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Load Frequency Control of Interconnected Power System in Deregulated Environment: A Literature Review

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Abstract—This paper reviews the requirements and the procedure used to obtain Grid Stability. The Grid stability requirements , Interconnected System, Automatic Generation Control (AGC), requirement for intelligent controller ,Fuzzy logic Controller and High Voltage DC transmission are discussed with their usage in Grid Stability.

Index Terms— Automatic Generation Control, Integral Controller, Fuzzy logic Controller, Deregulated Environment, Wind Turbine Generator

I. INTRODUCTION

Grid Stability is a technical requirement for the proper operation of an interconnected power system and it is the prerequisite for a stable electricity grid and guarantees secure supply at a frequency of 50 Hz [1]. As far as production is concerned, this is relatively simple: the production of electrical energy is largely foreseeable, apart from the new renewable energies [2]. Consumption is a different matter; however it can be estimated but never accurately predicted. A worldwide trend in the development of power systems is to build interconnections with the goal to achieve economical benefits. Such large interconnected systems can cover many countries or even wide continental areas. Interconnections of power systems may offer significant technical, economical and environmental advantages, such as pooling of large power generation stations, sharing of spinning reserve and use of most economic energy resources taking into account also ecological constraints: nuclear power stations at special locations, hydro energy from remote areas, solar energy from desert areas and connection of large off-shore wind farms [3]. With time, the operating point of a power system changes, and hence, these systems may experience deviations in nominal system frequency and scheduled power exchanges to other areas, which may yield undesirable effects. Also, when load changes or abnormal conditions occur like outages of generation and varying system parameters, mismatches in frequency can be caused. These mismatches can be corrected by controlling the frequency. Automatic Generation Control (AGC) is used to maintain the schedule system frequency. With the advancement of systems analysis techniques such as optimal control theory, their application to power system problems was inevitable. In particular, there are three significant reasons to search for better control strategies for the AGC problem. First, the continuing growth of this nation has been and will continue to be achieved at the expense of an enormous consumption of electrical energy, thus causing a demand for more efficient use of generation facilities. Second, careful usage of generating facilities reduces the ecological impact through reduction in fuel consumption and discharge problems [4-8]. Finally, the trend is toward larger and larger units, which increases the problems of system stability. Thus, better control strategies are required in improving stability margins and overall power system reliability. Controlling the frequency has always been a major subject in electrical power system operation and is becoming much more significant recently with increasing size, changing structure and complexity in interconnected power systems. Next importance is given to the use of High Voltage DC transmission (HVDC) link in the system rather than High Voltage Alternating Current (HVAC) transmission only. HVDC is a foreseen technology due to huge growth of this transmission system and due to its economic, environmental and performance advantages over the other alternatives [1, 9-10]. Therefore it is proposed to have a dc link in parallel with HVAC link interconnecting control areas to get an improved system dynamic performance. These studies are carried out considering the nominal system parameters. Practically system parameters vary considerably with changing operating conditions. Intelligent controllers are designed using proportional-plus-integral control strategy and implemented in the interconnected area. The conventional control method does not give required solutions due to complex and multivariable power systems. Therefore next step is taken to improve the reliability and robustness of the system using Fuzzy Controllers [11-13]. Fuzzy Controllers are advantageous in solving wide range of control problems including AGC of interconnected power system. Fuzzy logic based controller can be implemented to analyze the load frequency control of two area interconnected power system with HVAC and HVDC parallel link taking parameter uncertainties into account. In the system working under deregulated environment, a Wind Turbine Generator (WTG) or other locally generating plants can be simulated to carry out all the proposed operations and to control the frequency of the system using AGC and Integral Controller with the Fuzzy Controller [14-16].

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II. GRID STABILITY

Every day the electricity from energy producers finds its way to our power socket at the right time, in the right amount and at market prices. Grid operates any area's transmission system. The transmission system is high voltage grid, which is used to transport energy over long distances and has some important responsibilities. First responsibility is the transportation of electricity from producing power plant to the end consumer via transmission system and next important responsibility is to ensure that the balance between electricity consumption and production is maintained at all times [2]. Grid stability has been considered as an important problem for system operating securely for long time, and power system frequency is one of the vital parameters in power system operation. The deviation of system frequency must be controlled within an allowable range under any disturbances. A steady frequency is significant to keep the loads or generators stable and safe. Frequency stability means the ability of a power system to maintain steady frequency following a severe system upset resulting in a significant imbalance between generation and load. It depends on the ability of restoring equilibrium between generation and load, with the minimum unintentional loss of load. Since, to maintain frequency within its allowable range is a vital mission in a stable power system. System frequency is regulated through primary and secondary frequency controls generally. Primary frequency control (PFC) regulates the system frequency in a dynamic process, but the secondary frequency control regulates the frequency as close as its nominal value by adjusting the loads of units participating in system frequency control [17]. Since PFC is a feedback regulation function related to all the units in the power system, the problem of the stability in power system arises. This is the only way to ensure that the grid remains stable, i.e. operates at the standard frequency of 50 Hertz. If this balance is disturbed, the frequency will fall below or rise above 50 Hertz. The electricity consumption and therefore grid usage are constantly increasing. Large scale power systems are normally managed by viewing them as being made up of control areas with interconnections between them. Each control area must meet its own demand and its scheduled interchange power. Any mismatch between the generation and load can be observed by means of a deviation in frequency [1, 18]. A severe system stress resulting in an imbalance between generation and load seriously degrades the power system performance and stability, which cannot be described in conventional transient stability and voltage stability studies [19]. This type of usually slow phenomena must be considered in relation with power system frequency control issue. Therefore, it is very important to maintain grid stability using efficient and reliable methods. In the analysis of Grid Stability the speed governing model of interconnected power systems is studied. Maintaining frequency and power interchanges with neighbouring control areas at the scheduled values are the two main primary objectives here.

