IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 5 Ver. II (Sep – Oct. 2015), PP 86-91
www.iosrjournals.org

A Review: Fuzzy Logic techniques improve the efficiency of the power system stability

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Abstract: *This paper present an overview of fuzzy logic control based on published literature, concerned the stability of the electric power system and considerable effort has been directed to the development control system process. This review work on fuzzy logic elaborates the scope of fuzzy logic implementation in process control applications to enhancements the efficiency of the electrical power system stability*

I. Introduction:

The concept of fuzzy set was introduced by Prof. Lofti Zadeh in 1965. Since then, the theory has been successfully implemented in various engineering applications, and developed to address inaccuracy and uncertainty which usually exist in engineering problems. Fuzzy logic attempts to systematically and mathematically emulate human reasoning and decision making. It provides an intuitive way to implement control systems, decision making and diagnostic systems in various branches of industry [1]. Fuzzy controllers were developed to imitate the performance of human expert operators by encoding their knowledge in the form of linguistic rules [2]. They provide a complementary alternative to the conventional analytical control methodology. So the human experience and knowledge can be applied to design of the controller by using fuzzy logic, depended on rule-based and the rules of the system are written in natural language [3].

Generally conventional system modeling techniques suggest to construct a model by using the available input-output data based upon empirical or physical knowledge about the system; which lead to the determination of a set of mathematical equations. This kind of approaches is effective only when the system is relatively simple and mathematically well-defined. Beside that most of the real-world problems in controlling do not obey such simple, idealized, and subjective mathematical rules. Fuzzy Logic is a problem-solving control system methodology which can be implemented in hardware, software, or a combination of both. It provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information.

II. Power System Stabilizer (PSS)

Most PSS used in electric power system employ the liner control theory approach based on a linear model of a fixed configuration of the power system and thus tuned at a certain operating condition. Such fixed parameter PSS, called conventional PSS (CPSS), is widely used in power systems, it often does not provide satisfactory results over a wide range of operating conditions [4].In conventional control, the amount of control is determined in relation to a number of data inputs using a set of equations to express the entire control process. The parameters of CPSS are determined based on a linearized model of the power system around a nominal operating point where they can provided good performance. 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 [5]. 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). Hens, expressing human experience in the form of a mathematical formula are a very difficult task, if not an impossible one [6].

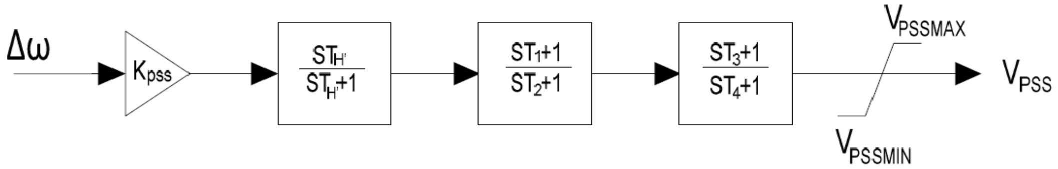


Figure.1 Block diagram of the conventional power system stabilizer

III. Fuzzy logic Controller

Zahah introduced his fuzzy set theory; due to that, he observed conventional computer was unable to handling data similar to human idea. In fact, digital computer dealing with binary reasoning, hence fuzzy logic method builds to allow conventional computers to get reason in ways similar to the human, to solve mismatch between computers and machines. It proposes deriving solutions to problems that are not possible to construct with exact mathematical models [6][7]. Fuzzy control systems are rule based systems in which a set of fuzzy rules represents a control decision mechanism to adjust the effects of certain causes coming from the system. The structure of the FLC resembles that of a knowledge based controller except that the FLC utilizes the principles of the fuzzy set theory in its data representation and its logic. The basic configuration of the FLC can be simply represented in four parts, as shown in figure-2 [8].

