TECHNICAL AND VOCATIONAL TRAINING INSTITUTE (TVTI)

SCHOOL OF GRADUATE STUDIES

FACULTY OF ELECTRICAL AND ELECTRONICS TECHNOLOGY AND INFORMATION AND COMMUNICATION TECHNOLOGY
(DEPARTMENT OF ELECTRICAL AND ELECTRONICS TECHNOLOGY)

Thesis On:

Modeling and control of pitch angle of wind turbine using fuzzy logic based adaptive controller

MSc Thesis Proposal for the Partial Fulfillment of
Master of Science in Electrical Automation and Control Technology Management

By,

ELIAS ASHEBO (MTR/524/13)

Supervisor,

Dr. Lebsework Negash

August 2022

Addis Ababa, Ethiopia

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TECHNOLOGY MANAGEMENT

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Declaration

I hereby declare that the work presented in this thesis, which is titled “Modeling and control of the pitch angle of wind turbine using fuzzy logic based -adaptive controller" is my own unique artwork, hasn't been submitted for a degree at this or any other university, and all sources of information included in this thesis have been primarily on the basis.

Name: - **Elias Ashebo (MTR/524/13**)

Signature ________________________

Place: Addis Ababa

Date of Submission: _________________

This thesis has been submitted for examination with my approval as a TVTI advisor.

Dr. Lebsework Negash	-----------	-------------
Advisor Name	Signature	Date

Acknowledgement

To begin with and first, I would need to precise my appreciation to God; He gave me the courage, perseverance, and strength to effectively complete the thesis. I would like to precise my significant appreciation to my advisor, **Dr. Lebsework. N**, for his consistent support of my research paper/thesis as well as for his tolerance, inspiration, curiosity, and, most importantly, advice throughout the research and thesis writing process. Finally, I want to thank my complete family for their love, support, and sacrifices they have made for me, especially my friends and my electrical/electronic automation and control instructor.

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APPROVED BY THESIS ADVISOR COMMITTEE

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ABSTRUCT

Wind energy is a none convectional energy source that is now the subject of much research. Variable wind turbines are the most widely used type of wind turbine system because they are the most effective and provide more control across a broad speed variety. Wind behavior determines the manner in which a wind turbine converts energy. The main advantage of renewable energy is to avoid air pollution and to maximize society use of energy. Wind energy and wind speed controller very important to improve energy performance by using fuzzy logic based adaptive controller. Pitch angle control phenomenon assists in optimizing at lower wind speeds and stabilizing output power at higher wind speeds. It also assists in running the system with greater efficiency and dependability under turbulent weather situations or temperature change of high flow air.

However, a pitch angle controller will adjust blades of wind turbines attack angle internal or external of wind waves based on wind speed in order to improve extracted energy conversion. In this thesis, an FLC and FLBADC is utilized to regulate the wind turbine's pitch angle in order to decrease the impact of outside disturbances, the uncertainty of the parameters, and to increase robustness. The MIT Rule Based MRAC and Lyapunov rule MRAC stability design have been used. It's found that MIT rule has less overshoot but a slower reaction/response. When comparing the Lyapunov rule configuration of MRAC to the MIT rule, the complexity is minimized. As a result, with Lyapunov theory, the physical manifestation /external of the system under investigation is more possible. According to the working zones of the wind turbine, the controller's goal is to keep the rotor speed and pitch angle at optimum levels. Wind energy and wind speed controller very important to improved energy performance. Depending on wind speed, A pitch angle controller will change the wind turbine rotor blade's attack angle into or out of the wind. The simulation results demonstrate that the FLBAC controller has the greatest performance when comparing the proposed techniques since it controls the pitch system as well as the disturbances and uncertain system-related elements. Finally, the fuzzy logic based adaptive controller better than MIT rule, Lyapunov rule design and fuzzy logic controller compared and the simulation results used to analyzed

Keywords- *Adaptive Controller (AD), Fuzzy Logic controller (FLC), fuzzy logic based adaptive controller (FLBAC) Pitch angle , Lyapunov rule, MIT rule and Variable Speed Wind Turbine.*

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Acronym (List of Abbreviations)

WT	wind turbine
AC	Alternate current
DC	Direct current
DFIG	Double fed induction generator
MRAC	Model reference generator
IGS	Induction generator system
MIT	Massachusetts Institute of Technology
FLBAC	Fuzzy logic based adaptive controller
FLC	fuzzy logic controller
PID	proportional integral derivative
PMSG	Permanent magnet synchronous generator
SCIG	Squire cage induction generator
SG	synchronous generator
WECS	wind energy system

CHAPTER 1

1 .INTRODUCTION

1.1Bak ground

Wind energy is the most fundamental things to accelerate different activities in the world. There two types of energies, they are convectional /none renewable and none convectional/renewable energy .These renewable energy are hydro, wind, solar and geothermal and also the other. Conventional/non renewable energy sources like coal, oil, natural gases or uranium. These materials have an unlimited supply. More research is now being done to improve the technology that can effectively transform renewable energy sources into usable electrical energy sources. Growing environmental concerns, especially issues connected to global warming have sparked a push for the use of renewable energy sources. In this setting/context, wind energy plays a significant role and is now the most used non-convectional fuel, however there is still more technological development needed. In wind energy applications, wind turbine (WT) control is essential because it provides high effectiveness and cost-efficiency. This has been a subject that has been extensively explored, and its advancements are critical in the construction of indeed superior and more effective wind turbines. However, there are currently few studies that consolidate and list wind turbine control concepts. A literature overview on wind turbine control is offered in this work, which covers the wind energy control methods. The thesis' major goal is to provide a detailed research of pitch angle control and that can be use a starting point for additional study on wind turbine control, which is important for long-term energy sustainability. The thesis also examines pitch angle control innovations and how they help to manage natural problems.

None convectional energy/wind is the most efficient or cleanest kind of energy among several renewable energy sources [1, 2]. Compared to other sources of generation, the cost of producing energy from wind power plants is lower. In any event, the available wind power is also changeable due to the wide range in wind speed. In order to make wind power controllers more dependable and effective, it is necessary to simulate, enhance, and evaluate the variability of wind power. Advanced WECS (Wind Vitality Transformation Framework) are controlled .When the wind velocity is greater [3]. As a result, the performance of the pitch point controller is a fundamental problem away of overestimated wind velocity operation. Due to the nonlinearity of both the wind turbine and the pitch point instrument, the pitch control is difficult [2, 4]. Due to the irregular nature of the wind, high performance pitch angle controllers must be utilized so they can function effectively even when wind bursts emerge. However, they must first understand the behavior of wind characteristics in order to build and construct the controller. In the natural world, wind speed fluctuates occasionally. Dynamic behavior is the term for this variety.

The necessity for wind energy to be capable to operate in various wind conditions and at various wind speeds determines the location of the turbine's operation [3]. Certain qualities need to be taken into account for each of these locations. Controllers must be planned and put into place in order to maintain the operation of a wind turbine under these circumstances. The most ideal controller must be chosen using dynamic/ stochastic modeling of wind speed in order to evaluate the impact of external control techniques on system behavior. The wind turbine's operational point fluctuates quickly and constantly across its as general cover due to the extremely dynamic fluctuations in wind speed. As a result, the controlled system's nonlinear behavior and performance must be the focus.

The need to maximize the actuators still justifies the usage of nonlinear control in wind turbines. The features of the actuator, in particular the torque restrictions, are one of the main variables limiting the performance a controller can achieve. Because the aerodynamic torque is more sensitive to variations in pitch than to changes. The most crucial factor is controller performance, even when loads are larger at higher wind speeds [4, 5].

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.1.2 Wind turbine and its Components

1 wind turbine

Wind turbines absorb the power of the wind and convert it to electricity. A wind turbine, in basic terms, works within the inverse course of a fan. Wind turbines, instead of utilizing control to form wind like a fan, utilize wind to form power. The primary goal of a wind turbine is to generate electricity from wind. On the one hand, quantifying this power output is crucial for any wind energy project's financial planning. However, in addition to the pure amount of energy produced, the dynamics of the power conversion also carry critical information about the turbine's mechanical and electrical performance, as well as power quality.

The power output of a wind turbine fluctuates on short time scales due to the turbulent behavior of the wind. Controlling the stability of the power output of wind turbines is critical when utilizing the free, uncontrolled input that is the wind. A broad integration into energy networks necessitates a thorough understanding of the subject. A high level of integration with energy networks necessitates a thorough understanding of power generation in terms of quantity, quality, and availability. To establish such control, it is vital to comprehend and quantify the behavior of wind turbines. This is the scope of power performance techniques.

A measurement of wind velocity is required in order to test power performance. A measurement in the rotor plane/blade or close by is not meaningful, at least not without extra modifications, because a wind turbine alters the entering wind field. In most cases, the incoming upstream velocity is chosen as a sample of the wind field and measured from a meteorological mast at turbine hub height, a set distance in front of the turbine. It becomes easy to quantify the power performance of a wind turbine in simple ways based on these principles.

2. Components of wind turbine

To convert kinetic to electric energy, a wind turbine is made up of various pieces. The blades on the rotor hub convert the wind's kinetic energy into mechanical energy. Most shafts contain the rotor-hub, which is occasionally referred to as the low speed shaft [1]. a system that converts power from the generator and transmits it to the grid, frequently aids this conversion. Other parts are needed for the system to function properly, efficiently, and dependably even if they are not directly connected to the power conversion. Pitch, yaw, the tower, the foundation, the mechanical fracture, the wind velocity and course sensors, the control conveyance mechanic rope/cable the heat transmission framework, the low security framework, or the fundamental components, and nacelle walled in area are fair a number of examples. Large wind turbines also feature a backup energy system, or an uninterruptible power supply (UPS), that makes sure that vital components will always be powered, like the control system, pitch motor, and brakes continue to operate without interruption [4].

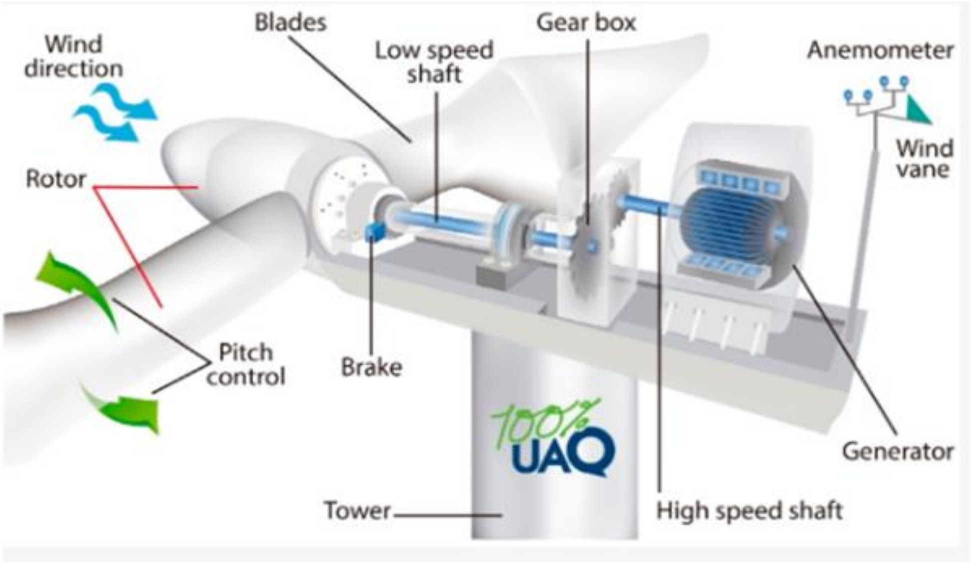

Figure 1. 1 components/parts of wind turbine

The rotor is made up of the blades and the hub. It is the rotating component that turns the wind's kinetic energy into mechanical energy. The blade, an aerodynamically constructed spinning component, converts wind kinetic energy into mechanical energy, which is subsequently moved via the shaft and converted by the generator into electrical energy. Two or three blades are found on most turbines [1, 4].

