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Design of WECS using HSA with fuzzy controller

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Abstract:

Wind turbines form complex nonlinear mechanical systems exposed to uncontrolled wind profiles. This makes turbine controller design a challenging task. As such, control of wind energy conversion systems (WECS) is difficult due to the lack of systematic methods to identify requisite robust and sufficiently stable conditions, to guarantee performance. The problem becomes more complex when plant parameters become uncertain. This paper considers the wind energy curtailment for which it provides a combinatorial planning model to maximize wind power utilization. The major objective of this study is to develop an effective method for optimizing size of wind. A novel multi-objective adaptation of the fuzzy based Harmony Search algorithm is proposed and tested for efficiently solving the problem of optimally deploying wind turbines in wind farms. In this paper, Harmony Search Algorithm (HSA) using fuzzy controller to achieve better optimization results and to increase performance. A general formulation of this algorithm is presented together with an analytical and mathematical modeling to solve the stability and performance of the system.

Keywords — **WECS, Fuzzy controller, Fault tolerant control, HSA**

I. INTRODUCTION

Wind energy has been received much more attention than ever before in the last decade. It will play more and more important role in the future energy market since the decreasing production of the fossil energy, mainly from oil, which will be almost totally exhausted in the next five or six decades. However, wind energy cannot compete with traditional energies until now since it is more expensive than others. The cost due to maintenance are still very high which is mainly caused by the failures of some components of wind turbines. Therefore, much effort is needed to enhance the reliability of the wind turbines. Since ancient times, people have used wind turbines to pump water and mill grain, along with many other uses. Today, wind turbines are used for similar purposes (i.e., water or oil pumping, battery charging, or utility generation) as a cheap, clean source of electricity, and well suited for isolated places with no connections to the electric grid .

Mainly there are two types of wind energy conversion system(WECS).Fixed speed turbines have no option to control input.They use pitch regulation for start up and after start up only to control the over above wind speed of the turbine.So we go for variable feed wind turbine.Variable speed wind turbine use the generator torque control for optimization of power output.They use pitch control to control the output power,only above their rated wind speed.With variable speed,there will be 20 -30 increase in the energy capture compared to fixed speed operation.

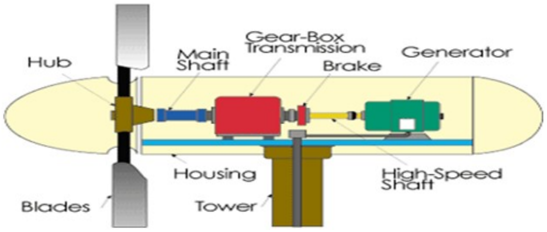

Fig 1.1 :Horizontal Axis WECS

The portion of the wind turbine that collects energy from the wind is called the rotor. The main rotor shaft and electrical generator are generally at the top of a tower for a horizontal axis wind turbine (HAWT). A horizontal axis wind turbine has a design which demands that it should be pointed to the wind to capture maximum power. This process is called yawing. The turbine shaft is generally coupled to the shaft of the generator through a gearbox which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator. The rotor usually consists of two or more wooden, fiberglass or metal blades which rotate about an axis (horizontal or vertical) at a rate determined by the wind speed and the shape of the blades.

The generator converts the mechanical energy of the turbine to electrical energy (electricity). Inside this component, coils of wire are rotated in a magnetic field to produce electricity. Different generator designs produce either alternating current (AC) or direct current (DC), available in a large range of output power ratings. The number of revolutions per minute (rpm) of a wind turbine rotor can range between 40 rpm and 400 rpm, depending on the model and the wind speed. Generators typically require rpm's of 1,200 to 1,800. As a result, most wind turbines require a gear-box transmission to increase the rotation of the generator to the speeds necessary for efficient electricity production. Aerodynamic subsystem, consisting mainly of the

A hybrid wind diesel system with battery storage of wind power can benefit islands and other isolated communities and increase fuel savings. However, control of such system is very important as wind turbine produces excessive fluctuation of power output, which negatively influences the quality of electricity supplied to the load, particularly frequency and voltage Due to the strong requirement from the wind energy field, fault detection of the wind turbine components has received significant attention in recent years. Fault detection becomes even more complex when multi variable nonlinear wind energy conversion systems (WECS) are subject to parameter uncertainties. Uncertainties often degrade system performance and may even lead to instability and so, in order to overcome these kinds of difficulties, different techniques have been developed . As such, a residual-based scheme is presented to detect and accommodate faults in wind turbines. An observer-based scheme was proposed to detect and isolate faults in the wind turbine .