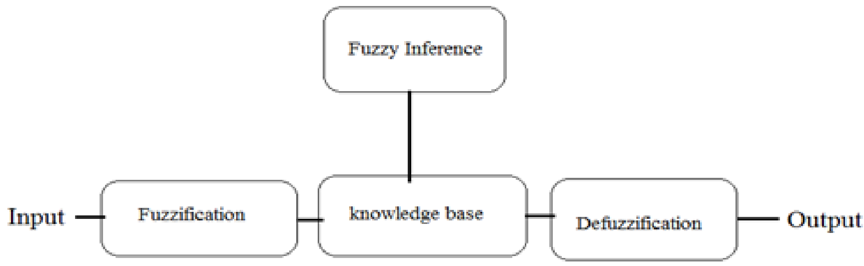
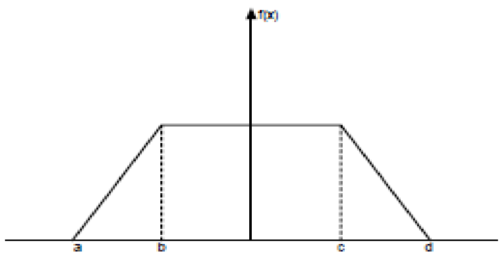
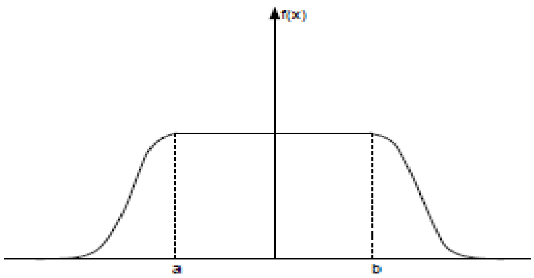


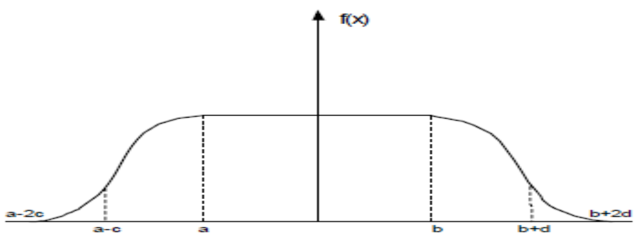
Figure-2. The basic configuration of the FLC

• Fuzzification module – the functions of which are first, to read, measure, and scale the control variable (speed, acceleration…) and, second, to transform the measured numerical values to the corresponding linguistic .Fuzzy logic can be seen as an extension of ordinary logic, where the main difference is that we use fuzzy sets for the membership of a variable; the membership function may be triangular, trapezoidal, Gaussian or any other shape.
• Knowledge base - this includes the definitions of the fuzzy membership functions defined for each control variables and the necessary rules that specify the control goals using linguistic variables;
• Inference mechanism – it should be capable of simulating human decision making and influencing the control actions based on fuzzy logic;
• Defuzzufication module – which converts the inferred decision from the linguistic variables back the numerical values.





(a) The trapezoidal membership functions (b) The exponential membership functions



(c) The singleton membership functions
Figure-3 show three basic membership functions

Designing process of an FLC may split into the following steps described as:
a. Selection of the control variables: The selection of control variables (controlled inputs and outputs) depends on the nature of the controlled system and the desired output [9].
b. Membership function definition: Each of the FLC input signal and output signal, fuzzy variables (Xj={e, de,u}), has the real line *R* as the universe of discourse. In practice, the universe of discourse is restricted to a comparatively small interval [Xminj, Xmaxj]. The universe of discourse of each fuzzy variable can be quantized

into a number of overlapping fuzzy sets (linguistic variables).Membership functions can be of a variety of shapes, the most usual being triangular, trapezoidal, singleton or an exponential.

c. Defuzzification strategy

Defuzzification is a process of converting the FLC statement in to control actions, or from fuzzy values to crisp values. Depending on the output fuzzy set, generated from the fired rules. The performance of the FLC depends very much on the deffuzzification process. It produce a non-fuzzy control action that best represents the membership function of an inferred fuzzy control action as a result of combining several rules(fig.4).