The generator, controller, low-speed and high-speed shafts, gearbox, brake and all housed within the nacelle, a cage that's situated on a tower. Additionally, the nacelle reduces noise and shields the turbine parts from outside elements. The main rotating component that distributes .The low-speed shaft transmits rotor torque to the rest of the driving system. It moreover bears the mass of the systems. In more ways; the generator is driven by the high-speed shaft, which transfers the speed and torque from the gearbox. As it raises speed to match the needs of the electric generator, the gear box is one of a wind turbine's most costly (and bulkiest) parts. Rotational mechanical energy must be converted to electrical energy via the generator. For a very long time, several types of generators have been employed in wind energy systems. [2, 4] . They incorporate the squirrel cage acceptance generator (SCIG), doubly encouraged acceptance generator (DFIG), and synchronous generator (SG) (wound rotor with permanent magnet). Anemometer and wind vane are two further components of a wind turbine that measure wind speed and direction, respectively [4].

The following is a list of the parts of a wind turbine and what they do.

Anemometers: The controller receives data from this instrument, which detects wind speed.

Blades;. The blades rotate when wind passes across them, causing the rotor to revolve. Most turbines have two or three blades.

Gear box: The primary function of the gear box is to join the low-speed shaft to the high-speed shaft, increasing the speed from 30 to 60 rotations per minute (rpm) to around 1,000 to 1,800 rpm—the speed required by generators to create electricity.

High speed shaft: .the generator is driven by

Low speed shaft:. Rotate the low-speed shaft at a speed of 30 to 60 rpm. The hub and the blades make form the rotor.

Rotor; The hub and blades make form the rotor.

Wind vane: To properly orient the turbine in relation to the wind, this device senses wind direction and interacts with the yaw drive.

Brakes:. Mechanically, electrically, or hydraulically, the brake stops the rotor.

Controllers;. Wind speeds of 8 to 16 miles per hour are used to start up the machine (mph) Pitch:

Pitch: The primary purpose of pitch is to control the wind turbine's rotor speed by turning the blades in or out of the wind and keep it inside the operational limit.

Pitch control:- is the technology used to operate and regulate the pitch angle. (For instance, a turntable or windmill).

Wind –direction;.-: is often described by the direction it comes from. A north wind, for instance, blows from the north to the south.

Tower;. – The blades and nacelle are mounted on beat of a tower. The tower is developed to hold the rotor edges off the ground and at an perfect wind speed. Towers are as a rule between 50-100 m over the surface of the ground or water.

Generator;. - is a device that transforms mechanical energy, or motive power, into electrical energy for use in an external circuit or it converts mechanical energy to electrical energy for the system/plants.

1.1.3 Configurations of Wind Energy Conversion Systems (WECS)

The horizontal axis and vertical axis are the two main turbine layouts. Due to vertical wind shear, when the particularly tall tower is home to a horizontal axis rotor, which has been proved. There are two types of wind turbines: fixed-speed and variable-speed. The rotational speed of fixed-speed wind turbines is affected by the generator pole count, grid frequency, and gear ratio. Only at a particular wind speed can the system achieve its maximum conversion efficiency, and at that wind speed, the system efficiency decreases [4, 5].The turbine is shielded from damage caused by heavy gust winds by aerodynamic control of the blades. Fixed-speed turbines produce drastically variable output power to the grid, creating power system disruptions [5]. However, across a wide range of wind speeds, variable-speed wind turbines may achieve the highest energy conversion efficiency. According to the wind speed, the turbine may continually change its illustrates.

In order to achieve optimum efficiency of power conversion at various wind speeds, It is possible to maintain the tip speed ratio at the ideal level, which is the ratio between the blade tip speed and the wind speed. The wind turbine generator is often connected to the electric grid via a control converter so that the turbine speed may be altered. The generator's speed, which is mechanically connected to the rotor (blades) of the wind turbine, may be controlled according to the converter system [6, 5].

1.1.4 Wind turbine generator Operating Regions

The power curve shows two operational modes, three wind speeds, and their respective [3-6] meanings.

1. Cut in speed; .Wind turbines can generate useable electricity at their maximum wind speed. is known as the cut-in speed.

2. rated speed;. It is the greatest wind speed at which a wind turbine can generate the rated power for which it was designed. Wind operation in "maximum power point tracking mode" between the cut-in speed and the assessed speed, and when the wind speed increases the output power will also rise.

3. cut out speed;. Most wind turbines stop producing energy and are switched off for safety concerns at very high wind speeds, which are frequently beyond their rated velocity. The cut-out speed is the wind speed at which the shut-down operation occurs. when the wind speed is high, A safety measure is to have a cut-out speed.

1.1.5 Controlling the Power of Wind Turbines

In today's energy conversation systems, control is quite vital. In fact, wind turbine control allows for more efficient advantage of the turbine's ability furthermore to the lightening of mechanical and aerodynamic forces that reduce the installation's useable portions. The most often used control methods for controlling generator speed, torque, and pitch angle are [4-6].The timing of each WT control system's operation is determined by WT control objectives.

and they must be clearly defined to avoid misunderstandings when assessing WT control systems. The operational zones of wind turbines influence the definition of control objectives. These and wind speed have a tight relationship and three operational regions can be identified based on wind speed (Burton et al., 2011).

a. Torque Control by Aerodynamics

Using this tactic, the shaft's aerodynamic torque will be affected by changing the rotor shape, which will either boost or reduce the turbine's efficiency and the input control. Ailerons are required to modify rotor geometry without the use of a blade pitch controller [1, 2]. These are autonomous wings that will move in response to changes in wind and blade shape. However, in order to establish the pitch angle that will be used, The wind speed must be known in order to operate this control system. These are autonomous wings that will move in response to changes in wind and blade. This control system, however, is only as accurate as the wind speed data since it depends on To establish the pitch angle that would optimize wind power, one must know the wind speed [3, 4].

b. Torque Control by Aerodynamics vs Torque Control for Generators

The generator torque can be changed to adjust the wind turbine's power output. The kind of generator and the grid connection define the control systems that are used. To keep the speed at or near synchronous, grid-connected generators must run with a relatively narrow speed range [5,6]. As a result, the generator torque must fluctuate frequently to compensate for the rotor torque and maintain a virtually constant speed. The generator torque control regulates the WT rotor speed so that it may run at various rates and generate the greatest power. The controller must change the generator thrust to accelerate or decelerate the turbine (Man well et al., 2010). The Wind turbine may be thought of as a stiff, inert, and inert system that is vulnerable to wind and generator torque. Since the wind torque varies with wind speed, the generator torque serves as an actuator to move the dynamic system to its best operating position. Torque control was not available on early WTs.

Power electronic converters are one approach to manage the generator. Generator torque torque may be quickly adjusted with the help of power electronics without affecting the grid's production of power. Additionally, the generator may be managed. The converter's job is to regulate the generator's torque, which in turn regulates the wind turbine's mechanical power production. This type of control will boost the turbine's ability to produce electricity under partial load. The converter's job is to regulate the generator's torque, which in turn regulates the wind turbine's mechanical power production. Utilizing this type of control will increase the turbine's capacity at partial load [4, 6].

c. Torque and rotational motion

Torque is a measurement of how much a force acts on an object to cause it to rotate. Turbine torque is a measurement of the relationship between power and turbine rotation speed. The torque will be less as the turbine's spinning speed increases. There are times when the Turbine Torque is compared to the power and rotation speed of the turbine. The torque will be less as the turbine's spinning speed increases. When the rotational speed is increased, the torque increases in some cases. The torque decreases as the turbine power decreases, especially as the rotation speed increases. When the turbine is connected to the generator, the turbine load increases, causing the rotation speed to decrease. It is critical to understand the turbine's maximum torque rotation speed so that maximum power can be obtained later when the wind turbine is connected to the generator. This is a compelling reason to examine or investigate the effects of increased turbine torque on rotational speed. The turbine rotation speed must be controlled to achieve maximum power. The turbine power will increase as the wind speed increases. The torque will increase as the turbine power increases. Furthermore, when the wind speed increases, the spinning speed increases

1.2 dynamic vs static or stochastic of wind turbine

A simulation model is a specific form of mathematical system model. A static simulation model, often known as a Monte Carlo simulation, depicts a system at a specific time point. Simulation models that alter over time are known as dynamic simulation models. Deterministic simulation models are those that have no random variables. Deterministic models have predefined inputs that result in a certain set of outcomes. One or more random variables are used as inputs in a stochastic simulation model. The randomness of the inputs leads to the randomness of the outcomes. Because outputs are unpredictable, they can only be used as estimations of a model's true properties. A stochastic simulation's output measurements must be considered statistical estimates of the system's actual attributes. The state variable(s) in a continuous model change continuously over time.

1.3 Problem statement of the wind turbine

The most challenging task in controlling a wind turbine is creating an accurate model due to the nonlinearity of the device, external disturbances, and unknown characteristics. Given that the energy in the wind is primarily determined by the variation in wind speed, Future wind speed and power generation are predicted based on the change of the energy. Consequently, the primary goal is to Design, analyze and improve performance of pitch angle speed controlling FLC and fuzzy based adaptive control and the best selected for controlling and The nonlinearity of the system taken into consideration in the wind energy conversion system allows for the construction of a controller that performs the variability and uncertain variables.

1.4 objectives

1.4.1 General objective

The main objective of the thesis is to Modeling and control of the pitch angle of wind turbine using fuzzy logic based adaptive controller

1.4.2 specific objectives

- ✓ To create a mathematical model that captures the dynamic reaction capability of a wind turbine.
- ✓ To design FLC and fuzzy logic based adaptive controller (FLBAC)
- ✓ To analyze and enhance the performance of the construct controller/ FLC and FLBAC using mat lab/Simulink.

1.5 Significance of the thesis

- ✓ To maximize the extracted energy from wind
- ✓ To assist in improving system performance and reliability in the face of unpredictable weather (nature)

- ✓ To optimize at lower wind speeds and to stabilize output power at greater wind speeds..
- ✓ To model information to adjusting parameter and change the process that occur with time and other parameter
- ✓ To enhance the performance of the wind turbine pitch -angle controller and analyze these controllers to identify the best controller.

1. 6 Research Scope and study limitations

The study to cover the analysis, improve the performance the pitch angle control utilizing FLC and a fuzzy-based adaptive controller, as well as dynamic modeling of the system. Simulation will be done using MATLAB/Simulink® when wind speed varies and to select better controller. Parameter can be carried out either with or without knowledge of the actual mathematical model of the plant.

1.7 Methodology

The effectiveness of the wind speed generator affects system dynamics, energy conversion analysis, and output predictions; hence wind speed modeling is crucial. The position, height above the ground, roughness of the terrain, and adjacent impediments all contribute to the geostrophic and local winds that are present at the site. It has a unique Van der Hoven spectrum, or distribution of kinetic energy, in the frequency range. The forces created on a wind by airflow are described by turbine aerodynamics. The actuator -disc hypothesis and the blade component hypothesis are the two fundamental strategies utilized to function wind turbine aerodynamic models. The extraction procedure is simply explained in the first. Theoretical top-bound energy conversion vital is also provided. An actuator disc (turbine rotor) is thought of as the turbine. A general term for a machine that captures energy from the wind. Take into account that the airflow around the actuator disc is incompressible and may be thought of as such. Upstream wind speed must be higher than downstream wind speed .The downstream cross-sectional area is less than the upstream cross-sectional area for the steam tube that is only enclosing the actuator disc as a result of the smaller actuator disc area. The rate of change of energy determines how much power is generated by the wind. To assess how the FLBAC-designed controller performs in comparison to other controllers

1.8 thesis organization

This thesis organized as follows

Chapter 1: present background of the study, statement the problems, goal of the study, scope and limitation of the thesis research

Chapter 2: describes in full the basic concepts of the generator, fuzzy logic controller, and literature review. And fuzzy logic based on adaptive controller and field oriented control of squirrel cage induction generator and other need wind turbine controller experienced done with the pitch angle controller.

Chapter 3: describes the model, materials, and methods used in this thesis's study.

Chapter 4: Controller designs and mathematical model pitch angle controllers.

Chapter 5: Design, Simulation of the Results and discussion plant with controller.