Based on the aforementioned studies, the contributions of this paper are twofold:

1) The design of an robust active fault tolerant fuzzy control with HSA subject to a wide range of wind variation, wind disturbance, parameter uncertainties, and sensor faults

2) The system increase efficiency and reduce error and will be viewed in the present simulation.

II. DESIGN OF WECS

The aerodynamics of the wind turbine is modeled as torque acting on the blades. Maximum Power produced by wind turbine is

$$P_m = 0.5\pi\rho C_t(\beta,\lambda)\, R^2 V^3 \qquad (1)$$

$$T_m = 0.5\pi\rho C_t(\beta,\lambda)\, R^3 V^2 \qquad (2)$$

P_m =Power, T_m =Torque, ρ = Air Density, C_t = Power Coefficient, λ = Tip Speed Ratio, β = Pitch Angle, R=Radius of rotor , V=Wind Velocity

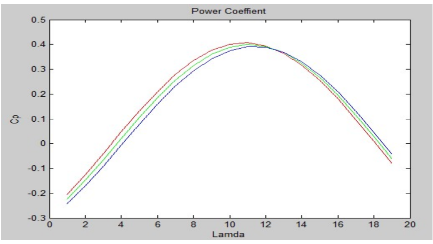

Fig 2.1 :Power coefficient versus lamda

To extract the maximum power angular speed should vary with the wind speed . Wind turbine operated at variable rotational speeds .Power coeffcient versus lamda is plotted. At lamda = 0 the rotor doesnot rotate and hence cannot extract power from wind.For tht wind turbine a cutin speed is needed for tht wind turbine to operate.In between cutin and rated speed power vary proportional with wind speed.At very high the rotor will run very fast so that can cause damage.so in this figure in between 0 and 12 maximum value is acheieved and thus optimized value for which maximum power can be acheived. Obtain power at maximum power coefficient over a wide range of wind speeds.

III. WECS CONTROLLED USING FUZZY CONTROLLER

In the WECS while power is being captured from the wind it is desired that the power captured may be maximized. Also, it is to be made sure that the turbine safety is not compromised under any circumstances. Thus, power control is a very important feature of a wind turbine. To avoid damage to the wind turbine at very high wind speeds, the aerodynamic forces on the rotor can be controlled to limit the power captured.

Wind turbine can be controlled by using many controllers. But the response is not proper for all controllers. Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensor or other inputs, such as switches, thumb wheels, and so on, to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value.The processing stage is based on a collection of logic rules in the form of IF-THEN statements, where the IF part is called the "antecedent" and the THEN part is called the "consequent". Typical fuzzy control systems have dozens of rules.

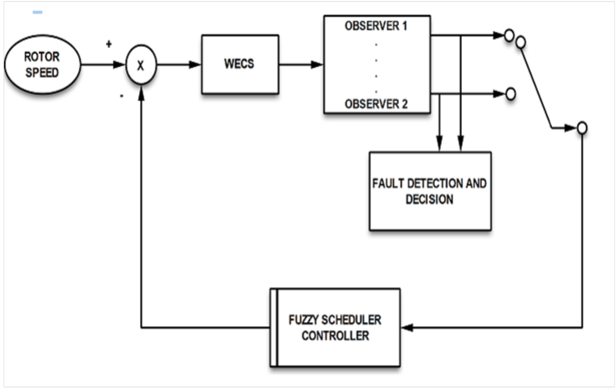

Fig 3.1: Block Diagram of Fuzzy with WECS

Introducing a new fuzzy scheduler fault-tolerant control (FTC) methodology using a bank of observers proposed . Each observer of the proposed bank of observer s scheme has an associated output sensor for residual generation. The residuals are compared with the threshold value at each sampling time by a switching mechanism that selects the healthy one. The estimated states from the healthy observer are used to compute the new control law. Multiple sensors observers (g observers) and a switching mechanism to automatically detect the healthy observer that uses the output of the healthy sensor and avoid the use of faulty one in closed loop. Each observer has an associated state estimator in a structure, similar to the dedicated observer scheme .Here proposes a fuzzy scheduler fault tolerant controller . The FDI scheme developed here follows a classical strategy such as the well-established observer-based FDI methods . Because each observer is driven by a single sensor output to generate residual signals corresponding to the difference between measured and estimated variables. By using a switcher, we select the state reconstructed by the observer that uses the output of the healthy sensor accordingly.

