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Tunning of FLC using GA & PSO for Wind Generation System

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Abstract: ***Various experiments has been performed in variable wind generation system using different soft computing techniques in order to get maximum output power. A fuzzy system has a characteristic to represent human knowledge or experiences as fuzzy rules. However, the fuzzy system has some problems. In most fuzzy systems, the shapes of the membership functions of the antecedent, the consequent, and fuzzy rules were determined and tuned through trial and error by operators; therefore, it takes a lot of time to determine and tune them, and it is very difficult to design the optimal fuzzy system in detail. This problem is more serious when the fuzzy system is applied for more complex systems. In order to solve this problem, some self-tuning methods have been proposed using the meta heuristic (Particle Swarm Optimization and Genetic Algorithm). The effectiveness of the proposed controller is demonstrated by the control performance of such an FLC of a wind generation system. The results are compared favourably to GA with PSO for better exploration of search space.***

Keywords: Doubly fed induction generator, direct power control, grid side converter, rotor side converter, particle swarm optimization, fuzzy lozzy controller proportional integral derivative, wind farm model, Genetic Algorithm, Particle Swarm Optimization

1. Introduction

To get reliable, secure, and efficient electricity by integrating the wind farm model into power grid has become a very difficult task and also for the development of renewable energy systems through optimal control of large-scale wind farm has become a challenge. Many researchers have found that computational intelligence (CI) research provides key technical innovations that can be used for this challenging problem.[1]

The use of fuzzy logic principles in variable speed wind farm model is very good for efficiency optimization and performance enhancement control. Here a squirrel cage induction generator is used to feed the power to a converter system that feeds power to an autonomous system. Three fuzzy logic controllers have been used in order to extract the maximum power and efficiency improvement. [2]

The system maintains unity power factor under all conditions by feeding utility grid and also helps to optimize efficiency.[3] In such condition where wind speed is variable, a stator side converter of Permanent Magnet Synchronous Generator (PMSG) has been used to estimate maximum power. [4]

A new nonlinear control approach based on the fuzzy logic controller is used for the generation of power from WECS and its transmission to the grid. [5]

It shows the excellent performance of variable speed wind turbines with torque. Also blade pitch control provides an excellent performance. Although the use of fuzzy logic controller in wind generation system improves wind energy capture.[6]

To extract maximum power from fuzzy logic controller based variable speed wind generation system. The input applied in fuzzy logic controller is the change in mechanical power with respect to change in wind speed and the output variable is the generator current. The output power is consist of mechanical power of generator plus the dynamic power. Thereby now controller is able to track the maximum power for changing wind condition.[7]

However, the fuzzy system has some problems. As known tuning of fuzzy rules were determined and tuned through trial and error by operators; therefore, it takes a lot of time to determine and tune them, and it is very difficult to design the optimal fuzzy system in wind generation system. There are several different method that has been used for tuning of fuzzy membership function and find the problems being faced during tuning. To overcome these difficulties various techniques have been reported to automate the tuning process of MFs.[8]

The main objective this present work is to automatically adjust the MFs of a Mamadani-type fuzzy controller in performing tracking control through PSO & GA. In particular, we are using the proposed FLC to control the Output of a wind generation system. Although there are research results in the area of automatic fuzzy MF tuning, most of them are in the area of Takagi-Sugeno type of fuzzy controllers. To the best of our knowledge the comparison of PSO and GA for wind generation system is not reported in literature which is novelty of this study.

2. Methodology

2.1. Particle swarm optimization (PSO)

PSO is a non-parametric optimization method introduced by Kennedy. It is inspired by the formation of swarms by animals such as birds and fish. The principle behind PSO is that each individual in the swarm, called a particle, will move towards the best performing particle (leader) in the swarm while exploring the best experience each particle has.