Chapter 6: Conclusions and recommendation whole of the thesis work

CHAPTER 2

2. LITRATURE REVIEW

A detailed historical analysis of the wind device that powers a machine alternator, Pitch angle control, wind characteristics, and previous efforts linked to this on method shaping and manage planning are provided in this introduction. In order to improve the output of energy from indestructible sources, internal-combustion engine control schemes that explicitly compute the disputable characteristics of wind are considered. To solve these concerns on the adulthood of new controlling system [2, 7].

2.1 wind turbine generator

The invention of abundant types of Plans for wind turbines that employ several types of electric generators has developed from the progress of renewable resource adaptation technologies [1, 4]. Fixed-speed and variable-speed wind turbine generators are two together types of Squirrel-cage agreement generators are promoted in fixed-speed wind turbine generators. Both synchronous generators and doubly-fed induction generators (DFIG) with asynchronous generators are used in wind turbine generators with variable speeds [4, 8]. Wind generators are classified into two classes based on their construction and operating principles: induction generators (IGs) and synchronous generators (SGs). Wound rotors are used in both induction and synchronous generators, and they are fed by brushes or slip rings [2]. And manage without and therefore not brought out for association along outside circuits, squirrel-cage induction generators (SCIGs) are additionally daily utilized.

The generator speed was tied to the grid frequency, and the generator torque was fixed, because WTs used Squirrel Cage Induction Generators (SCIG) that was directly connected to the grid. Because of advancements in solid-state devices, variable speed operation became possible. PCs (electronic power converters) are now appropriate for usage in wind turbine. The electronic power convers are devices that decouple the generator speed from the grid frequency, allowing the generator to communicate with the grid. Electronic power converters regulate generator torque and active/passive power through electronic switching of stator and rotor voltages to achieve the desired voltage frequencies. In constant magnet synchronous generators, permanent magnets produce the rotor magnetic flux (PMSGs) that have recently happened used to generator.

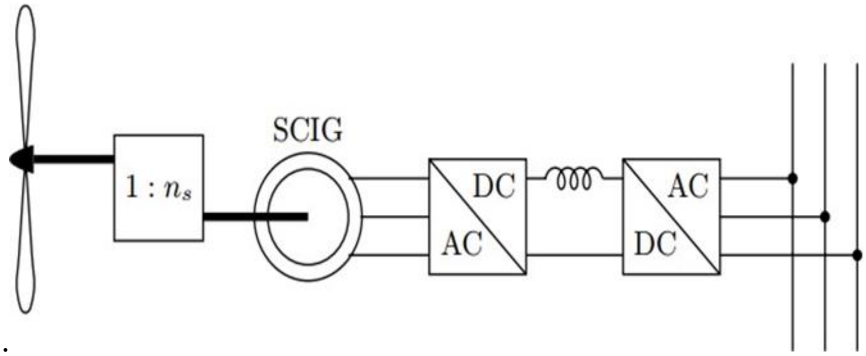

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Figure 2.1 SCIG-based fixed-speed wind turbine system

2.1.2 Doubly Fed Induction Generator

Today's manufacturing, the lion's share of increased-fed induction generators is utilized to create electrical control in great (capacity-serviceableness scale) wind turbines. When a blast of wind blows, the revolution at the wind engine rotor enlargements drastically when in fact, the rotor speed debris mainly constant. As a result, each gust of wind stresses the wind generator's machinelike elements (specifically the gear box), creating a fast rise in rotor torque in addition to capacity at the generator output [4, 7]. Variable pace the stator windings of DFIG and established-speed generators may both be connected to the grid straightforwardly, that is one of their joint characters While the

Alternator's rotor absorbs gridiron excitation current; a DFIG's stator may productivity power directly to the grid. The capacity converter has the competency to transport strength bi-directly, that means it can both transmit and receive power

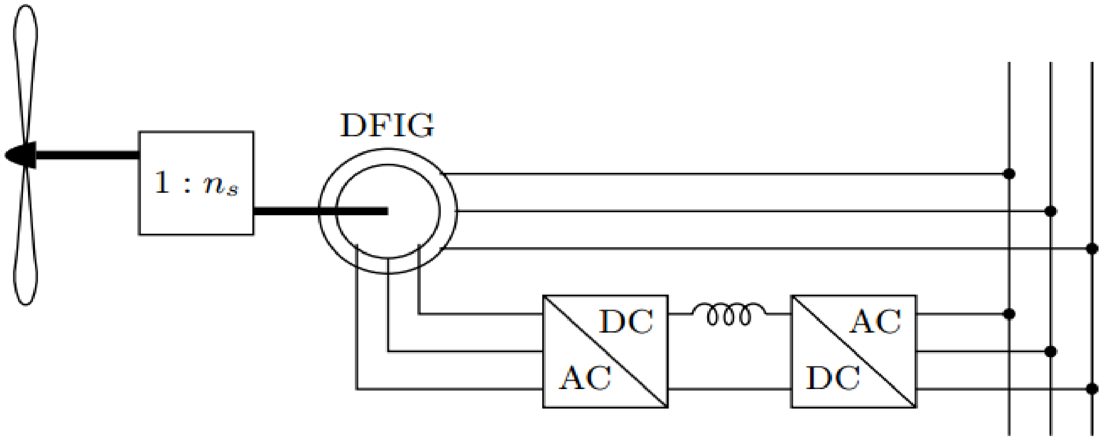


figure 2 .2. figure of variable speed dfig wind energy system

2.1.3 Generators with Permanent Magnets (PMSG)

In variable-speed wind energy conversion systems, synchronous generators have been frequently used (WECS). Synchronous generators, which range in power from a few kilowatts to a few megawatts, offer a lot of flexibility in meeting varied technological necessities in actual wind energy systems [4, 9]. The Doubly-Fed Induction Generator (DFIG) and the Permanent Magnet Synchronous Generator (PMSG) are the most common generators utilized in variable-speed operation (PMSG). WT torque is controlled by a two-layer controller in a cascaded composition (Rajendran and Jena, 2014). In the extrinsic control loop, an MPPT approach decides the necklace set-point. The central control loop, as known or named at another time or place the electrical control loop, that is completed activity by PCs, accepts the force set characteristic from the exterior control loop. The electrical control loop is thought of as an actuator with no substantial control issues since the mechanical dynamics of the WT are much slower than the electrical dynamics of the generator.

The simultaneous alternator maybe built accompanying a extreme alike to the knife speed of the turbine. A conveyance isn't necessary accompanying specific a direct-drive method. It has an advantage over induction generator (IG)-located turbines, that demand the utilize of a conveyance, on account of the lower establishment and maintenance costs [4, 8]. Prepare drive ideas by way of the advantages of a more natural driveline and bigger strength produce [9, 10]. When a low-speed generator is used in direct-drive systems to match the turbine speed, the gearbox can be taken out. When a low-speed generator is used in direct-drive systems to match the turbine speed, the gearbox can be taken out and heavier than one with fewer poles [4, 10].

2.1 .4 full rated converged generator

These are quite adaptable when it comes to the sort of generator they may be fitted with they can be either synchronous or induction (SCIG). A wound-rotor synchronous generator (WRSG) or a permanent-magnet synchronous generator (PMSG) can be used as the synchronous generator [1, 11]. Without employing a gearbox, the generator's rotor is linked to the turbine's rotor directly, and full-scale AC-DC-AC power converters are used to connect the generator to the grid. Over the whole speed range, the full-scale power converter is capable of performing a seamless grid connection [4, 12].The PCS implemented in this design serve two purposes: they allow the system to regulate active and reactive power and serve as a buffer (DC-link) for energy variations brought on the turbine as well as transient from grid side [5, 12]. Its grid side attempts to balance reactive power consumption while its rotor side assures a wide range of rotational speed adjustments. While its rotor side assures a wide range of rotational speed adjustments.

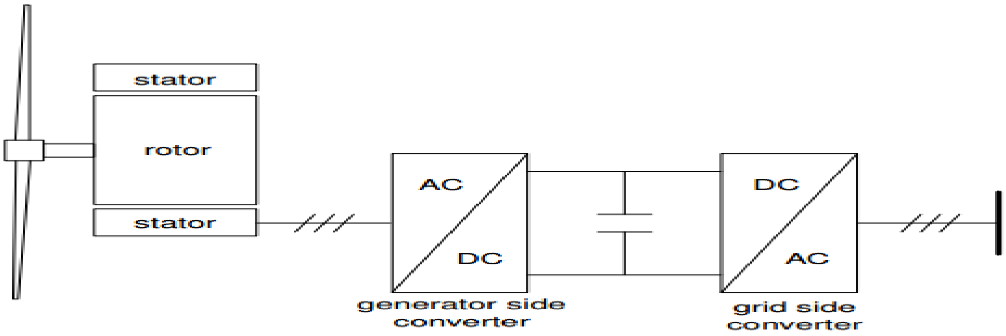


figure 2.3 .Full converter wind generator

The PMSG is preferred as the wind turbine generator in this place belief for the following reasons [4, 13]:

I. The PMSG is capable of complete speed regulation.

II. Because the PMSG eliminates the need for a gearbox, when gusty winds happen, there is no mechanical tension.

III. The PMSG will require less maintenance because it doesn't need brushes or slip-rings. In this manner, a wind turbine based on PMSG will be steadier than one based on DFIG.

IV. The PMSG in addition control both active and reactive power

V. The manage techniques are basic and straightforward to produced.

VI. Full-scale power converters are part of a wind turbine-generator and motor system based on PMSG.

VII. Power producing, implying that the power converters will produce excessive sinusoidal components and cause losses. At high temperatures, permanent magnets are at risk of demagnetization.

2.2. Techniques for a Wind Turbine System of control

In addition to hardware selection, wind turbine control methodology also affects performance. In conditions of weak and moderate wind, the wind turbine's performance can be improved by maximizing rotor power [15]. Pitch control preserves the optimum operating condition for high winds that are over the nominal level, and The pitch controller decreases the attack angle when the wind speed exceeds the nominal amount, progressively pitching the blades (turning them into the wind) [4, 7]. Reduced pressure gradients exist between the blade's front and back. Due to its quicker reaction time, pitch control is more controlled than active stall control [16].

The author [3] suggested using a self-correcting fuzzy logic controller. The probability nature/dynamics of wind theory is still not fully understood, maintains a fundamental activity that entirely enables the unavoidable state mistake and boosts the control plot's effectiveness in regards to display instabilities and unpleasant influence release. The suggested turn estimator will allow preserving a determined distance from the guess and allure subtract even if the be computed in order to need system standard. The author attempts to assert modeling for transient wind speed by further developing fluffy self-adjusting PID [15]. It immediately translates the use of fluffy in combination with PID's poorly thought-out compliance mechanism. The white noise wind speed is still recorded in the report, but it is seen as changing continuously..

PI/PD, Fuzzy Adaptive PID controller maybe achieves control acts as a unoriginal manage action was projected by reference [16]. But this controller controller's manually control most of time because of convectional type and not feedback for the parameter estimation and individual not nonlinear parameter considered. The issue with this study is that the gain and parameter are not constant. The nonlinear PI/PD controller is made up of a conventional PI/PD controller plus a nonlinear gain [17]. The parameters in fuzzy logic control are fixed. Therefore, it cannot be used in situations where the operating circumstances vary much. Therefore:. To mitigation he alternate is this gap fuzzy based adaptive. These techniques make no mention of the limitations and characteristics of wind speed models. For one columnist, the Proposed fuzzy feeling manager assume the control of schemes with constraints that are difficult to mathematically represent, perplexing, or cryptic was produced in [18]. However, the paper showing of the generator at this location is not specified, therefore the fuzzy philosophy is more restricted in its use. With its well-known uncertainty and nonlinear approach, a wind turbine may be photographed as a complete. Fuzzy controls, however, are used to both enhance the conquered.