III. INTERCONNECTED POWER SYSTEM

Large scale power systems are normally divided into control areas based on the principle of coherency. The coherent areas are interconnected through tie-lines which are used for contractual energy exchange between areas and provide inter-area support during abnormal operations. The successful operation of interconnected power systems requires the matching of total generation with total load demand and associated system losses. Electricity grid interconnections have played a key role in the history of electric power systems. Most national and regional power systems that exist today began many decades ago as isolated systems, often as a single generator in a large city [20]. As power systems expanded out from their urban cores, interconnections among neighbouring systems became increasingly common. Groups of utilities began to form power pools, allowing them to trade electricity and share capacity reserves. One of the great engineering achievements of the last century has been the evolution of large synchronous alternating current (AC) power grids, in which all the interconnected systems maintain the same precise electrical frequency. By interconnecting separate utilities with the high voltage transmission system, it is possible to pool both generation and demand, not only providing a number of economic and other benefits, including [21-22]:

- An interconnected transmission system providing a more efficient bulk transfer of power from generation to demand centres.
- The interconnected transmission system, by linking together all participants across the transmission system, makes it is possible to select the cheapest generation available.
- Transmission circuits tend to be far more reliable than individual generating units, and enhanced security of supply is achieved because the transmission system is better able to exploit the diversity between individual generation sources and demand.
- An interconnected transmission system enables surplus generation capacity in one area to be used to cover shortfalls elsewhere on the system, resulting in lower requirements for additional installed generation capacity, to provide sufficient generation security for the whole system.
- Without transmission interconnection, each separate system would need to carry its own frequency response to meet demand variations, but with interconnection the net response requirement only needs to match the highest of the individual system requirements to cover for the largest potential loss of power (generation) rather than the sum of them all.

In India the north, west, east and north east grids are operating synchronously and all four regions are interconnected with AC as well as HVDC links. The Southern region is connected to East and West by HVDC links. Each regional grid is divided further into state grids which form the respective control areas. Within a region the various control areas are interconnected by AC links [23].

IV. HIGH VOLTAGE DIRECT CURRENT TRANSMISSION

The Advancements in power electronics are making high Voltage Direct Current Transmission Systems (HVDC) more and more attractive and reliable. Developing countries like India and China with their ambitious power capacity enhancement program are installing more HVDC systems for long distance transmission [24].

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The use of high voltage direct current (HVDC) interconnections is also rapidly expanding as a result of technical progress over the last two decades. HVDC permits the asynchronous interconnection of networks that operate at different frequencies, or are otherwise incompatible, allowing them to exchange power without requiring the tight coordination of a synchronous network. HVDC has other advantages as well, especially for transmitting large amounts of power over very long distances. A two area interconnected system is presented in the Fig.1[1] connected via HVAC tie line in parallel with HVDC link.

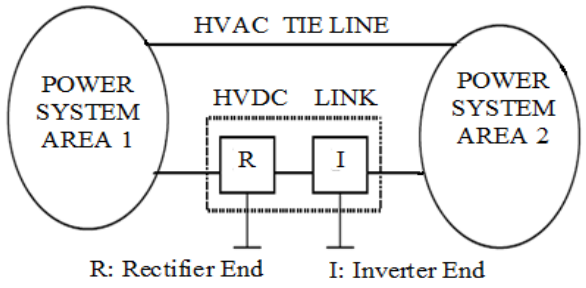

Fig. 1: Single line diagram of two area power system with parallel HVAC/HVDC Links

HVDC is a proven technology employed for power transmission. The power is taken from one point in an AC network and converted to DC in a converter station (rectifier) and transmitted over a line and converted back to AC again in another converter station (inverter) before it is injected into the receiving AC network [22]. HVDC interconnection could contribute better to both technical and economic advantages of interconnection system [25-26].

