered. For the latter, turbine governor response, turbine load reference control and steam pressure change due to turbine control valve movement are considered. [8]

9] A. Fathi, Q. Shafiee, and H. Bevrani 2018
Integration of inverter - interfaced distributed generators (DGs) via microgrids into traditional power systems reduces the total inertia and damping properties, while increasing uncertainty and sensitivity to the fault in the system. The concept of the virtual synchronous generator (VSG) has been recently introduced in the literature as a solution, which mimics the behavior of conventional synchronous generators in large power systems. Parameters of the VSGs are normally determined comparing the conventional synchronous generators. This paper introduces an extended

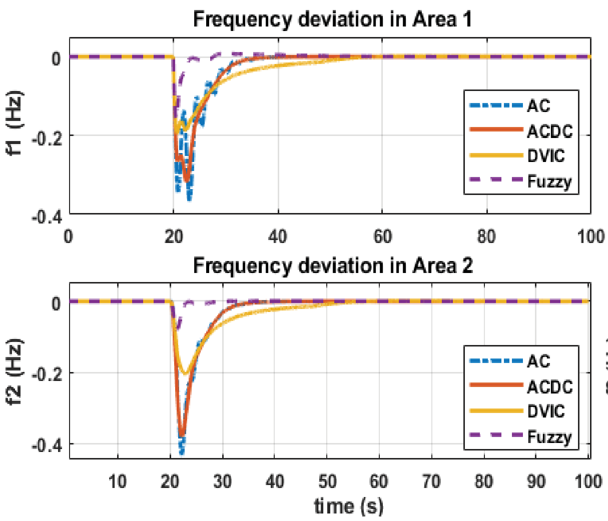
VSG for microgrids by combining the concept of virtual rotor, virtual primary, and virtual secondary control as a virtual controller to stabilize/regulate the system frequency. An H_∞ robust control method is proposed for robust\optimal tuning of the virtual parameters. The effectiveness of the proposed control methodology is verified via a microgrid test bench. [9]

10] M. S. Mahmoud, N. M. Alyazidi, and M. I. Abouheaf 2017
This paper introduces a survey on the adaptive and intelligent methods that have been applied to microgrids systems. Interestingly, the adaptive technique is effectively exercised in various control issues including stability, tracking error, and parameter uncertainties. Adaptive control has been extremely developed by using intelligent algorithms to automatically tune the control parameters namely fuzzy logic, particle swarm optimization, bacterial search algorithm, and etc. The objective is to evaluate and classify the design control methods and evaluation algorithms for the microgrid systems to maintain stability, reliability, and load variations by adjusting the controller parameters especially in standalone operation mode. The stability of islanded microgrids are constantly impacted by the related loads. A significant part of the research on an islanded microgrid involves droop control technique. In normal operation, distributed generation units and storage units provide power quality control. Once a shutdown is occurred, microgrid can be isolated from the main grid and operate in a local grid to support the local loads. Thus, distributed generations co - operate storage units to sustain the stability of the islanded microgrid. [10]

3. Results Discussions in Previous Paper

To analyses the performance of the proposed controller under system disturbance, a 10 % (0.1 p. u) step load increase in Area 1 is simulated. Fig.4 shows the frequency response of the system. It is obvious the frequency oscillations of the ac system (blue line) is damped when a HVDC link is added to the system (orangeline). Therobustness of the fuzzy logic virtual inertia controller can be observed (purple line) because it reduces the frequency deviation of the system by providing the needed power with a faster response that the derivative virtual inertia controller (yellow line).

To further investigate the performance of the fuzzy logic controller and effect of inertia in the system, the inertia constant of the system is reduced by 50 % and load perturbation is simulated to observe the frequency response ofthesystemasshowninFig.5. It is observed that reduction in system inertia increases the frequency deviation in both areas, the oscillations in Area 1 are also increased but effectively damped by the HVDC link. The effectiveness of the ESS with fuzzy logic control is observed with least frequency deviation, fastest response time and shortest time to reach steady state.