2.2.1 over view of FLBAC and Fuzzy Logic Controller

Fuzzy control belief is a type of mechanical control belief that uses fluffy set belief, a form of fuzzy vocabulary information likeness and interpretation, and fluffy sense rules to imitate human thinking and interpretation. Enrollment a suggestion of correction fresh profit. It has proved expected an active choice for an assortment of control requests because it approximately parallels human control rationale. It is containing a fuzzifier, an inference tool, and a confirmed. [3,5]. The fuzzier transforms the input parameter's crisp value into a fuzzy set, which is then, with the aid of control method specialists, framed as a collection of IF-THEN rules based on fuzzy rules built on membership functions for a certain system parameter [19].Nonlinear and adaptive approaches for wind turbine systems have been shown in recent studies to produce dependable results and high system performance. The process of construction a boss with programmable limits and an within means for altering ruling class is famous as adjusting control. From different adjusting control and fuzzy logic control others approach in this place belief model remark adaptive control is picked. An adjusting order is referred to as the model-located process of equating the act of the actual plan to a assumptive numerical [20]. A branch of adjusting control belief known as fluffy philosophy-located adaptive control allows the adjusting controller to increase the scope of its request and its capacity to correctly change a order's backgrounds. [19 21].

2. 3. Wind experience by the turbine

Winds are largely temperature-driven motions of air masses in the atmosphere. Uneven solar heating causes temperature gradients. The wind is supposed to be extremely complex in wind speed modeling, and it is divided into two categories: deterministic and stochastic. In the rotor area, the wind speed model involves disturbance and tower darkness. Practical disturbances have the feature of being absurd to anticipate their future principles right. Because the principles of an examining function are famous in an without delay brief ending, the principles of the function for supplementary inputs maybe got by logical maintenance; it is not likely to illustrate disturbances utilizing an examining function. Because logical, we can try to represent disturbances using a statistical principle, which is known as stochastic Nonlinear and complicated functions are un reliable structures modeling [20, 21].

A particular type of mathematical system model is a simulation model. Models for static and dynamic systems can be classified as discrete or continuous, deterministic or stochastic. a still Systems develop throughout time, as shown by dynamic simulation models. Models for deterministic simulation are ones without random variables. Deterministic models generate a distinct set of outcomes from a known set of inputs. One or more random variables are used as inputs in a stochastic simulation of design. So, the Wind turbine pitch angle controller analyze best controller gaps to address fuzzy logic based adaptive approach is extremely significant from those over seen controllers experience by dynamic modeling and Simulink.

2.4 Summary

From the literature review, it has been noted that many methods used to enhance the effectiveness of wind turbine pitch angle control systems, to obtain more energy from the wind, advanced relay-based controls like fuzzy control, PI/PD control, fuzzy pid control, and others require a wind energy conversion system. But the wind turbine pitch angle control system makes it difficult to fulfill the control requirement due to inherent limitations in the techniques of automatic controls, stability checked and parameter estimation. The advanced or better controls to be selected (MIT rule stability ,Lyapunov rule stability, automatic control depend on stability of fuzzy logic controllers, and fuzzy logic-based adaptive controllers) rely on experts, regular updates, and other issues and are compared to fuzzy logic-based adaptive controllers with fuzzy logic controllers due to automatic control, parameter estimation, error reduction, and stability analysis.

2.5 Research gap

From 2.2 explained control strategies wind turbine pitch angle controllers of wind energy conversion system may reduce and leads to complex operation. The wind turbine pitch angle controller performance problem that happens due to inherent limitation in techniques and quality are huge impacts on any applications that operation wind energy conversion for the achievement goals. The researcher has done many researches on this idea in different control mechanism. The research gaps at discussed at the end of each researcher's ideas, generally researchers as a whole to solve the wind turbine pitch angle control some of them uses for specific tasks and controller methods the performance is not better that is why I designed wind turbine pitch angle control and I designed controller is best performance improvement, stability and parameter as standard control (fuzzy logic based adaptive control) well fulfilled from these done pitch angle controller.

CHAPTER 3

3. MATERIALS AND METHODOLOGY

3.1 Wind speed modeling

Modeling and advantage change of the wind speed generator impact energy output forecast. The height over the ground, the roughness of the terrain, and the nearby obstructions all contribute to the geostrophic and local winds that are present close to the location. It has a unique frequency-domain kinetic energy distribution called as the Vander Hoven spectrum. [1, 2]. There are two primary elements in the Van der Hoven spectrum the forecasting of the strength gain, study of the energy change and structure action. The wind forthcoming the home association involves of terrestrial field altitude over the ground, the coarseness of the landscape, and the abutting obstacles. It has a singular commonness-rule moving power classification named as the Vander Hoven spectrum. [1, 21]. There are two basic materials in the Van der Hoven range. 1, 21]. The high frequency side of the spectrum indicates the turbulence related to local winds, whereas geostrophic winds are associated with the low frequency portion of the spectrum. Let us consider φi, ωi $i= 1, 2...N$. The discrete angular frequency and the corresponding values of the power spectral density .The harmonic at frequency has amplitude A_i

$$A_i = 2/\pi\sqrt{1/2}[w(\varphi i) + w(\varphi i+1)(\varphi+1-\varphi i)] \ldots\ldots\ldots\ldots\ldots\ldots \; 3.1$$

$$V(x) = \tilde{v} + \sum_{i=0}^{N}(A_i \cos(\omega i + \varphi i) \ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where v` is the mean wind speed, calculated on a time horizon greater than the largest period in Van der Hoven's characteristic (i.e., $T=2\pi/\omega i$). The average value of wind speed is obtained from annual and seasonal variations while year to year variation in annual mean wind speed remains hard to predict, wind speed variations during the year be characterized in terms of a probability distribution. The Weibull distribution has been found to give a variation in hourly mean wind speed over a year at many typical sites [1, 20].

Γ where the gamma function is found in its entirety. The formula for the average wind speed is

$$\mathbf{X} = \int_0^\infty xf(x)\,dx \text{...} 3.3$$

Since the Rayleigh distribution is a rare example of the Weibull distribution

The von Karman expression provides the power spectrum model for the second component, which is the turbulent component with a high frequency component and turbulent speed [1, 2].

3.2 Aerodynamic modeling of wind turbines

The forces created on a wind by airflow are described by turbine aerodynamics. Theory of an actuator disc and blade component theory are the two primary procedures for driving aerodynamic models for wind turbines [1, 9]. The former gives a straightforward explanation of the extraction procedure and offers a theoretical upper bound on the efficiency of energy change. The latter analyses the force that an element of a blade experiences from the air flow.

3.2.1 The Atuator disc model

The momentum theory underpins this concept. The mechanism used to harvest wind energy is known as an actuator disc (turbine rotor), which is a general category for the turbine.. Consider the case where the actuator disc is immersed in an incompressible airflow. Because the actuator disc removes a portion of the wind's kinetic energy, the upstream wind speed must be larger than the speed of the downstream wind. Therefore, for the steam tube that is immediately within the actuator disc, the upstream cross-sectional region is littler than the actuator disc range, which in turn is littler than the downstream cross-sectional range [1, 22]. The power produced in the wind is given by the rate of change of energy:

$$E = \frac{1}{2}mv^2 \text{…………………………………………………..} 3.4$$

$$P = \frac{dE}{dt} = \frac{1}{2}v^2\frac{dm}{dt} + mv\frac{dv}{dt} \text{ ……..…………………………………..} 3.5$$

As flow rate given by

$\frac{dm}{dt} = \rho Av$………………………………………………….3.8

where E is the wind's kinetic energy. To maintain speed Vdv/dt=o

As a result, the power may be defined using its mass flow rate and speed V as follows:

$P=dE/dt= \frac{1}{2} v2\ dm/dt\ = \rho A\ v3$ ……………………………….3.6

If D is the blade's diameter, then

$P = \frac{1}{2}\rho\pi\frac{D^2}{4} V^3$ ………………………………………………….3.7

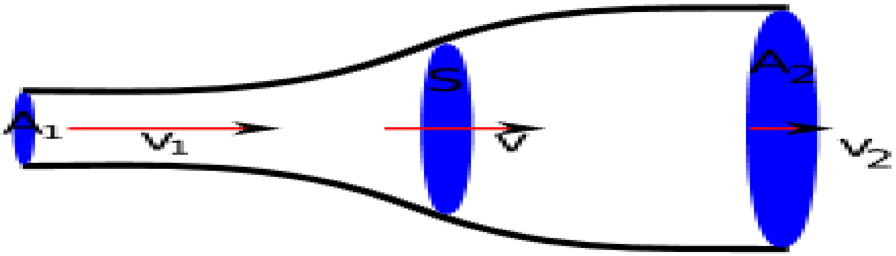


Figure 3.1 air flows through the actuator disc

The equation for the conversion of mass or the continuity may be expressed if the air stream is thought of as an example of an un common flow as: $S=A_2-A_1$

$\frac{dm}{dt} = \rho A_1V_1 = \rho\ A\ V = \rho\ A_2V_2$……………………….3.8

Where S is the area of the turbine, a, and anA1 is the cross-sectional area of the wind approaching it and A2 is the cross-sectional area of the air stream following the turbine, is the air density ρ (kg/m3).Upstream wind speed is denoted by V1, turbine blade air velocity by V, and downstream air velocity by V2 after the turbine has been passed.. According to Euler's Theorem, the wind exerts the following force on the turbine rotor (actuator disc):

$F=\frac{dm}{dt}\Delta V = \rho AV\ (V_1 - V_2)$……………………………….3.9

The wind stream's ability to shift its energy or do work is determined by

$dE = Fdx$………………………………………………….3.10

$$P = \frac{dE}{dt} = F\frac{dx}{dt} = FV \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.11$$

Substitute equation 12 and 14 The wind's usable electricity is provided by:

$$P = \rho A V^2 (V1 - V2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.12$$

Applying the law of conservation of energy results in the following power as the rate of change in kinetic energy from upstream to downstream:

$$P = \frac{\Delta E}{\Delta t} = \frac{\frac{1}{2}mV1^2 - \frac{1}{2}mV2^2}{\Delta t} = \rho AV (V1^2 - V2^2) \ldots\ldots\ldots\ldots\ldots 3.13$$

$$V = \frac{1}{2} V1 + V2, \quad V1 \neq V2$$

According to this, it is possible to compute the wind speed at the rotor by adding the wind speeds in the ups and downs directions. The power produced by the powered turbine

$$P = \frac{\frac{1}{2}dm}{dt} (V1^2 - V2^2) = \frac{1}{2}\rho AV (V1^2 - V2^2) \ldots\ldots\ldots 3.14$$

Substitute equation 12 and 13 expressed as

$$b = \frac{v1}{v2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.15$$

$$P = \frac{1}{4}\rho A V^3 (1 + b1^2 + b + b3^3) \ldots\ldots\ldots\ldots\ldots\ldots 3.16$$

Equation (3.16 demonstrates that the control produced by the turbine is proportional to the upstream wind speed cube and depends on the ratio of the upstream and downstream air velocities, b. The wind speed, V1, is constant in the absence of the turbine (at the highest amount of energy collected). As a result, the cross-sectional areas A1, A2, and S are identical and the term dV1/dt drops to zero. The whole power can be written as;

$$P\ total = \frac{1}{2}\rho A V1^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.16$$

Equation (3.14) roughly corresponds to the outcomes observed for the extractable turbine. The power extracted at the turbine is expressed equation (3.16) and overall amount of wind energy is expressed by (3.17).

Therefore efficiency of the ideal wind turbine

$$\eta = \frac{P}{Ptot} = \frac{1}{4}\rho AV^3(1 - b1^2 + b - b3^3)\,/\frac{1}{4}\rho AV1^3 \text{........................3.17}$$

$$= 1 - b_1^2 + b - b_3^3 \text{ ....3.18}$$

Calculus will be used to determine the maximum points at which the turbine's maximum efficiency occurs by taking the derivative of equation (3.18) with respect to b, setting it equal to zero, and solving for b.

$$\frac{d\eta}{db} = \frac{1}{2}(-2b + 1 + 3b^3) \text{ ....3.19}$$

The solution of (19) given as follows:

b = -1 and b = 1/3...3.20

The later solution is more significant and practical because it demonstrates that to get the most power out of the turbine of the first option doesn't appear to hold up practically. One can insert equation to find the most efficient factor (b = V2/V1= 1/3) into (18)

$$\eta = \frac{1}{2}(1 - \frac{1}{9} + \frac{1}{3} - \frac{1}{27})$$

$$\eta = \frac{16}{27} = 0.593 = 59.3\% \text{ ....3.21}$$

In 1919, German engineer Albert Betz wrote equation (3.21) and the Betz limit for the first time. Additionally known as the highest or ideal value of the performance coefficient (Cp). The tip speed ratio and blade pitch angle both affect the turbine's power coefficient (Pc). The power coefficient, which is determined by the blade pitch angle and tip speed ratio, is used to define the power output from realistic wind turbines

$$.\mathbf{P}m = \frac{1}{2}\rho SV^3 Cp(\lambda, \beta) \text{..3.22}$$

Pa is Mechanical power extracted from wind.