The most common reasons behind the choice of HVDC are [22]:

1) Lower line costs – beyond a certain distance (the break-even distance) the DC line will pay for the investment cost for the DC stations (See Fig. 2) (ABB, 1998).
2) Lower losses - with HVDC, no reactive power is transmitted. The line losses are lower than AC. The losses in the converter terminals are approximately 1.0 – 1.5 per cent of the transmitted power, which is low, compared with the line losses.
3) Stable operation at low power flow is also among the other advantages taken into consideration.

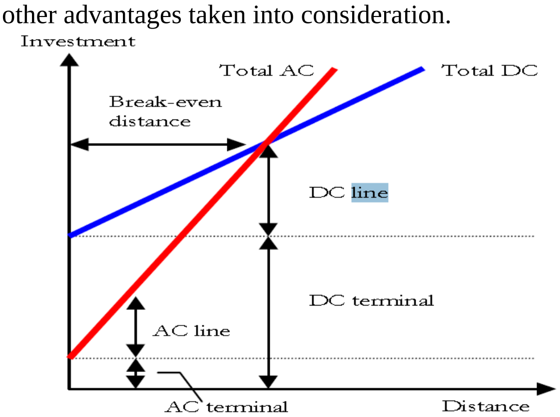

Fig. 2 Investment Cost vs. Distance (Source: ABB 1998)

However, HVDC has some shortcomings including [22, 26]:

1) Additional filters have to be installed to absorb the harmonics occurring in the system.
2) A large reactive power requires to be installed in the converter station since the system needs reactive power to be injected to the system to support its normal operation.
3) If the controllers are not properly set, the HVDC system may bring about sub synchronous oscillation (SSO) which can cause instability in the system.
4) Cost of converter station of HVDC system is much higher than that of AC substation.

Therefore Hybrid interconnection is used i.e. AC and HVDC both for reliable and economical interconnection of Power Systems. With this combination of AC/DC systems the interconnected systems become more stable since HVDC can damp oscillations by its fast control [27]. Moreover, a weak AC interconnection (small power exchange) can then be allowed to exchange increased power between interconnected systems supported by HVDC control. In an interconnected electrical power system, as the load varies, the frequency and tie-line power interchange also vary. To accomplish the objective of regulating system electrical frequency error and tie-line flow deviation to zero, a supplementary control action to control the load reference set points of selected generating units is utilized [8]. This control process is referred to as Automatic Generation Control (AGC). A transfer function model is developed for each power system and the different controls and links used i.e. AGC and HVDC. A complete block diagram is developed for the system and then studied using their dynamic performances with and without consideration of AGC and HVDC.

V. AUTOMATIC GENERATION CONTROL

The most important components in the daily operation of an electrical power system is the scheduling and control of generation. This function is the primary concern of the Energy Control Centre, and is largely provided by an AGC. In general, electrical power systems are interconnected to provide secure and economical operation. The interconnection is typically divided into control areas, with each consisting of one or more power utility companies. The control areas are connected by transmission lines commonly referred to as tie-lines and the power flowing between control areas is called tie-line interchange power [14]. An essential part of an interconnected system is that all generators in the system respond to changes in frequency via their governor speed control. When the load increases in a particular control area, it is supplied initially by the kinetic energy stored in the rotating masses of the turbine generators. The result is a drop in the system frequency throughout the interconnected system. All generators in the interconnection respond to the speed change and adjust generation to return the frequency to a new steady state value, thereby establishing a balance between the total system generation and the total system load.

The main objectives of Automatic Generation Control (AGC) are [6]:

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1) To maintain the desired megawatt output and the nominal frequency in an interconnected power system.
2) To maintain the net interchange of power between control areas at predetermined values.

AGC in the disturbed control area readjusts its generation in an economical manner such that any tie-line interchange power deviation that resulted from the load change is returned to zero, and the new steady-state frequency is brought back to the scheduled value [5]. The Power System is first modelled using differential equations. Then its transfer function model will be formed. The following Fig. 3 shows the transfer function model of single area power system [14].