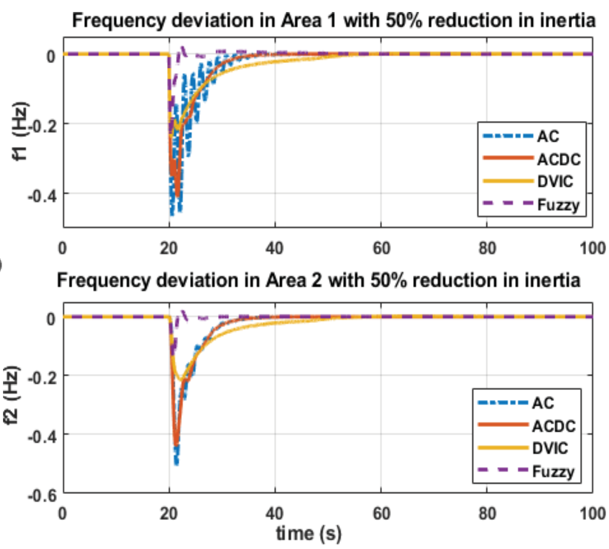


Figure 4: Frequency deviation plot. **Figure 5:** Frequency deviation plot with 50% reduction in inertia

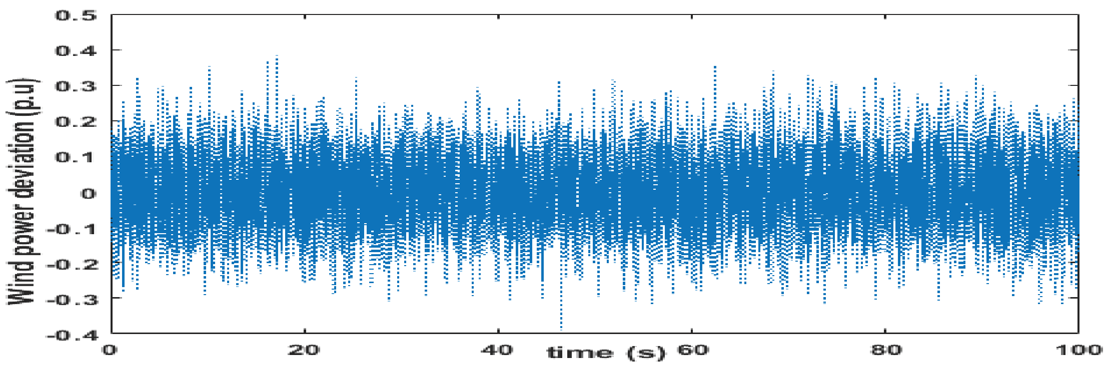


Figure 6: Wind power intermittency

In Area 1, a fluctuation in wind power is simulated to examine the influence of intermittency associated with renewable energy systems. This intermittency is replicated in tandem with the previously mentioned step load increase. The continual variation in wind power affects the system's frequency continuously. Again, the fuzzy logic virtual inertia controller performs better under this intermittent circumstance, with reduced frequency deviation and effective frequency zero - reference tracking in both areas.

4. Future Scope

In the future, work will be done employing neural fuzzy logic and support vector machines. I will investigate the effect of inertia in the system by reducing the system's inertia constant by a certain percentage and simulating load perturbation to observe the frequency response of the system. I will also investigate the effect of frequency deviation on system inertia reduction. The efficiency of the ESS with fuzzy logic control and support vector machine is demonstrated by the lowest frequency variation, the quickest response time, and the shortest time to reach steady state.

5. Conclusion

It is vital to maintain system stability in modern power systems with greater integration of renewable energy sources and dynamic system disruption. In this research, a fuzzy logic controller integrated into an energy storage system was employed to provide the system with virtual inertia for power - frequency stability. The developed controller has a faster response time than the typical derivative controller. In addition, the benefit of HVDC links in parallel with alternating current tie - lines for interconnected power systems has been established.

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