Betz' Law (maximum 59.3 percent) governs the conversion of mechanical energy into electrical energy in wind turbines. The power factor of the turbine

$Cp = P_m/P$……………………………………………………………….3.23

Where, P is the power of the wind, and Pm is the mechanical power of the rotor blades.

3.2.2. Wind turbine curve characteristics and dynamic mathematical modeling

The output power of turbine is given by the following

$\mathbf{P}m = \frac{1}{2} \rho\ AVw^3 Cp\ (\lambda, \beta)$ …………………………………………………….3.24

Where Pm is the mechanical output power of the turbine (W), is the air density (kg/m3), A is the turbine's swept area (m2), Vw is the wind speed (m/s), and λ= is the rotor blade's tip speed in relation to the windβ = is blade pitch angle (deg),

$Cp\ (\lambda, \beta) = C1(C_2/\lambda i\ \ -\ \ C3\ \beta\text{-}C4\beta^{x})\ \exp C_6/\ /\lambda i$

Where c_{P1}= 0.50, c_{P2} = 116.0, c_{P3} = 0.40, c_{P4} = 0.0, c_{P5} = 5.0, cC_{P6} = 21.0[2 10]. Or for dynamic model

$\frac{\mathbf{1}}{\boldsymbol{\lambda}\mathbf{i}} = \frac{\mathbf{1}}{\boldsymbol{\lambda}+\mathbf{0.08}\boldsymbol{\beta}} - \frac{0.035}{1+\beta^3}$……………………………………………..3.25

The λ (tip speed ratio)is presented as a ratio of the blade tip speed to the effective wind speed.

$\lambda\ \ = \frac{\omega R}{V}$…………………………………………………………3.26

Where R is the radius of turbine rotor (m) and ωr is rotor speed (rad/s).

The graph clearly shows that the Cp, relationship changes depending on the pitch angle, hence the mechanical power may be stated as follows: In light of this, the power of mechanical Pm may be written as**:**

$P_m = 1/2\rho\pi R^2 V^3 Cp(\lambda, \beta)$

$Tm = \frac{Pm}{\omega} = 0.5\rho\pi\omega^2 rCp(\lambda, \beta)\ \frac{R5}{\lambda 3}$ ……………………………3.26

The angle at which Blade pitch [3.21] refers to how far a wind turbine rotor's blades are rotated toward or away from the wind to regulate power production or absorption. Nowadays, large horizontal-axis wind turbines almost always have blade pitch control. Pitch angle management is therefore essential for optimum wind turbine performance.

The MPPT control technique, which is stated as in [21, 23], determines the power reference of a wind turbine.

$Popt = kopt\ \omega^3 r$……………………………………………........................3.27

$Kopt = 1/2\ \rho\ \pi Cp opt\ \frac{R5}{\lambda 3}$……………………………………………….3.28

The ideal tip speed ratios opt, or a zero pitch angle, corresponds to the highest power coefficient Cp (opt). Cp(opt) and's ideal value are extracted from $c_p(\beta,\lambda)$ curve .

P_{ref} is selected as rated power of wind turbine (24 25)

Based on various pitch angle values β = 0°,5°,10°,15°,20°. The values of the coefficient are as follows c_{p1} =0.5,c_{p2} = 116,c_{p3} = 0 ,c_{p4} =0, c_{p5} =5, c_{p6} =21(2 26)

3. 3. Actuator model for pitch

Rated wind velocity is achieved, a pitch actuator is used to move the blades along their longitudinal hub, making it one of the most widely and often used control systems to regulate both the output and speed of a wind turbine [27, 28]. Either hydraulics or electricity can be used to control the pitch actuator system. Each blade of an electric actuator may be changed on an individual basis of pitch angle of wind turbine. A pitch controller's demands exhibit dynamic behavior, as the actuator model describes. ($demand, \beta d$) and measurements of pitch angle β. Pitch angle variation is determined by

$$\frac{d\beta}{dt} = \frac{(\beta d-\beta)}{\tau\beta}\text{……………………}3.29$$

When Laplace transforms are used, we obtain;$\boldsymbol{\tau}\beta S\beta = \beta d$…………………3.30

$$\frac{\beta}{\beta\mathrm{d}} = \frac{1}{\tau\beta s+1}\text{…………………}3.31$$

From the initial Wind Turbine characteristics shown in Table 1, it is possible to derive the value of the pitch actuator's time constant, T p.

Power rating for generators, Pg	1Mw
Generator speed, Wg, when rated	1500 rpm
Rated turning speed of rotor, Wt	20 rpm
Wind turbine blade radius, R	50
Reference pitch angle, βd	0 to 90 deg
Rate of the pitch angle , $d\beta/dt$	0.6 deg/sec
Control accuracy of pitch angle, (β_d-β)	0.30 degre
Damping coefficient, B	2 N.m/rad/sec
Drive train inertia ,Jt	0.75 N.m^2

Table 3. 1: Parameters of Wind Turbine

The dynamics of actuator are described by following differential and for the dynamic transfer function

$$\tau\ \beta = 1 + \frac{\beta\mathrm{d} - \beta}{d\beta/dt} = \frac{0.30}{0.60} = 0.50$$

$$\beta / \beta_{\mathrm{d}} = \frac{1}{0.5s+1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.37$$

3.3. 1 Drive actuator model

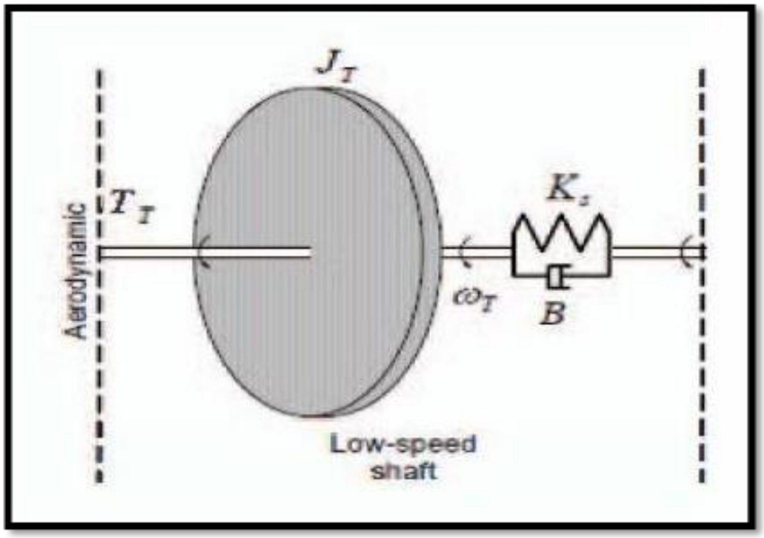


Figure 3.4 shows the drive train model.

In Table 2, the parameters used to model the drive train are listed.

Parameters	Description	Parameters	Description
J_T	Wind turbine inertia (kg.m^2)	W_T	Wind turbine shaft speed(rad/s)
G_T	Generator inertia, (kg. m^2)	Wg	Generator shaft speed ,(rad/sec)
Ks	Stuffiness coefficient N.m/rad	θ_T	Wind turbine pitch angle ,(rad)
B	damper coefficient, (N.m/rad/sec)	θ_g	Generator shaft angle,(rad)
T_T	Wind turbine torque(Nm)	1: n_{gear}	Gear ratio
T_G	Generator electro machine torque,(N.m)	β	Pitch angle
Pm	Mechanical power		
. λ	The tip speed ratio		
P	the power of the wind		

Table 3. 2: Drive Train Mechanical Model Parameters

The following differential equations explain the dynamics of the drive-train.:

$$JT.\frac{d}{dt}(WT) = TT- (Ks\ \delta\theta_{T+}\ B\delta W)$$

$$\frac{d}{dt}(\delta\theta) = \delta W$$

Newton's second rule of motion is then applied, and we obtain

$$JdW/dt = T- BW$$

Laplace transform is used on both sides.

$$JWs = T- BW$$

$$JWs + BW = T$$

$$W / (Js+B) = T$$

$$W/T = \frac{1}{Js+B}$$

This is often the drivetrain's essential to begin with arrange exchange function. Furthermore, this may be expressed

$$W/T = (1/B)/ (J/B).s+1$$

$W/T= (0.5)/ ((0.75/2).s+1) = 0.5/(0.375s+1)$ ……………….3.31

As a result, the transfer function version of this mathematical model of a wind turbine is used.

3.4. General Pitch-angle-controlling wind turbine of model

A hydraulic or electrically operated pitch actuator system is available. Pitch demands (d) from the pitch controller and pitch angle measurement were expressed by the actuator model. and the drive train offers considerable oscillations to active power output, because The inertia of the gearbox and shaft is much lower than that of the rotor generator. Since the plant uses the design MIT rule and Lyapunov, both the wind turbine actuator and the drive train model of reference adaptive control or MIT rule and Lyapunov for adaptive control of the wind plant transfer function.

Generally, the products are transfer function form implemented equation 3.37 and 3.38 as followed

$T(s) = \beta / \beta_{d*}\ W/T$

$= 1/0.5s+1 *0.5/(0.375s+1)$

$T(s) \quad =0.5/0.1875s^2+o.875s +1$

$T(s) = 2.667/s^2+4.667s +5.333$…………………………..3.32

CHAPTER 4

4. CONTROLLER DESIGN

In order to provide reliable, quick reaction and high performance in the wind energy conversation system, the controller is created. The dynamics of another plant or process are governed or controlled by a control system. It is one of the most critical processes in wind production systems, as it to avoid power overloads, should be restricted and reduce aerodynamic and mechanical loads on the turbine, hence extending the system's usable life. Two controllers are often utilized for variable-speed wind turbines. When the wind speed is less than the estimated value, the speed controller may continually adjust the rotor speed to maintain the tip speed ratio at the value that produces the maximum power coefficient and the turbine's efficiency. When the rotational speed is kept constant in conditions exceeding the rated wind speed, pitch angle management is required, which can have a significant impact on the power output. Pitch angle is managed when the wind speed exceeds the evaluated speed by monitoring maximum power below the advised speed while maintaining rated speed values. The term "control design," sometimes known as "controller design," describes methods for regulating a system's modes using any controllable device, like as a generating unit or a FACTS device. To create linear control techniques, a thorough modal study of a power system's modes is necessary. Participation factor analysis and residue analysis are both parts of modal analysis. The participation factor displays the degree to which various system states participate in a particular mode.

Controllers are essential for the following purposes:

- ✓ By reducing steady state error, controllers improve steady-state accuracy.
- ✓ The stability increases as the steady-state accuracy does.
- ✓ Additionally, controllers aid in reducing the system's undesirable offsets.
- ✓ Controllers have control over the system's excessive overrun.
- ✓ Controllers can help reduce the amount of unwanted signals the system produces.
- ✓ Controllers can help a maximum damped system's minimal reaction time to accelerate.

4.1 Adaptive controller

"To adapt" implies to adjust one's conduct to fit new conditions in any language. Adaptive control, on the surface, is a controller that can vary its behavior in response to changes in the process dynamics and the nature of the disturbance. A controller with configurable parameters and a mechanism for modifying the settings is known as an adaptive controller. Two loops can be considered of in an adaptive control system. One loop is a standard process and controller feedback loop.