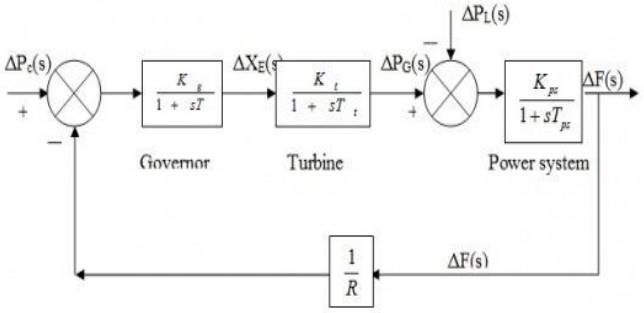

Fig. 3: Load frequency control of an isolated power system

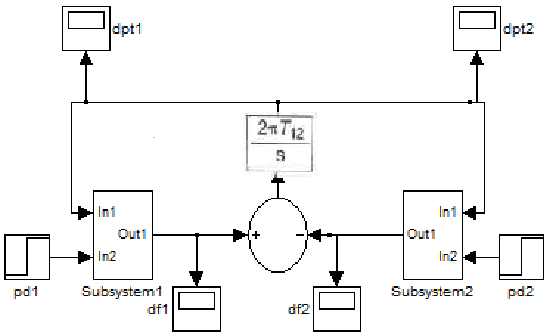

Fig. 4: Composite block diagram of two area interconnected system

VI. WIND TURBINE GENERATOR AS DEREGULATED SYSTEM

The main sources of electrical power have been fuel burning engines, which use the energy from non-renewable fuels to mate a shaft connected to an electric generator**.** These systems have seen vast improvements in the areas of efficiency, emissions and controllability because they have always been the primary power sources. The deregulation of electricity has seen rise in research geared towards alternative energy sources. Some of the major sources being investigated include fuel cells, micro-turbines and wind turbines. Wind turbines are the main focus of this research. The wind turbine plant model was divided into two main parts. The first part was the wind turbine, which included a turbine rotor on **a** low-speed shaft a gearbox and high-speed shaft. The second part was the electric generator whose input was constant angular rotation from the turbine plant and whose output was electrical power. Fig. 6 illustrates the general block diagram of the wind turbine system [29].

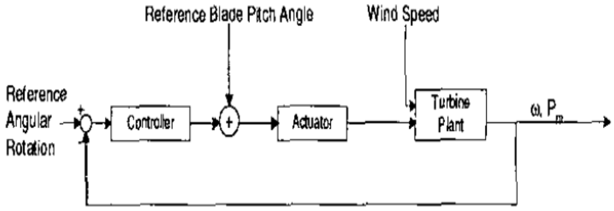

Fig. 5: Block Diagram of a Wind turbine System

Although the goal of this control sequence is to maintain a constant angular speed and constant power, P_m. Only the angular speed is fed back to accommodate the wind speed fluctuations. This is because controlling the angular speed automatically means that the aerodynamic torque T_A that causes the rotation, is controlled and hence the extracted mechanical power, P_m. This is derived from the fact that these three quantities, P_m, T_A and ω are related by equation [29] (1).

$$P_m = T_A \, \omega \quad (1)$$

Therefore controlling T_A and ω to remain constant will cause the power P_m to remain constant as well. The dynamic modelling of wind power generators (WTG), in order to estimate their impact on the power system dynamic behaviour, is a matter of high interest. The development of these models has been the subject of many discussions: it requires a compromise between making substantial simplifications to reduce computational efforts on the one hand, and maintaining the necessary adequacy to be able to predict the wind power's influence on the electrical power system's dynamic behaviour on the other hand. By investigating the dynamic behaviour of wind power generators, more insight is obtained concerning the ability of a wind farm to provide frequency control [30-31]. It is independent on any other power system and it is working as a deregulated system here.

VII. NEED FOR INTELLIGENT CONTROLLERS

Intelligent control techniques are of great help in implementation of AGC in power systems. Today's power systems are more complex and require operation in uncertain and less structured environment. Consequently, secure, economic and stable operation of a power system requires improved and innovative methods of control. Intelligent control techniques provide a high adaption to changing conditions and have ability to make decisions quickly by processing imprecise information [1]. Some of these techniques are rule based logic programming; model based reasoning, computational approaches like fuzzy sets, artificial neural networks, evolutionary programming and genetic algorithms [6].

VIII. FUZZY LOGIC CONTROLLERS

The inherent characteristics of the changing loads, complexity and multi-variable conditions of the power system limits the conventional control methods giving satisfactory solutions. Artificial intelligence based gain scheduling is an alternative technique commonly used in designing controllers for non-linear systems.

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Fuzzy system transforms a human knowledge into mathematical formula. Therefore, fuzzy set theory based approach has emerged as a complement tool to mathematical approaches for solving power system problems. Fuzzy set theory and fuzzy logic establish the rules of a nonlinear mapping. Fuzzy control is based on a logical system called fuzzy logic which is much closer in spirit to human thinking and natural language than classical logical systems. Nowadays fuzzy logic is used in almost all sectors of industry and science. One of them is automatic generation control. The main goal of AGC in interconnected power systems is to protect the balance between production and consumption. Control algorithms based on fuzzy logic have been implemented in many processes [1, 15]. The application of such control techniques has been motivated by the following reasons [6]:

1) Improved robustness over the conventional linear control algorithms;
2) Simplified control design for difficult system models;
3) Simplified implementation