2.2 Automatic fuzzy MF tuning using a PSO

Fuzzy logic controllers (FLCs) are designed based on expert knowledge that is in the form of rule-based behavior. In general the FLC rules are expressed in the form:

If input 1 is A and input 2 is B then output is C where antecedents A and B are expressed by membership functions (MFs). A typical set of MFs are depicted in Figure 8.

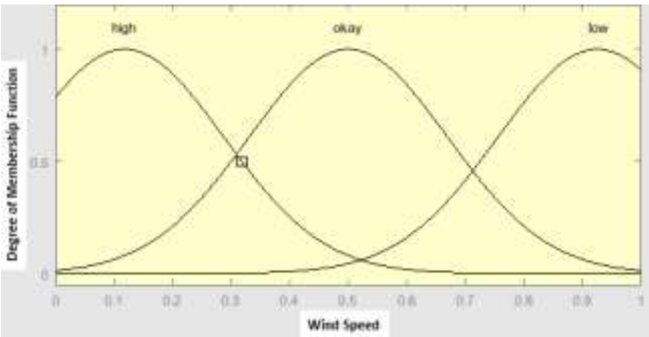

Figure 1: A typical set of MFs in an FLC

There are two types of expressions for consequent C. In Tagaki-Sugeno (TS)-type FLCs, the C is expressed as a linear combination of all inputs. On the other hand, if a Mamdani-type of FLC is used, C is expressed by a set of MFs. The process that is used to calculate the overall control action in FLC is determined by different type of 'defuzzification' process. In general, a Centre of Area method is commonly used, where the output u* is calculated as:

$$u^* = \frac{\int u m_o(u)du}{\int m_o(u)du}$$

u is the output variable, O is the output fuzzy set and mO is the MF of the output fuzzy set. In general, fuzzy rules expressed in (5) are relatively easier to obtain from expert knowledge. However, the design which involves the determination of where in the variable space each membership function should locate is a time consuming process.

It can be seen in Figure 8, the Gaussian type MFs are determined by parameters such as the mean and deviation values of each MF. For other types of MFs, such as triangular or trapezoidal MFs, there are similar parameters that determine the shapes of the MFs. Therefore, it is possible to use PSO as a global optimization search method to find a set of such parameters that will produce the best control performance of the FLC.

The strategy of using a PSO for MF tuning in FLC is depicted in Figure 2. In the proposed PSO process, each particle is formed to represent the MF parameters of the FLC's inputs and outputs. As the purpose of the PSO is to minimize the control error of the FLC, the objective function of PSO is defined as:

$$f(X(k)) = \sum_{t=0}^{t_f} \epsilon^2$$

where t_f is the total running time of the FLC, ε is the control error.

2.3 Genetic Algorithm

Traditional optimization methods are based on the fact that certain functions are differentiable. Unfortunately, in many real world problems such functions can not be defined. But even if they can, gradient search methods may not find global optimal solutions. A possible way to overcome such problems is to use genetic algorithms (GAs). Generally a GA consists of a problem, a number of encoded solutions for that problem, some genetic.

```
Genetic Algorithm
begin (1)
t = 1
Initialize Population(t)
Evaluate fitness Population(t)
While (Generations < Total Number) do
begin (2)
select Population(t + 1) out of Population(t)
Apply Crossover on Population(t+ 1)
Apply Mutation on Population(t+ 1)
Evaluate fitness Population(t+ 1)
t = t + 1
end (2)
end(1)
```

During selection individuals with high fitness values within the current population are selected to build the basis for the new generation. Crossover is a way of creating new solutions by randomly selecting two chromosomes of previous solutions from the gene pool and exchanging portion of their strings. Mutation is performed upon a selected chromosome by randomly changing a part of its coded value. Mutation is needed to ensure diversity in the population.

2.3.1 Automative Tunning Using Genetic Algorithms

When the optimization process is initialized, it is desirable to produce a generation that has enough parameters to gain exibility. For that reason, at the beginning of the optimization process the structure of the Fuzzy System is opened. This means that for each multiply used MF in the rule base, we produce copies of the function for each rule to which it participates. Thus each rule has its own MFs. All copies are equal at this point of the process, but they are allowed to vary independently in the next steps. Now, the GA has the possibility to eliminate the extra parameters while running.