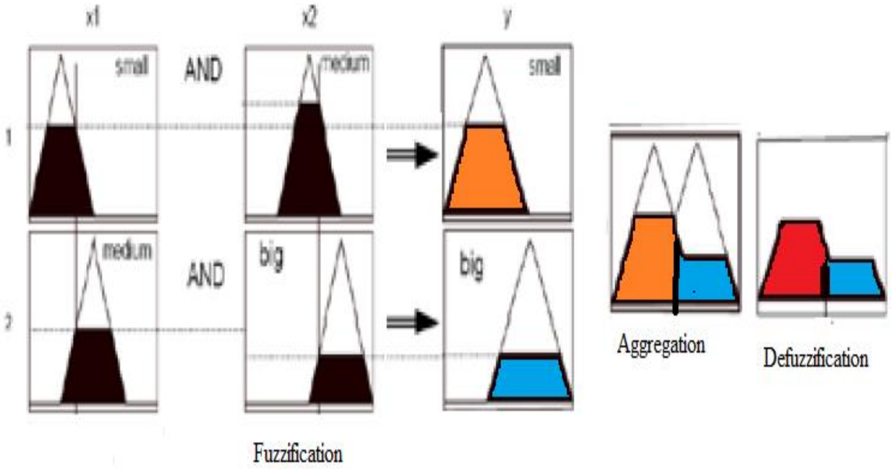


Figure. 4 shows the process of fuzzification, aggregation and defuzzificaiton operation together for a process control system

There are many techniques to perform defuzzification operation. The choice of defuzzification method is fairly technical matter and is strictly as per the requirements of the problem. The important methods to perform defuzzification are max-membership, centre of gravity method, weighted average method, mean-max method and centre of sums method [10].

IV. Fuzzy Logic Based Power System Stabilizers

The conventional control techniques utilize mathematical models for controlling the process. Some heuristics do not fit into mathematical framework, which compelled the modern control system to use soft computing techniques for improving the efficiency and efficacy of the process to be controlled. A Fuzzy Logic is a kind of a state variable controller governed by a family of rule and a fuzzy inference 0.mechanism. The fuzzy logic control algorithm reflects the mechanism of control implemented by people, without using a mathematical model the controlled object, and without an analytical description of the control algorithm. So it emerged as a powerful tool and is starting to be used in various power system applications.

There are four possible forms for construction of a fuzzy logic control system based on input-output relations. A FLC can be in the form of a single-input-single-output (SISO), double-input-single-output (DISO), multi-input-single-output (MISO) system, or multi-input- multi-output (MIMO) system [9].In any practical system, one of most common ways of designing a fuzzy controller is through "fuzzy rule-based systems". The concept of FLC is to utilize the qualitative knowledge of a system to design a practical controller. A typical feedback control system with direct fuzzy controller is shown in Figure-5

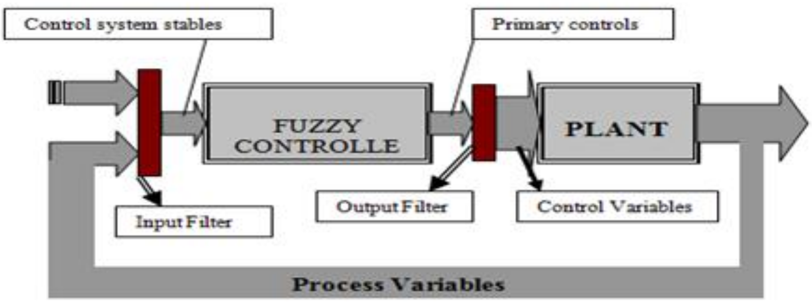


Figure.5 Fuzzy controller with feedback system

On the other hand, fuzzy control focuses on gaining intuitive understanding for better control of the process, and this information is then loaded directly into fuzzy controller. The performance objectives and the design constraints usually involve the stability, rise time, overshoot, settling time and steady state error of process controllers.