Low –frequency oscillations are a common problem in large power systems. A power system stabilizer (PSS) can provide an supplementary control signal to the excitation system and/or the speed governor system of the electric generating unit to damp these oscillations. Due to their flexibility, easy implementation, and low cost, PSSs have been extensively studied and successfully used in power systems for many years. Most PSSs in use in electric power systems employ the classical linear control theory approach based on a linear model of a fixed configuration of the power system. Such a fixed-parameter PSS, called a conventional PSS (CPSS), is widely used in power systems and has made a great contribution in enhancing power system dynamics [1], [9]. The power system stabilizer (PSS) is used to generate supplementary control signals for the excitation system in order to dampen the low frequency oscillations. The conventional power system stabilizer is widely used in existing power systems and has contributed to the enhancement of the dynamic stability of power systems. The parameters of CPSS (Conventional Power System Stabilizer) are determined based on a linearized model of the power system around a nominal operating point where they can provided good performance [32]. Because power systems are highly nonlinear systems, with configurations and parameters that change with time, the CPSS design based on the linearized model of the power systems cannot guarantee its performance in a practical operating environment. To improve the performance of CPSS, numerous techniques have been proposed for their design, such us using intelligent optimization methods (genetic algorithms, neural networks, fuzzy and many other nonlinear control techniques) [33]. It recent years, fuzzy logic control has emerged as a powerful tool and is starting to be used in various power system applications [1.11,15]. The application of fuzzy logic control techniques appears to be most suitable one whenever a well-defined control objective cannot specified, the system to be controlled is a complex one, or its exact mathematical model is not available. Recent research indicates that more emphasis has been placed on the combined usage of fuzzy systems and neural networks [1, 6, 15, 32, 33].The fuzzy logic controller designed can be of the form shown in Fig. 6[1]

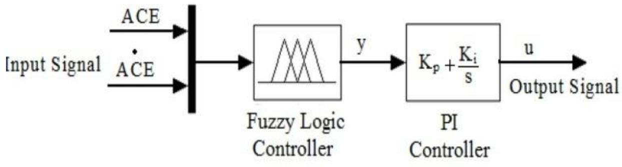

Fig. 6: Fuzzy Logic Controller

The fuzzy logic controller is comprised of four main components [1]: the fuzzification, the inference engine, the rule base, and the defuzzification, as shown in Fig. 5[35].

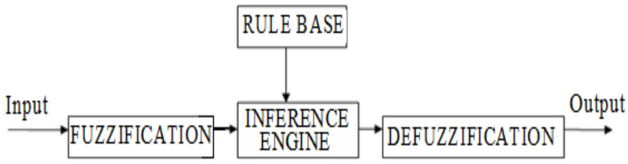

Fig. 7: Components of Fuzzy Controller

The fuzzifier transforms the numeric/crisp value into fuzzy sets; therefore this operation is called fuzzification. The main component of the fuzzy logic controller is the inference engine, which performs all logic manipulations in a fuzzy logic controller. The rule base consists of membership functions and control rules. Lastly, the results of the inference process is an output represented by a fuzzy set, however, the output of the fuzzy logic controller should be a numeric/crisp value. Therefore, fuzzy set is transformed into a numeric value by using the defuzzifier. This operation is called defuzzification. The control signal is given by (2)[1,15]

$$u(t) = -(K_p y + K_i \int y dt) \quad (2)$$

K_p and K_i are the proportional and the integral gains respectively and taken equal to one.

IX. CONCLUSION

In this paper, it has been observed that responses of frequency deviation with Fuzzy Controller and WTG are better in terms of steady state error, settling time. Simulation results justify the use of Fuzzy Controller in deregulated environment for the supply of reliable and quality power.

REFERENCES

[1] Yogendra Arya, Narender Kumar, Hitesh Dutt Mathur, "Automatic Generation Control in Multi Area Interconnected Power System by using HVDC Links" *IJPEDS*(International Journal of Power Electronics and Drive System) Vol.2,No.1,March 2012, pp.67~75, ISSN :2088-8694.

[2] The Grid of Tommorow, http://www.swissgrid.ch/swissgrid/en/home/grid/development.html

[3] V. Sitnikov, D. Povh, D. Retzmann ,E. Teltsch, "Solution For Large Power system Interconnections" Conference paper for East-West Interconnection in Europe , CIGRE Russian National Committee,September 2003.pp1~8.

[4] Naimul Hasan, "An Overview of AGC Strategies in Power System"*IJETAE*(International Journal of Emerging Technology and Advanced Engineering,Vol.2,Issue 8,August 2012, ISSN 2250-2459,pp 56~64.

[5] Pardeep Nain, K.P.Singh Parmar,A.K. Singh, "Automatic Generation Control of an Interconnected Power System Before and After Deregulation" International Journal of Computer Applications*(IJCA)* (0975 – 8887) Volume 61– No.15, January 2013,pp 11~16.

[6] C.B.Bangal "Automatic generation control of interconnected power systems using artificial neural network techniques", A PhD Thesis Report, Bharat University, Department of Electrical Engineering, May 2009.

[7] Nasser Jaleeli, Donald N. Ewart, Louis S. VanSlyck, Lester H. Fink, "Understanding Automatic Generation Control"IEEE Trans. Power App.Syst vol. PAS-7, no. 3, pp. 1106–1122, Aug. 1992.