The chromosomes of the GA are built by two or three genes (parameter sets). Two genes are selected if the MF is symmetric, three if it is non symmetric (mean gene, right sigma gene, left sigma gene). The first gene consists of the means of the MF, while the second one consists of the respective sigmas or σ right and σ left. Each mean and sigma is converted from a real number to a fixed binary number of I = 8,16 bits accuracy using the gray encoding scheme. Graycoding makes genetic operators more robust against single bit changes: The value of the gray coded gene is only 1 higher or lower, if one bit of the encoding is changed. On the contrary several bits of a binary coded number may change if it increases or decreases by 1, e. g. 4 bits if 7 increases to 8. Every chromosome S contains all fuzzy set parameters

$$m_{ij} \text{ and } \sigma_{ij}^{(left,right)}$$

where i = 1. . . . . n is the number of variables and j = 1. . . . . qn is the number of respective MFs per variable.

During fitness evaluation the reverse process (decoding) is done to get back the means and sigmas as reals. With these real values the MFs of the fuzzy variables are constructed and the fitness function is evaluated.

3. Simulation Results

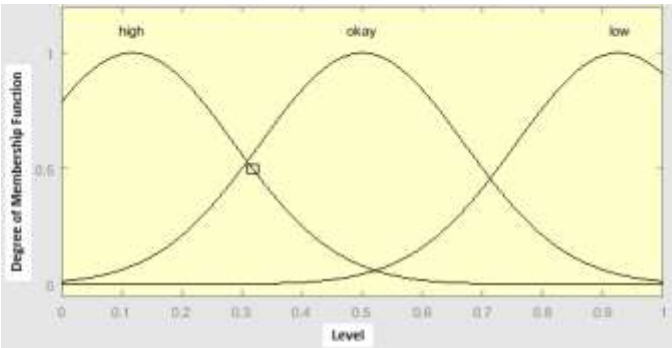

Figure 2: Fuzzy logic based control block diagram of wind generation system.

The MFs used in this FLC are all of Gaussian forms. The parameters that define the MFs are the mean c and the deviation of each MF. The membership function is defined as:

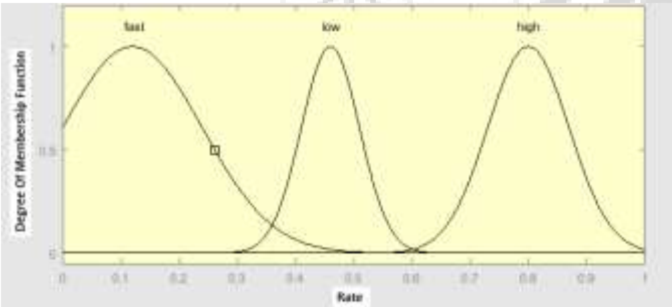

Figure 3: The intial MFs for the FLC inputs

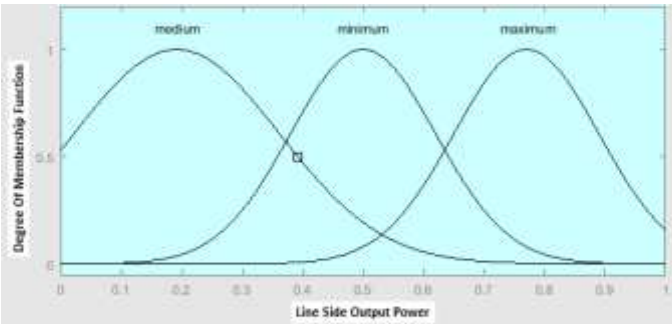

Figure 4: The initial MFs for the FLC output

The objective function that evaluates the fitness of each particle was defined in above equation. Therefore, after the proper tuning of the MFs, the FLC will have a minimized control error.