The parameter adjustment loop is the other loop. "To adapt" implies to adjust one's conduct to fit new conditions in any language. Alternatively, the control technique known as adaptive control is frequently used to create complex control systems with higher performance and accuracy. A Reference Model a direct adaptive approach with specific programmable controller setting and an adjusting -mechanism is adaptive control, sometimes referred to as MRAC. When it comes to coping with unforeseen parameter fluctuations and environmental changes, adaptive controllers excel. An adaptive controller is composed of an inner and an outer loop, often known as parameter adjustment and regular feedback loops, respectively. The goal of this study is to construct an adaptive controller for a second order system utilizing the MRAC scheme and the Lyapunov rule and the MIT rule.

In this proposed reference adaptive control is chosen from among various adaptive control approaches. The model reference adaptive system measures how well the real system performs in relation to develop a control input that lowers the comparison error to zero after creating a model that represents the actual system. [19, 27].

4.1.1 Model reference adaptive control

Building a linear controller or nonlinear to linearization (in a deterministic situation) starts with the assumption that the desired performances and the plant dynamic model are understood. The features of a dynamic system that "realizes" the desired behavior of the closed-loop system may often be used to describe the desired feedback control system performance. An example of a tracking target would be the required input-output behavior of an exchange work. By identifying the specified shaft area of the closed loop, a regulatory target may be described in way of the creation of the output beginning from an starting disturbed value (i.e, by a given transfer function). The closed-loop control system for a certain plant model is developed so that it has the properties of the required dynamic system.

The controller is now configured so that

(1) Under identical conditions, the error between the output of the plant and that of the reference model is exactly zero, and (2) An initial error disappears after a certain period of time. When plant parameters are unknown or change over time, an adaptive control technique must be explored to attain the desired results. (3)The reference model is a representation of a system that achieves the intended results. This method is based on the discovery that a measure of the discrepancy between actual and anticipated performance is the output difference between the plant and the reference model (hence forth referred to as plant-model error). The adaptation mechanism uses this information (together with additional information) to automatically change the controller's settings in an effort to push the plant-model error to zero asymptotically.

1. Working principles

A Reference Model The adaptive controller is created using an adaptive control approach, which operates on the tenet of modifying the controller's settings to ensure that the out-put of the plant follows that of the reference model with a similar reference -input.

2 Components

Reference model: t is used to give a perfect adaptive control system response to the reference input. Controller: It typically has a collection of reliable parameters that characterize it. In this thesis as it were the control law is described by one parameter. The value of θ is essentially dependent on adjustment gain.

Adjustment component: This component is used to modify the controller's settings so that the real plant can follow the reference model. Using the input from the discrepancy as a guide The adaptation loop modifies the relationship model output ym(t) and the process output y(t) the controller's settings. The parameter is altered by the outer loop, sometimes referred to as the adaptation loop, such that the difference is minimal. A method for creating an adaptive controller the gradient approach and the stability theory (Lyapunov) design can both be used to find the parameter adaptation mechanism in MRAC. On the other hand, employing the stability technique while constructing an MRAC will guarantee the stability of the closed loop system. Reference adaptive controllers are used to alter parameter estimation in order to solve the problem of this model.

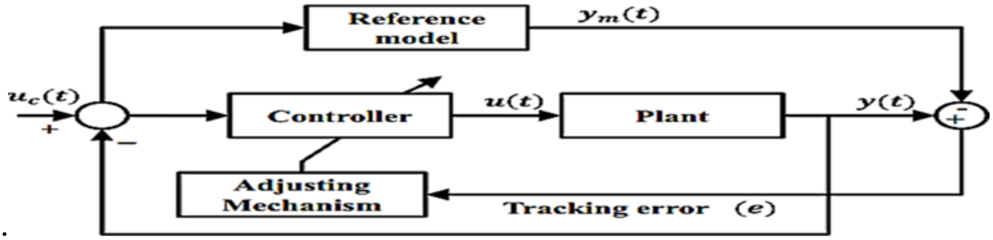


Figure 4. 1 Block schematic of model reference adaptive control,

To create the adjusting mechanism, mathematical model techniques such the MIT rule, Lyapunov theory, and theory of augmented error can be applied. In this thesis, we apply the MIT rule to the design of a wind farm; this method is known as adjusted MIT rule and stability. The basic block diagram of the MRAC system is shown in Figure 4.2. As seen in the image, the output of the reference model is denoted by ym (t), whereas the output of the actual plant is indicated by y(t) ,e(t) stands for the difference between the two. To determine the controller parameter vector of control's adaptation rules law using Lyapunov Rule Parameter adjustment mechanism in MRAC was updated by MIT rule and Lyapunov θ = Kp,Ki and Kd [20] or Using an adaptive controller, Pitch angle control for wind turbines: design and stochastic modeling

$e(t) = Y(t) - Ym$ ………………………………4.1

by applying laps transform ,for equation 4.1

Y(s) =u(s) kG(s)

Ym (s) = UcYm

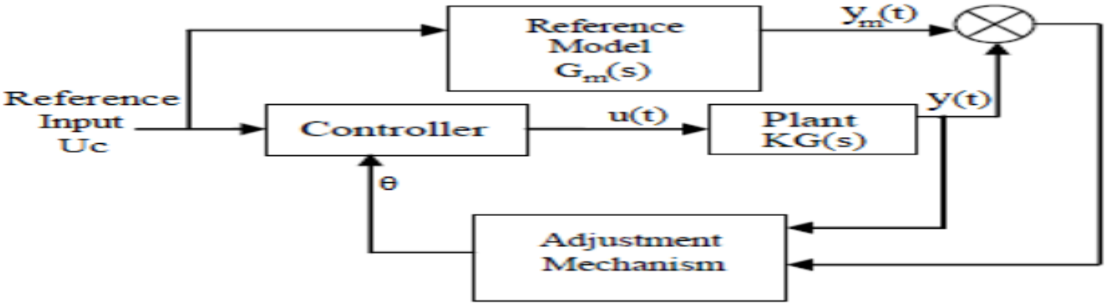


Figure 4.2 fig of model reference adaptive control (MIT rule and Lyapunov rule design)

4.2 .Gradient or MIT rule and stability

MIT used to construct the wind turbine plant or pitch angle controlled system. Any system's controller using MRAC scheme may be designed using the MIT rule. The cost function for the MIT rule is $J(\theta) = \frac{e^2}{2}$……………………………………………………….4. 2

Where error (e) between the outputs of process and the model, and θ is the control parameter Since J has a negative gradient the parameter continues to vary in that direction.

$\frac{d\theta}{dt} = -\gamma \frac{\partial J}{\partial \theta}$…………………………………………………..........4. 3

From equation 2

$\frac{d\theta}{dt} = -\gamma e \frac{\partial e}{\partial \theta}$………………………………………………………….4.4

The derivative term ∂e/∂θ is called as the sensitivity of derivative. This component, which shows how the error is evolving with respect to the parameter θ, is maintained in the direction of the negative gradient of J. And eq. (4.3) explains how the parameter changes over time in order to essentially eliminate the cost function J (θ). Here, is a positive value that denotes the adaption-gain of controller. Let's expect that the method includes a direct exchange work with the notation KG(s), where G(s) is a second order recognized transfer function and K is an unknown parameter. In order for our prepare to take after the reference show with the transfer work Gm(s) = KoG(s), where Ko could be a known parameter, our objective is to develop a controller. Based on equation 4.1

$E(s) = KG(s)U(s) - KoG(s)Uc(s)$…………………………4.5

Defining a control law,

$U(t) = \theta * Uc$……………………………………………..4.6

From equation. (5 and 6), and taking partial differentiation,

$\partial E/\partial\theta(s) = KG(s)UcG(s) = K/KoYm(s)$………………….4.7

From equation 4 and 7 we will get,

$d\theta/dt= -\gamma e\ K/Koym = -\gamma' eym$ ……………………………4.8

The rule for changing the parameter is provided by Eq. (4.8), and the Simulink model is seen in fig (4.2). The findings of the simulation show that the plant's reaction depends on the adaption gain. Larger values of this parameter, which might lead to system instability in some industrial units, must be carefully chosen, from top equation [4.1] MIT rule and Lyapunov stability and design rule plant transfer function as to use reference model such that the following second order equation form. we know that dy/dt =dθ/dt or Ym/Um = T(s)

$\frac{Ym}{Um} = \frac{400}{s^2+40s+400}$ for the optimal design model reference plant [5 26] or angle of wind turbine pitch control of the transfer function and adaptive pitch angle control.

$\frac{Ym}{Um} = \frac{400}{s^2+40s+400}$……………………………………………………4.9

The model transfer function from

$d^2Ym \quad = -40\ dY_m - 400\ Y + 400Um$

Model error, e = Y-Ym it is equivalent equation [1]

4.3 Method of Lyapunov rule Stability

The Lyapunov stability method is a type of adaptive control that is widely used. This method aims to identify the Lyapunov function and an adaptation mechanism that minimizes the error /to zero between the plant and the model. This strategy also assures that the system's control parameters are stable. We look at the design using the Lyapunov stability method in this thesis (Lyapunov rule). The reference model, controller structure, and tuning gains for the adjustment mechanism are all chosen while constructing an MRAC utilizing the Lyapunov rule. By evaluating the general second order transfer function, the system's anticipated closed loop behavior is used to select the second order reference model. From the equation 4. 8 and 4.9 for the design of fuzzy logic based adaptive controller of reference model proved or stated

$d\theta/dt = -\gamma e\, K/Koym = -\gamma' eym$, $\frac{Ym}{Um} = \frac{400}{s^2+40s+400}$…………………………..4.10

Let assume $\frac{Ym}{Um}$= G(s)or T(s) it mean that transfer function

4.4 Fuzzy logic controller

To create the controller, a mathematical model of the system is necessary. Mathematical models of nonlinear and unpredictable systems are difficult to come by. Fuzzy control, on the other hand, refers to systems that have complicated mathematical models and numerical solutions expressed in terms of linguistic variables. Zadeh was the first to introduce fuzzy logic theory (ZADEH, 1965). He later emphasized that fuzzy logic can be applied to systems with uncertainty and precise mathematical models in other publications regarding fuzzy logic (ALTA, 1999). Zadeh (1965) made a significant contribution to science by developing a new control approach for complicated systems. For the first time in history, Madman and his colleagues applied fuzzy logic theory to control systems (ALTA, 1999). The fuzzy logic controller in this work is made up of several components. Fuzzification, data basis, rule base, and defuzzification are all terms used to describe these processes. When compared to other types of controllers, the fuzzy logic technique was shown to be the greater fit for the pitch-angle controller design.

The major contribution of this FLC as follows:

- Using an analytical method, the induction generator's comparable steady-state model was created. The findings of mechanical torque vs rotor speed were obtained at various pitch angles.
- A fuzzy - logic controller (FLC)-based pitch angle control system has been presented, which can sustain output power when the wind speed exceeds the rated

Figure shows the fuzzy logic controller's fundamental block diagram.

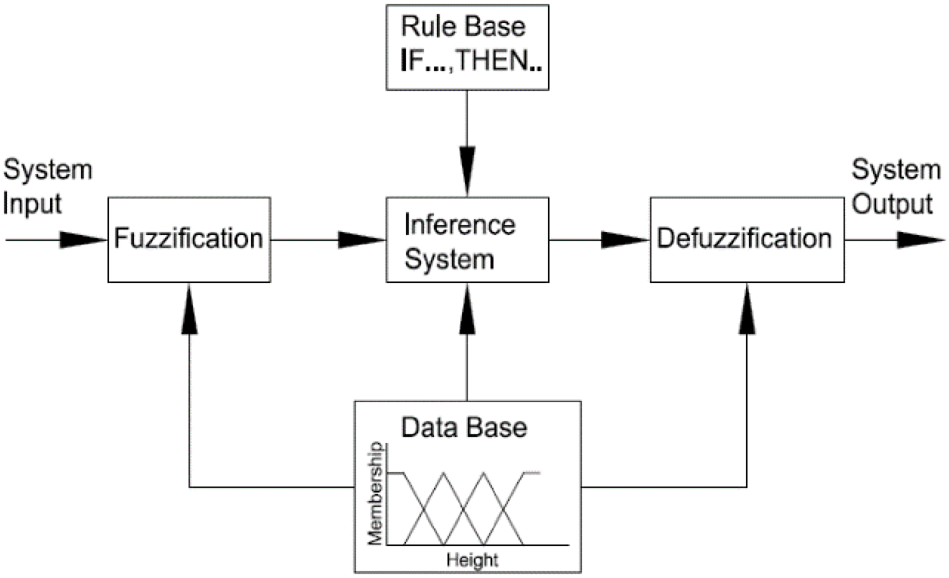


Figure 4.3 Blocks diagram of FLC structure

The fuzzy logic control approach was used to build the system. Fuzzy control basically refers to an adaptive control system. The fuzzy input variables error and error change were established. The Madman/Gaussian inference system is used as a rule foundation. Defuzzification method Centroid is used. The amount of angle change is the output variable.