A. FUZZY CONTROLLER

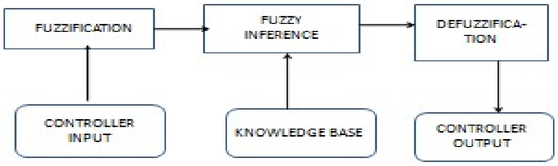

Fig 3.2 : Fuzzy Controller

The first block inside the controller is Fuzzification , which converts each piece of inputdata to degrees of membership by a lookup in one or several membership functions. The fuzzification block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matches that particular input instance. There is a degreeof membership for each linguistic term that applies to that input variable.The rules may use several variables both in the condition and the conclusion of the rules. The Rule Base is basically a linguistic controller contains rules in the Rule Base format, but they can be presented in different formats. Defuzification is resulting fuzzy set must be converted to a number that can be sent to the process as a control signal. This operation is called Defuzification. The resulting fuzzy set is thus defuzzified into a crisp control signal.

With fuzy controller the plant is controlled.But the response obtained by using fuzzy controller is poor. Drawbacks of using fuzzy in controlling WECS are Fault settling Time is High and High overshoots are also occurring here.Error computation is done.Integral square error,Integral absolute error and Integral total absolute error are computed.But the error is very high by using fuzzy controller.So a low stability system is obtained

IV. HARMONY SEARCH ALGORITHM IN WECS

In this paper , proposes fuzzy based Harmony Search algorithm and tested for efficiently solving the problem of optimally deploying wind turbines in wind farms. The objective functions consist of the output sensitivity functions of the sensitivity models defined with respect to the parametric variations of the processes. The proposed method solves the optimization problems resulting in a fuzzy controller with a reduced time constant sensitivity. In this paper, one of the parameters of Harmony Search Algorithm is controlled using fuzzy controller to achieve better optimization results and to increase performance.Moreover by using the new algorithm drawbacks of fuzzy controller is rectified.Fuzzy controller is having high oscillations and settling time is also very high.Error for this system is also very high.So by using HSA algorithm the response is better and Error is reduced.Fault settling time is reduced and stability is also high for this system.

Harmony Search was inspired by the improvisation of Jazz musicians. Specifically, the process by which themusicians (who have never played together before) rapidly refine their individual improvisation through variation resulting in an aesthetic harmony.

Steps of harmony search algorithm are shown as flowchart

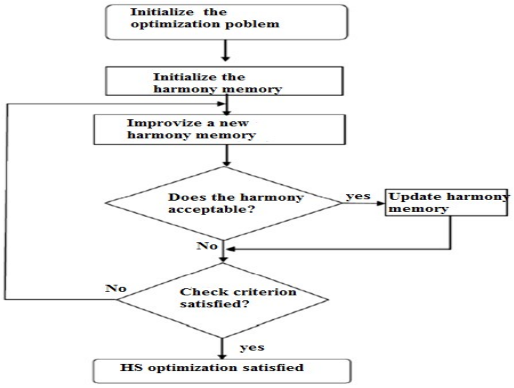

Fig 4.1: Flow chart of HSA

Step 1. Initialize the problem and algorithm parameters.

Step 2. Initialize the Harmony Memory (HM).

Step 3. Improvise a New Harmony memory.

Step 4. Update the Harmony memory.

Step 5. Check the stopping criterion.

Step1: Initialize the problem and algorithm parameters

Consider an optimization problem which is described as: Minimize the make span, Minimize the mean flow time and Minimize the mean tardiness. The HS parameters are specified in this step. These are Harmony Memory Size (HMS), or number of solution vectors in the harmony memory; Harmony Memory Considering Rate(HMCR); Pitch Adjusting Rate (PAR); and Number of Improvisations (NI) or stopping criterion. The Harmony Memory (HM) is a memory location where all the solution vectors (sets of decision variables) are stored. The parameters HMCR and PAR are used to improve the solution vector and these are defined in step 3.

Step2: Initialize the harmony memory

Initialize the HS memory (HM). The initial HM consists of a givennumber of randomly generated solutions to the optimization problems under consideration

Step3: Improvise a new harmony from the HM set

A new harmony vector, $x = x_1', x_2' \quad x_n'$, is generated based on three rules, namely, random selection, memory consideration and pitch adjustment.

Step 4: Updating HM

If the new harmony vector, , $x = x_1', x_2' \quad x_n'$, is better than the worst harmony in the HM, from the viewpoint of the objective function value ,the new harmony is entered in the HM and the existing worst harmony is omitted from the HM.