[8] Aprajita Salgotra, "Assessment of Automatic Generation Control in a deregulated Environment" M.E. Thesis report ,Thapar University, Department of Electrical Engineering, July 2012.

[9] Rani Thottungal P Anbalagan, T. Mohanaprakash, A. Sureshkumar, G.V.Prabhu, "Frequency Stabilisation in Multiarea System using HVDC Link" IEEE International Conference on Industrial Technology, ICIT,Mumbai, ISBN 1-4244-0726-5,December 2006, pp 590~595.

[10] Issarachai Ngamroo, "A Stabilization of Frequency Oscillations in a Parallel AC-DC Interconnected Power System via an HVDC Link" Research Article by Science Asia 28(2002),pp173~180. http://www.scienceasia.org/2002.28.n2/v28_173_180.pdf

[11] Manuel A. Matos, Eduardo M. Gouveia, "The Fuzzy Power Flow Revisited" IEEE Transactions on Power Systems, Vol. 23, No. 1, February 2008,pp213~218.

[12] E. C. TACKER, T. W. REDDOCH, 0. T. TAN, T. D. LINTON, "Automatic Generation Control of Electric Energy Systems-A Simulation Study" IEEE Trans. Syst. Man Cybern., vol. SMC-3, no. 4, pp. 403–5, Jul. 1973.

[13] Kamalesh Chandra Rout, "Dynamic Stability Enhancement of Power System Using Fuzzy Logic Based Power System Stabilizer", M.Tech Thesis Report,NIT RourKela,May,2011.

[14] I.J. Nagrath and D.P. Kothari, "Modern Power System Analysis" 3rd Edition, Sixteenth reprint 2009, Tata Mc-Graw Hill publication.

[15] Mukta, Balwinder Singh, "Grid Stability of Interconnected System with Fuzzy-logic controller & HVDC in Deregulated Environment" *IJSCE*(International Journal of Soft Computing and Engineering)Vol.2,Issue 6,January 2013,pp. 283~288,ISSN :2231-2207.

[16] Furat Abdal Rassul Abbas and Mohammed Abdulla Abdulsada, "Simulation of Wind-Turbine Speed Control by MATLAB" International Journal of Computer and Electrical Engineering, Vol. 2, No. 5, October, 2010,pp 912~915,ISSN:1793-8163.

[17] Lucas Friedrich, Matthias Gautschi, "Grid Stabilization Control and Frequency Regulation for Inverter-connected Distributed Renewable Energy Sources" Master Thesis report, University of Wisconsin-Madison, September 2009.

[18] Charles Vartanian, "Grid Stability Battery Systems for Renewable Energy Success" IEEE Conference on Energy Conversion Congress and Exposition (ECCE), ISBN 978-1-4244-5287,pp 132 - 135 , October 2010.

[19] Transmission Planning Guide report by National Grid USA Service Company, TGP26, Issue3, November 22, 2009. http://www.nationalgridus.com/non_html/transmission_planning_guide.pdf

[20] S.N.Soonie, S.C.Saxena, "Frequency Response Characteristics of an Interconnected Power System in India-A Case Study of Regional Grids in India" 6th R&D International Conference Report on Sustainable development of Water and Energy resources-Needs and Challenges"February,2007. http://www.nrldc.in/docs/documents/Papers/frc.pdf

[21] "Multi Dimensional Issues in International Electric Power Grid Interconnections" Report by United Nations, Department of Economic and Social Affairs ,New York, 2006, http://sustainabledevelopment.un.org/content/documents/interconnections.pdf

[22] "Power Interconnection in APEC region Current status and Future Potentials",Report by Asia Pacific Energy Research Centre Institute of Energy Economics, Japan, March 2000. http://www.ieej.or.jp/aperc/final/interconnection.pdf

[23] Anjan Roy, S. A. Khaparde, P. Pentayya, S. Usha, A. R. Abhyankar, " Operating Experience of Regional Interconnections In India" IEEE Conference Power Engineering Society General Meeting, Vol. 3,ISBN 0-7803-9157-8 ,pp 2528 - 2535 ,June 2005.

[24] "Simulation and Fault Analysis of HVDC on MATLAB" Project Report by 1000projects.org/ October 13, 2011.

[25] ABB Review Special report on Power transmission, ISSN: 1013-3119, 2003, pp1~67.