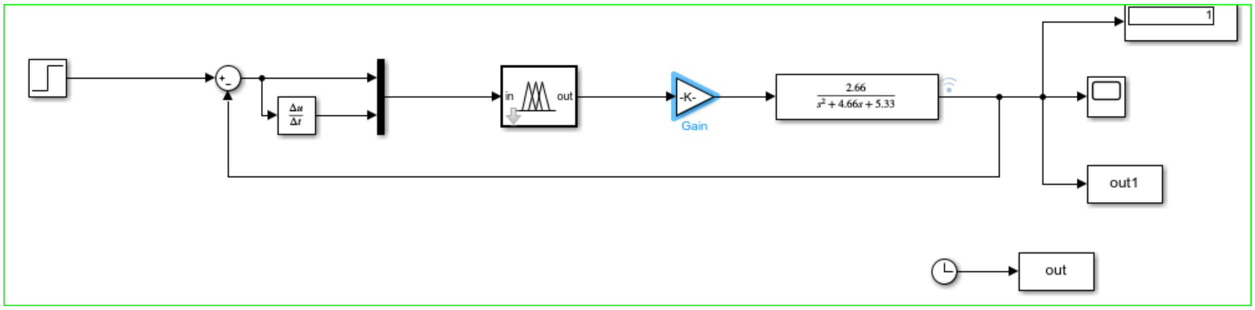


Figure 4.4 design of wind turbine pitch control FLC structure

The selection of adaptation gain settings is manually changed in modern reference adaptive controllers. We employed a fuzzy logic controller to choose an acceptable adaptation gain to solve this challenge. The values are directly related to the adjusted adaption gain. We choose parameters from three adaptation gains in order to minimize the steady state error. Fuzzification, rule base, inference, and defuzzification are all part of the fuzzy logic controller architecture.

Reference to the model to regulate the nonlinear system, an adaptive controller was used. However, the selection of adaption gain parameters is done by hand. We employed a fuzzy logic controller to choose an acceptable adaptation gain to solve this challenge. The constant values/gain values are directly related to the adjusted adaption gain. We choose steady state error from three adaptation gains. The rule foundation, inference, and defuzzification components of the fuzzy logic controller architecture are fuzzifier.

1. Fuzzification

The fuzzy controller's inputs and outputs are defined in this step. This programed has one output and two inputs (er and ce) (ad gain).The controller's adaptation gain is automatically modified depending on the inaccuracy and the variation in the error. In fuzzy set theory, membership functions such as triangle membership functions and Gaussian membership functions are utilized. We use the triangular membership function in this thesis since it performs better in way of stability sytem. The three fuzzy sets' value was divided into three levels by the variable universe of discussion for plant error and referance in error (ec). The three fuzzy sets' linguistic values were assigned the letters N, Z, and P, which stand for Negative, Zero, and Positive, respectively. In the discourse's flexible universe, the system error (e) and error change are substantial (ec).

2 Fuzzy Rule Base

Nine fuzzy rules have been applied for each parameter in accordance with the input and output membership function, as indicated in the table below.

de/dt=ce

	Ce		
e	n	m	p
n	L	S	m
z	n	m	m
p	n	m	m

Table 4. 1: Fuzzy rule base

Base of Fuzzy Rules

Ce =error change L=large M=medium S=Small E=system, Z=zero N=negative, P=positive,adg=adaption gain

The fuzzy controller's goal will be determined only by the rule base, which is made up of IF and THEN clauses. The accuracy of the output is determined by the rules that are created. The criteria are based on the output response being checked often and the range of member ship function, R=[0 1].

3. Defuzzification

Defuzzification is the process of changing a fuzzy set to a real integer. Several techniques have been designed to output actual values. In this thesis, centroid defuzzification—the conversion of a fuzzy set into a real integer—was used. Many strategies have been created to form true result as outputs. A pitch angle control system based on fuzzy logic controllers (FLC) has been proposed. By altering the pitch angle, a FLBAC idea is designed to lessen the stresses placed on the turbine and drive train at full load circumstances and to restrict the extracted power at rated value while improving its quality. The second part's main focus is the pitch control technique. The foundational elements of the fuzzy logic controller (FLC) are built based on literature research. Then those factors are tweaked (change slightly) to get the better FLC but the fuzzy controller are presence of always updated for the system control. By this case parameter estimation and stability analyzing the best controllers are fuzzy based adaptive control (fuzzy based MRAC)

4.5 Fuzzy logic based adaptive controller

Fuzzy base adaptive Controller is designed with some adjustable parameters along with an embedded mechanism for adjusting them. Adaptive controller has been used for improving the performance of controller. Fuzzy adaptive controllers that can learn from process data to develop a set of fuzzy control rules (as well as including expert-derived rules) and as the control process develops, performance might answer this need and provide considerable benefits. This thesis provides an overview of fuzzy adaptive control as well as a description of some current directions of research in this field. Methods that fuzzy logic control are given special attention since they appear to be the most promising. A fuzzy controller is made up of a rule base, which is a Fuzzifier and defuzzifier, as well as a fuzzy relation between the fuzzy sets for plant states and control variables.

Finally, the FLC based Adaptive /the new control/ to develop by automatically adjusting the scaling factors of this last configuration using a correction factor. Fuzzy logic controller and model reference controllers are included in the FLBAC controller. In comparison to both of them, the performance improves. Because there is no longer any error or uncertainty/disturbance error, and it controls automatically and stability of the plant design. The fuzzy logic control and fuzzy logic based adaptive good controller but it the best controller is fuzzy logic based adaptive controllers (explained chapter summary)

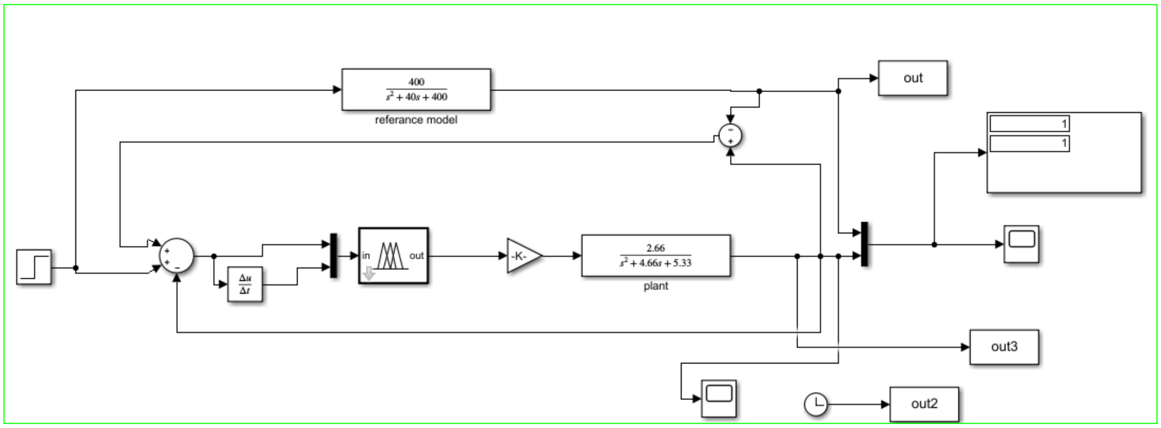


Figure 4.5 .design of pitch angle control fuzzy logic based adaptive controller

Chapter 5

5 .Design, Simulation of the results and discussion

Chapters 3 and 4, respectively, lay mathematical model and architecture. This chapter will provide and thoroughly examine the simulation results of the systems and system performance using matlab/simulk. A simulation of a 1000kw/1-MW wind power system was run to validate the correctness of the suggested technique. The simulation settings were used from earlier publications [29 - 31]. To regulate the pitch angle of the wind turbine, we will build three controllers in this chapter. I design the controller by Simulink to examine their effects and evaluate the outcomes.

5.1 model reference adaptive controller using MIT rule design and Lyapunov simulations

MIT Rule for second Order System Simulation for Model Reference Adaptive Controller (MRAC) Design. MRAC is a model-based, real-time adaptive control technique that computes control actions to make an uncertain controlled system track the behavior of a particular reference plant model. The MIT rule is a scalar parameter adjustment law for model reference adaptive management of linear systems described as a cascade of known stable plants and a single unknown gain. Model Reference as a working principle the adaptive controller is designed The output of a reference model using the same reference input tracks the output of the actual plant. by adjusting the controller settings according to an adaptive control approach.

5.1.1 Design, Results and Simulations of MIT rule/gradient rule

The controller's settings are altered (modified) using this component so that the actual plant can follow the reference model. The adjusting mechanism may be created using mathematical methods like the gradient rule/MIT rule, Lyapunov theory, and theory of augmented error. We combined the MIT rule and other rules to develop the Modified MIT rule for this simulation.

Figure1 displays a schematic of the MRAC system. The output of the reference model is shown as ym (t) =, the output of the actual plant is shown as y (t), and the difference between the two is shown as e (t) in the diagram