Researchers showing; a growing interest in artificial intelligent (FL) to design new controllers, because of its ability to effectively implement nonlinear control without much complexity . Metwally and Malik [11] describe a paper on fuzzy logic power system stabilizer using speed and power output variations as the controller input variables. Hiyama [12] obtained the required information i.e. acceleration, speed deviation and phase deviation of generator from measured real power signal. Juan et al. [13] compares the fuzzy logic based and rule base power system stabilizer. Also Moodley et al. [14] investigates the effect of FLPSS in a multimachine environment. Ferreira et al. [15] proposed a fuzzy logic PSS including a fuzzy PI controller to improve steady state behavior of a system .The PI controller as proposed uses only speed deviation as input and uses triangular membership functions with only small number of rules. Lim [16] proposed a new fuzzy logic control scheme using one input signal which is the linear combination of three signals, i.e. signal, its derivative and its integral.

Fuzzy logic is applied to in order to improve the power system stability Eltahir& Bahar [17]. The comparison of fuzzy logic with conventional proportional integral controller is made and the superiority of fuzzy logic method is quoted in the study. A methodology for designing and tuning the scaling gains of fuzzy logic controller was discussed and the new concept of fuzzy transfer function was invented to connect these gains of the well tuned conventional fuzzy logic controller. Furthermore Eltahir& Bahar [18] also presents a new approach to design of a robust controller for the auxiliary control loop of a static VAR stabilizer using fuzzy logic control concepts using the least number of rules for stabilization of a synchronous generator is presented. The performance of fuzzy stabilizer is compared with a conventional stabilizer of a variety of transient disturbances, highlighting the effectiveness of the stabilizer in improving significant damping to the system oscillations the relationship between the scaling gains and performance can be deduced to produce the comparative tuning algorithm, which can tune the scaling gains to their optimum by less trial and error.

Bahar Elmahi [19], study and investigating the effectiveness of an adaptive artificial intelligence on enhancing the stability of gas turbine, Linguistic rules and fuzzy inference mechanism are utilized to tune the controller parameters in different operating states. Results demonstrated that the proposed control scheme performs well and strongly control the power system under different loading conditions, disturbances and system parameter variations. The proposed controller is robust and more suitable for damping of low frequency oscillation and more effective in improving dynamic stability and voltage profile than the conventional systems.

Survey papers have been suggested some experimental examples for the process controllers have been implemented using fuzzy logic technique and compared with the conventional techniques. Induction motors are highly non-linear and complex in nature, it is inferred from the results, that fuzzy logic approach can reduce the flux and torque errors than conventional controllers. According to multivariate and non-linear in nature, it is difficult to achieve the optimum speed of the motor. Conventional proportional integral (PI) controllers suffer from their inherent losses [20]. Due to increasing size and complexity of electric power systems, there has been an increasing interest in stabilization of such large-scale power systems. Gas turbines are highly non-linear plants that have multiple inputs and outputs. The operating conditions span extremes of temperature, pressure and load conditions.

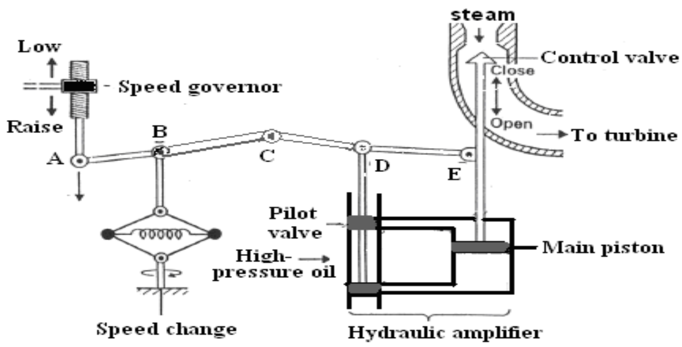


Figure.6 Block diagram of synchronous generator

A turbine is a mechanical device that extracts thermal energy from the pressurized steam, and converts it into rotary motion (Fig.-). The turbine is coupled with the compressor and eventually the compressor is run by the gas turbine. The hydraulic governor is used to control the flow of high pressure steam. It acts as a control valve which is used to throttle the amount of steam going to turbine section. Conventional controllers like proportional integral derivative (PID) are employed in every facet of process control system. Proportional integral derivative (PID) controllers are used in small industries as well as in high technology industries like refineries, ship buildings etc. fuzzy logic (FL) based controller is implemented to control the flow of high pressure steam. Figure-7 show block diagram of synchronous generator and FLC loops; governor controls the steam/gas, and the excitation system controls the generated EMF of the generator and therefore controls not only the output voltage but the power factor and current magnitude as well.