Step 5: Checking stopping criterion

Computation is terminated upon satisfying the maximum number of improvisations or maximum number of iterations, which is the stopping criterion. Otherwise, steps 3 and 4 are repeated. Finally the best harmony memory vector is selected and is considered to be the best solution to the problem under investigation.

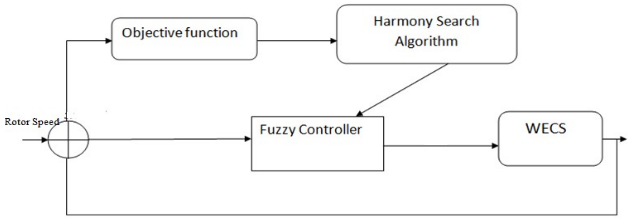

Fig 4.2 :WECS controlled using HSA with fuzzy

In the HS algorithm, each solution is called a harmony.It is represented by an n-dimension real vector. An initial randomly generated population of harmony vectors is stored in an HM. Then, a new candidate harmony is generated from all of the solutions in the HM by adopting a memory consideration rule, a pitch adjustment rule and a random re-initialization. Finally, the HM is updated by comparing the new candidate harmony vector and the worst harmony vector in the HM. The worst harmony vector is replaced by the new candidate vector if it is better than the worst harmony vector in the HM. The above process is repeated until a certain termination criterion is met.

The fuzzification, inferencing and defuzzication processes can be parallelized. For example, an input signal can be fuzzified by matching all membership functions simultaneously against the incoming value. In this way, fuzzy control processing can be viewed as a parallel neural network where each neuron represents a fuzzy membership function and each link represents the weight of a fuzzy rule. These links represent consequents of fuzzy rules which could be optimized by Harmony search. Tuning the membership functions requires adjusting many parameters simultaneously and is difficult to do manually. Harmony search can be employed to reliably find optimal membership functions and gives less time consuming.

Compared with the fuzzy controller more advantages are obtained by using HSA in fuzzy controller. They are :-

Maximizes the produced power

Speed control

Load control

High stability

Fault settling time low

Non linear tracking Error is low

V. STIMULATION RESULT

Simulations were performed in MATLAB using the nonlinear model . In this section, two cases of simulation are presented; the First case studies the responses for the WECS model with Fuzzy controller subject to sensor faults, parameter uncertainty, and wind disturbance. Error compuatation using fuzzy controller is also obtained.Integral Square Error(ISE),Integral Absolute Error(IAE),Integral Total Absolute Error(ITAE)is calculated.The second case compares the results of the proposed algorithm with the previous method subject to parameter uncertainty and disturbance and error is also computed. The simulation data represent a wind turbine with three blades, a horizontal axis, and variable speed. The proposed controller for the WECS is tested for random variation of wind speed to demonstrate the effectiveness of the proposed algorithm. System Response Subject to Small Disturbance under different parameter uncertainties.