[26] "High Voltage DC transmission", A review report by Siemens Energy ,2011,pp1,http://www.energy.siemens.com/hq/pool/hq/power-transmission/HVDC/HVDC_References.pdf

[27] Rafiqul Islam Sheikh, S.M. Muyeen, Rion Takahashi and Junji Tamura, " Multi-Area Frequency and Tie-Line Power Flow Control by Fuzzy Gain Scheduled SMES", Energy Storage, Rafiqul Islam Sheikh (Ed.), ISBN:978-953-307-119-0, http://www.intechopen.com/books/energy-storage/multi-areafrequency-and-tie-line-power-flow-control-by-fuzzy-gain-scheduled-smes

[28] Kanika Wadhwa, Sourav Choubey, Pardeep Nain, "Study of Automatic Generation Control Of two area thermal-thermal system with GRC and without GRC" First National conference on Power System Engineering(PSEC'12) Paper code PS1015, 2012. http://upload.wikimedia.org/wikipedia/commons/5/58/AGC_with_grc_and_without_grc.pdf

[29] Bongani Malinga ,Dr. John E. Sneckenberger, Dr. Ali Feliachi, "Modeling and Control of a Wind Turbine as a Distributed Resource" IEEE Conference on System Theory ,Proceedings of the 35th Southeastern Symposium, ISBN 0-7803-7697-8. pp 108~112,2005

[30] Jorris Soens, Johan Driesen, Ronnie Belman, "Equilvalent Transfer Function for a Variable Speed Wind Turbine in a Power System Dynamic Simulations" International Journal of Distributed Energy Resources ,Vol. 1 ,Number 2, ISSN 1614-7138, Pp 111-131.

[31] Clemens Jauch, Syed M. Islam, "Identification of a Reduced Order Wind Turbine Transfer Function from the Turbine's Step Response" AUPEC'05,Vol.1,S115 http://itee.uq.edu.au/~aupec/aupec05/AUPEC2005/Volume1/S115.pdf

[32] Dr. A. Taifour Ali, Dr. Eisa Bashier M Tayeb, Ms. Kawthar A. Adam, " A Multi-Machine Power System Stabilizer Using Fuzzy Logic Controller" International Journal Of Computational Engineering Research (ijceronline.com) Vol. 2 Issue. 6,pp28~33, ISSN 2250-3005,October' 2012.

[33] Jenica Ileana Corcau, Eleonor Stoenescu, "Fuzzy Logic Controller as a Frequency Stabilizer" INTERNATIONAL JOURNAL OF CIRCUITS, SYSTEMS AND SIGNAL PROCESSING,Vol.1,Issue3,2007,pp266~273 http://www.naun.org/multimedia/NAUN/circuitssystemssignal/cssp-44.pdf

[34] Glenn V. Hicks, "An Investigation of Automatic Generation Control for an Isolated Power System" Master Thesis of Mernorial University of Newfoundland, September'97. http://onlyengineering.wordpress.com/2012/06/26/thesis-1-automatic-generation-control-agc-part-1/

[35] Manuel A. Matos, "The Fuzzy Power Flow Revisited", IEEE Transactions on Power Systems, Vol.23, No.1, ISSN : 0885-8950,pp213~218,February 2008.

[36] Timothy J. Ross, "Fuzzy Logic with Engineering Applications" Second Edition, Wiley Publication, John Wiley & Sons, Aug-2004.

[37] MATLAB help with simulink www.mathworks.com/products/matlab-

[38] A.R.Abhyanker,S.A.Khaparde, "Introduction to deregulation in power industry", Report by Indian Institute of Technology, Mumbai, http://nptel.iitm.ac.in/courses/Webcourse-contents/IIT%20Bombay/Power%20System%20Operation%20and%20Control/Module%207/L01-Introduction%20to%20Deregulation-1.pdf

[39] "Basic Process Controllers" by http://www.engineeringtoolbox.com/process-controllers-d_499.html

[40] Mukta,Balwinder Singh,"Load Requency Control through Fuzzy Logic Controller in a Deregulated Environment"National Conference on Recent Innovations in Electrical Electronics and Communication Engineering(RIEECE),November 2012,paper code, RIEECE-173.

[41] Teofilo De la Torre James W. Feltes Tomis Gdmez San Romiin ,"Deregulation, Privatization, And Competition: Transmission Planning Under Uncertainity" IEEE Transactions on Power Systems, Vol. 14, **No.** 2,ISSN: 0885-8950 ,May 1999,pp460~465.

[42] Multi Dimensional Issues in International Electric Power Grid Interconnections, "Technical Aspects of Grid Interconnections – the United Nations",Chapter-2,pp.15~48. www.un.org/esa/sustdev/publications/energy/chapter2.pdf

[43] Wolfgang Hammer, "Dynamic Modeling of Line and Capacitor Commutated Converters for HVDC Power Transmission" DOCTOR OF TECHNICAL SCIENCES Thesis report of SWISS FEDERAL INSTITUTE OF TECHNOLOGY ,ZURICH,2000-2003.

[44] Stephen M. Hoyt, Charles E Abell, Thomas Kennedy, "Variable Non-Linear Tie Line Frequency Bias for Interconnected System Control" IEEE Transactions on Power Systems, Vol. 3, No. 3, ISSN: 0885-8950, August 1988,pp1244~1253.