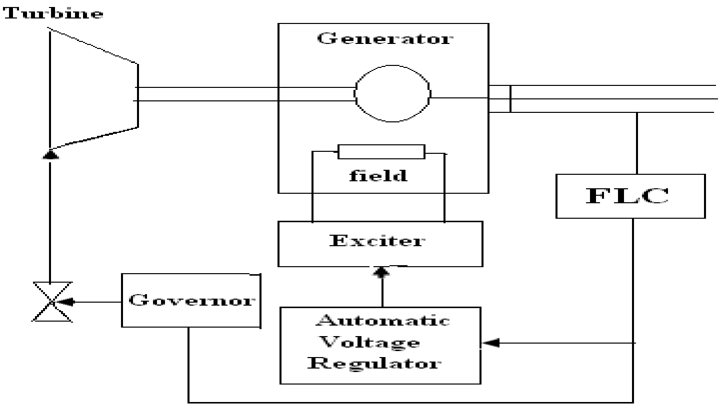


Figure .7 Block diagram of synchronous generator and FLC loops

The fuzzy controller is a heart of the system, it makes logic decisions depending on the input and output behavior of the generating unit. The fuzzy logic controller (FLC) gives much lower overshoot, settling time and peak time than the conventional proportional integral derivative (PID) controller. Fuzzy logic controllers can cope with non-linearities, load disturbances but tuning of fuzzy logic (FL) parameters and stabilities are its main problems. If the control parameters are fine tuned then the system will be able to control the speed in a better manner. The parameters of typical Gas turbine are given in table -1.

Table Parameters for typical Gas Turbine

Capacity	38MW
Output Current	2612A
Output Current	860A
Frequency	50Hz
Power Factor	0.8
Speed	300RPM
Output Voltage	10.5Kw

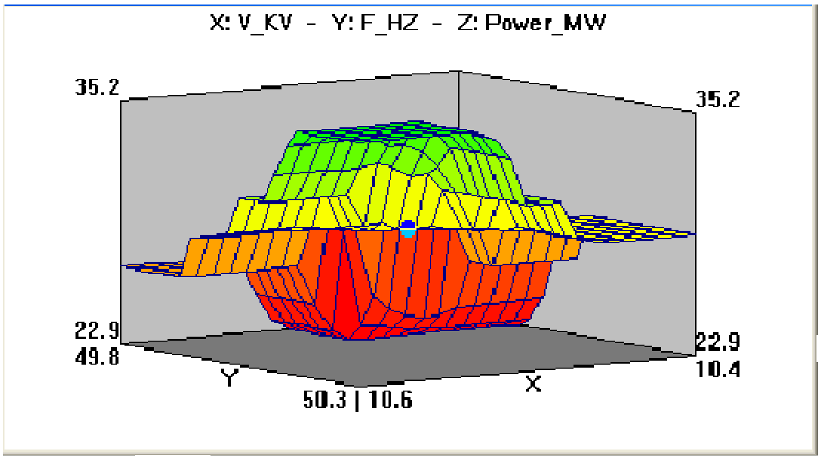


Figure. 5 shows the three dimensional of input - output mapping for fuzzy process control.

V. Conclusion and Future Scope

This paper presented an overview of fuzzy logic method applied to solve the power system stabilizers problems. Results of the different case studies were taken in this work, show that the fuzzy logic is a great deal of research for tackling non-linear complex process control systems. According to the efforts of these researchers, fuzzy logic is most robust and systematic approach for controlling process, and has been an active research topic in automation and control theory since the work of Mamdani proposed to deal with the system control problems which are not easy to be modeled, based on the fuzzy sets theory.

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