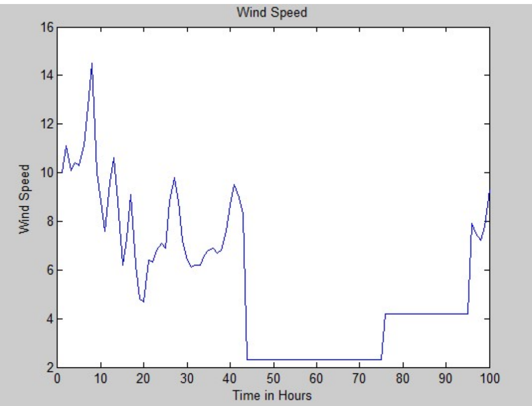

Fig 5.1: wind speed

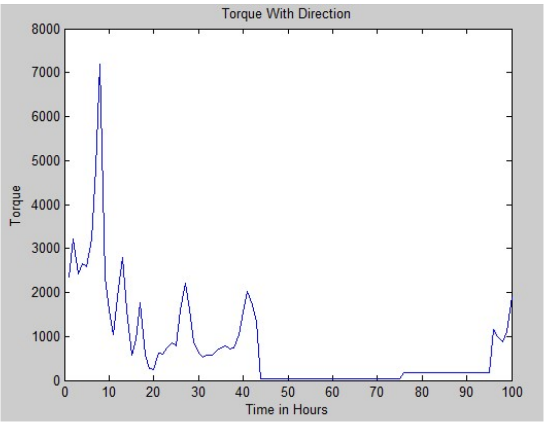

Fig 5.2: Torque with direction

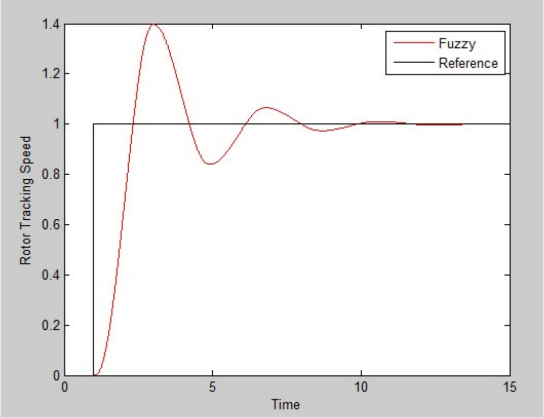

Fig5.3 : WECS controlled with fuzzy

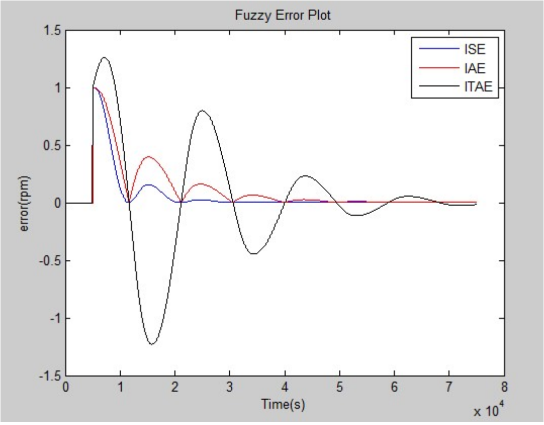

Fig 5.4 : Error plot using fuzzy

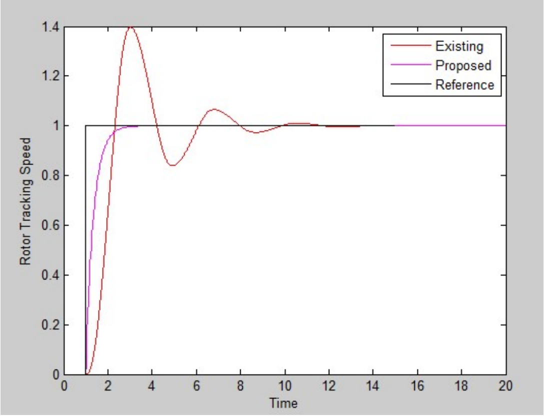

Fig 5.5 : WECS controlled using HSA with fuzzy

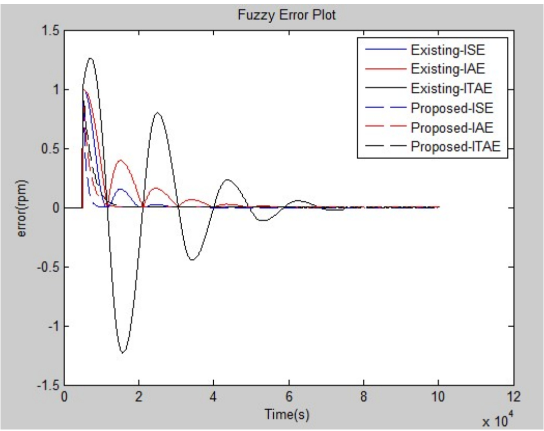

Fig 5.6 :Error plot using HSA with fuzzy

Table 1: Details of comparison

Parameters	Existing Method	Proposed Method
Rise Time	0.8297	0.7750
Settling Time	9.237	2.37
Overshoot	39.15	0.914
Peak	1.68	1.01

Table 2 : Error comparison

Parameters	Existing Method	Proposed Method
ISE	1.02	0.5
IAE	1.04	0.54
ITAE	1.35	0.62

From the details its clear that HSA with fuzzy controller much more better than using fuzzy controller.Error is also reduced by using HSA optimization.Proper step response is obtained by using propsed system.

VI. CONCLUSION

In this paper , proposes a new algorithm with fuzzy controller to solve the problems with fuzzy controller operating in WECS. On the other hand the HSA is applied to choose the best answer in optimization problem.In this paper, we propose a new HSA algorithm for robust active fault tolerant fuzzy control of variable-speed wind energy conversion systems (WECS) in the presence of wide wind variation, wind disturbance, parametric uncertainties, and sensors faults. The fuzzy model with parametric uncertainties is adopted for modeling the nonlinear WECS and establishing fuzzy state ob-server.By using Fuzzy controllers error is very high as well as settling time is also high which is not suitable for a good system.So new algorithm is proposed to obtain optimized value.Thus the system increase efficiency and reduce error .

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