[45] Hassan Bevrani, "Robust Power System Frequency Control" Book published by Springer Science Business Media, LLC,ISBN:978-0-387-84877-8

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

[46] Colin Pearson,Marc Yeung, "Wind Generation Integration with emphasis on grid stability" Conference presentation by BECA power, http://windenergy.org.nz/documents/conference09/ColinPearson.pdf
[47] Preghnesh Bhatt, S.P. Ghoshal, and Ranjit Roy, "Automatic Generation Control of Two-area Interconnected Hydro-Hydro Restructured Power System with TCPS and SMES" ACEEE Int. Journal on Control System and Instrumentation, Vol. 02, No. 02, June 2011,pp1-5, http://www.slideshare.net/ideseditor/automatic-generation-control-of-twoarea-interconnected-hydrohydro-restructured-power-system-with-tcps-and-smes
[48] J. Nanda, Lalit Chandra Saikia, "Comparison of Performances of Several Types of Classical Controller in Automatic Generation Control for an Interconnected Multi-Area Thermal System" IEEE conference on Power Engineering,Australasian Universities Power Engineering Conference (AUPEC), Paper P-022,ISSN : 978-0-7334-2715-2 ,pp1-6,2008.
[49] Peigao Zhang, Xingyuan Li, Yuhong Wang, Hongqiang Deng, "Research on frequency stability in isolated power grid" IEEE Conference on Power and Energy Engineering(APPEEC), ISBN**:** 978-1-4577-0545-8 ,pp1~4,March 2012.
[50] Dr. Prabhat Kumar,Ram Naresh Mishra, "Optimal Control of 3-Area Interconnected Hydro-Thermal System with EHVAC/HVDC Links"
[51] XXXII NATIONAL SYSTEMS CONFERENCE, NSC 2008, December 17-19, 2008,pp 536~541.
[52] Vijay Rohilla, K. P. Singh Parmar, Sanju Saini, "Optimization of AGC Parameters in the Restructured Power System Environment Using GA" International Journal of Engineering Sciences & Emerging Technologies, Oct. 2012.ISSN: 2231 – 6604 Volume 3, Issue 2, pp: 30-40
[53] Cuicui Wu, Lin Gao ,Junrong Xia ,Yiping Dai, "Analysis of Effects on Primary Frequency Control and Power Grid Stability of Different Control Logic" 5th IEEE Conference on Industrial Electronics and Applications, ISBN**:** 978-1-4244-5045-9,June 2010,pp887-892.
[54] Yipping Dai, Pan Zhao, Shuping Chang, "Primary Frequency Control Characteristics of a grid" IEEE Conference on Industrial Electronics and Applications (ICIEA),ISBN : 978-1-4244-1717-9,pp1493~1497,June 2008
[55] N. Cohn, 'Some aspects of tie-line bias control on interconnected power systems,' IEEE Transaction on Power Apparatus and Systems, Part III. Transactions of the American Institute of Electrical Engineers, Vol. 75, Issue 3,pp. 1415-1436, ISSN **:** 0018-9510, Feb. 1957.
[56] C. Concordia and L.K. Kirchmayer, 'Tie line power and frequency control of electric power systems,' IEEE Transaction on Power Apparatus and Systems, Amer. Inst. Elect. Eng. Trans., Pt. II, Vol. 72,Issue 2, ISSN: 0018-9510 ,pp. 562-572, Jun. 1953.
[57] L. Shanmukha Rao, N.Venkata Ramana, "Recent Philosophies of AGC of a Hydro-thermal System in a Deregulated Environment" International Journal of Advances in Engineering & Technology(IJAET), Vol. 1 Issue 6, p282, ISSN: 2231-1963,Jan 2012.
[58] Vaibhav Donde, M. A. Pai,Ian A. Hiskens, "Simulation and Optimization in an AGC System after Deregulation" IEEE Transactions on Power Systems, Vol. 16, No. 3,ISSN: 0885-8950, August 2001,pp481-489.
[59] Yong-Hua Song "Applications of fuzzy logic in power systems. I. General introduction to fuzzy logic" IEEE Journal on Power engineering, Volume: 11 , Issue: 5 ,ISSN: 0950-3366,Pp 219 – 222,Oct 1997
[59] K.S.S. Ramakrishna, T.S. Bhatti, "Load frequency control of interconnected hydro-thermal power systems" International Conference on Energy and Environment (ICEE) 2006. http://www.uniten.edu.my/newhome/uploaded/coe/icee%202006/proceedings/conventional%20energy%20technology/UNITEN%20ICEE%202006%20Load%20frequency%20control%20of%20interconnected%20hydro-thermal%20power%20systems.pdf
[60] Peter Meisen, "Cross-Border Interconnections on Every Continent" Report by Global Energy Network Institute (GENI), June 2010. http://www.geni.org/globalenergy/research/cross-border-interconnections/Cross-Border%20Interconnections%20on%20Every%20Continent.pdf

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