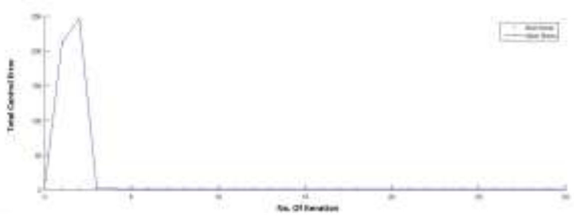

Figure 5: The reduction of control error during the GA Searching Process

In Figure 5, the fitness function value during the search of the optimal solution is given. As it can be seen in the figure, the searching was terminated after 30 iterations when there is no reduction in total control error was observed.

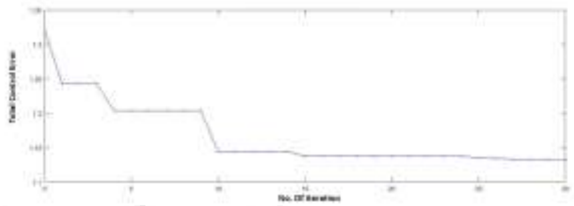

Figure 6: The reduction of control error during the PSO Searching Process

This result reveals that for a particular generator speed, if the wind velocity is increased, its corresponding turbine developed power is also increased. The system was assumed to be a lossless system, thus it can be said that the turbine developed power is equal to the line side power. This result reveals that for a particular generator speed, if the wind velocity is increased, its corresponding line side power is also increased. Performance Comparison of the GA and PSO tunned FLC Controller for Maximum output power in Wind Generation System is shown below.

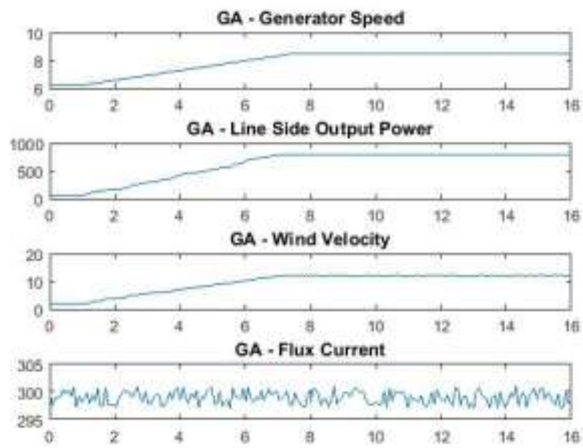

Figure 7: The GA tunned FLC control output for a wind generation system

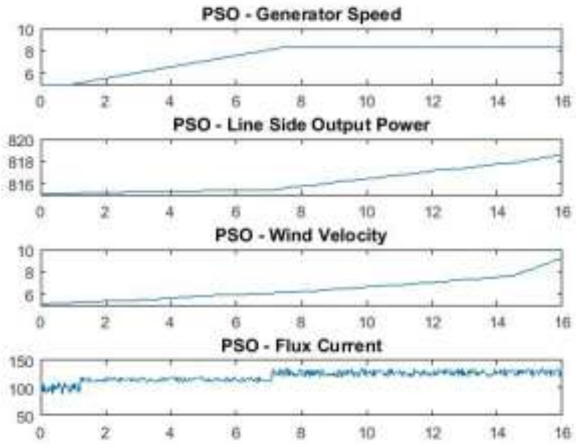

Figure 8: The PSO tunned FLC control output for a wind generation system

From the whole evaluation, we obtain that GA tunned FLC controller is able to extract maximum output power from variable speed wind generation system.

4. Conclusion

In fuzzy logic controller design, the process of tuning membership functions is a time consuming and often frustrating exercise. In this paper an autonomous MF tuning method in designing FLC is introduced to perform tracking control of a wind generation system. The results have shown that the GA tuned FLC is performing satisfactorily compared with the PSO tuned FLC.

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