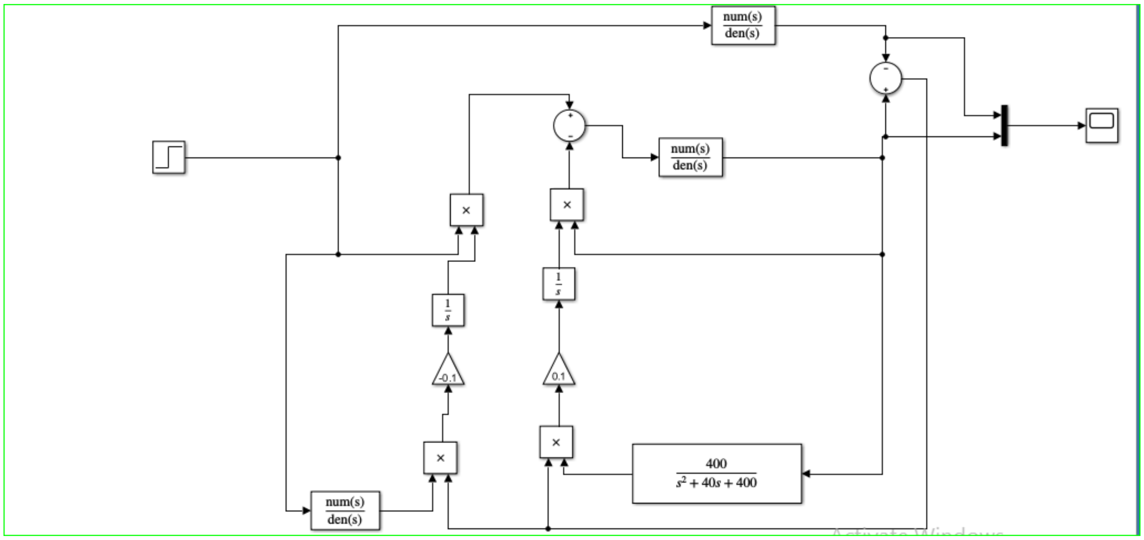


Figure 4.1.MIT rule of design wind turbine pitch angle control of MRAC

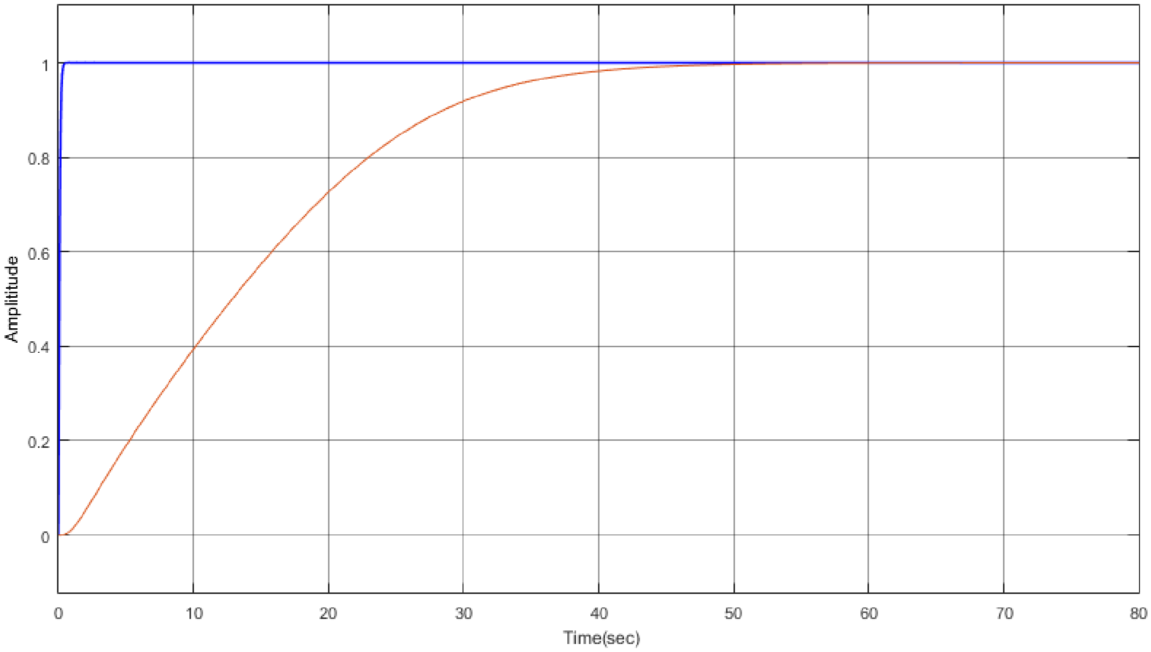


Figure 5.2. Simulation results for MRAC using the updated MIT rule for various plants and MRAC-controlled wind turbine pitch angles

The MIT rule and a modified MIT rule are used to mimic a second-order system using the MRAC approach, as demonstrated below Figure 5.2 displays the reactions of the reference model and the real plant to different values of the adjustment adaption gain gamma(γ),Table(1) shows the system's dynamic performance with respect to time-domain characteristics for various values of Figure 2 demonstrates that no overshoots happen for high values of system responses, but modest overshoots happen for low values of system responses. The system's performance is unsatisfactory beyond this point.

This thesis includes a full overview of the MRAC scheme employing the MIT rule, as well as performance evaluations using SIMULINK simulations. The outcomes of the MIT system are contrasted in Table 1 for a range of adaptation gain values. Figure2 shows that when the adaption gain increases, the system's reaction improves, but beyond a certain point 0.1, the system's performance deteriorates dramatically. Signal levels have an impact on the choice of adaptation gain, which is important. Even for extremely high and extremely low reference input amplitudes, the Normalized method utilized in this thesis is less sensitive. When the reference input amplitude is changed, the responses of the MIT and modified based controllers are shown in Figure 5.2. As a result, it suggests that a controller constructed using the MIT rule is extremely sensitive to changes in reference amplitude, implying that the MIT rule normalization algorithm renders the system extremely sensitive to input amplitude. When the gamma value is 0.1, there is no overshoot, but the transient reaction is slightly slower, i.e. the rise time is high, as shown in the above simulation result plot. The rise time will be lowered as the magnitude of gamma grows, but the system will become stable because of it use reference model two or more used for design.

The specifications for unit step input using a fuzzy logic controller are shown in the following table.

1	Raise time	25.4559
2	Settling time	39.0522
3	Settling minimum	0.9012
4	settling maximum	1
5	Over shoot	0
6	Under shoot	8.6393e-75
7	Peak	1.0000
8	Peak time	80
9	Steady state error	0

Table 5. 1: lists the time domain requirements for unit step input with MIT/gradient rule model reference adaptive controllers for controlling wind turbine pitch.

5.1.2 Results were based on the Lyapunov rule employing Model Reference Adaptive control.

In the MRAC Scheme, this employs and using Mat lab Simulink Theory, contrasting the Lyapunov Rule Based and MIT Rule Based MRACs designs Simulation for Comparative Investigation of MIT Rule Based and Lyapunov Rule Based. In order to maintain optimal performance regardless of system changes, the adaptive control method continually and automatically analyses the dynamic behavior of the plant, compares it to the intended output, and utilizes the difference to alter system parameters or create an actuating signal. The adaptive control system's ideal response to an outside order is represented by the reference model. It ought to line up with the performance standards for control jobs. The ideal behavior of the reference-model should be accomplished by the adaptive control system. A number of changeable parameters are frequently used to parameterize it. The controller law is defined in this study using two parameters, 1 and 2. The control law is linear in terms of the movable parameters. In order to put up an adaptation mechanism with guaranteed tracking convergence and stability, adaptive controller design usually necessitates linear parameterization. It is utilized to alter the parametre for the manage enactment. The adaptation law looks for variables that will cause a comparative response within the plant as within the reference model. It aims to ensure the stability of the control system and get rid of tracking inaccuracy.

Based on Lyapunov:

The following is a block diagram for the Lyapunov Rule Based MRAC Scheme: There is only one model to use as a reference.

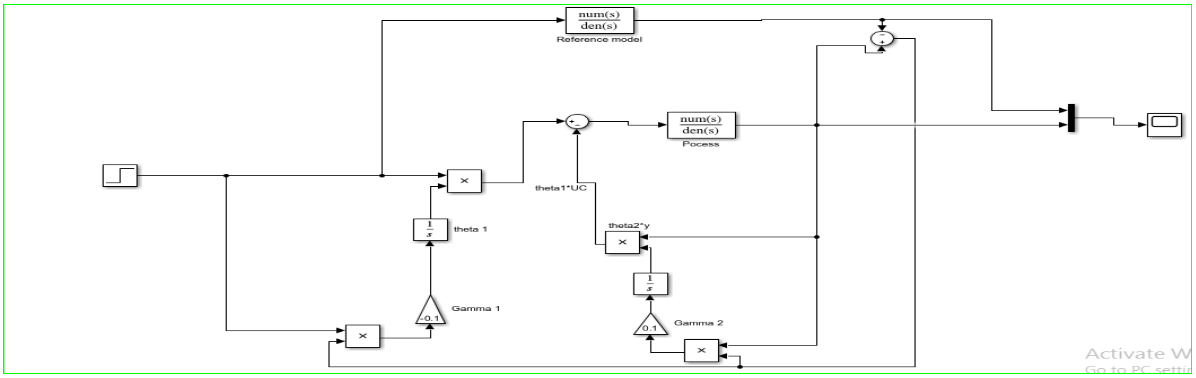


Figure5.3 Lypanove rule of design wind turbine pitch angle control of MRAC

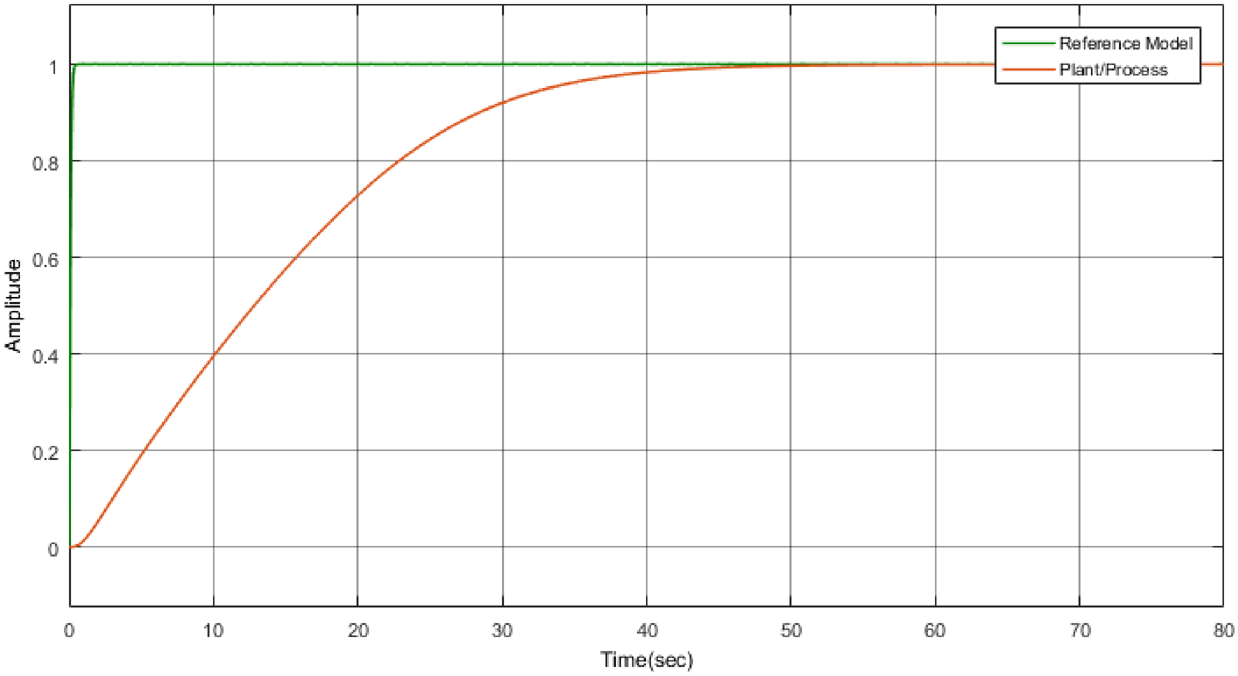


Figure 5.4 shows the outcome of a simulation using the MRAC and a modified Lyapnove rule for various plants and wind turbine pitch angle control.

Generally;. For both MIT Rule Based and Lyapunov Rule Based MRAC, the best response value is achieved at gamma=0.1. The primary distinction between MIT Rule Based and Lyapunov Rule Based MRAC is that Lyapunov Rule Based MRAC has only one reference Model, whereas MIT Rule Based MRAC has several Reference Models. Furthermore, we can see from the simulation results of the two models that Lyapunov Rule Based is better in terms of obtaining a fast response, but there is greater overshoot. The MIT Rule Based MRAC, on the other hand, has less overshoot but a slower reaction. When comparing the Lyapunov rule configuration of MRAC to the MIT rule, the complexity is minimized. As a result, with Lyapunov theory, the physical manifestation of the system under investigation is more possible. It is clear that when the adaption gain increases, the system's performance for both strategies improves (gamma). Lyapunov theory, on the other hand, has a faster rate of improvement. For = 0.1, the system response is not oscillatory, but it is quite sluggish. When the adaption gain is increased little, the response becomes oscillatory, and the settling time is reduced slightly. The Lyapunov rule has a significantly lower maximum overrun than the MIT rule. As a result, the system's stability is confirmed by the Lyapunov rule. The table below shows the time domain requirements for unit step input with Lyapunov rule design.

1	Raise time(sec)	25.3605
2	Settling time(sec)	38.8712
3	Settling minimum	0.9018
4	Settling maximum	1.000
5	Over shoot	0
6	Under shoot	0
7	Peak	1.000
8	Peak time(sec)	80
9	Steady state error	0

Table 5. 2: outlines the Lyapunov rule design stability theory-based wind turbine pitch control

5.1.3 The simulation outcome of the two models' comparison /MIT and Lyapunov rule

For both MIT Rule Based and Lyapunov Rule Based MRAC, the best response value is achieved at gamma=0.1. The primary distinction between MIT Rule Based and Lyapunov Rule Based MRAC is that Lyapunov Rule Based MRAC has only one reference Model, whereas MIT Rule Based MRAC has several Reference Models. Furthermore, we can see from the simulation results of the two models that Lyapunov Rule Based is better in terms of obtaining a fast response, but there is greater overshoot. The MIT Rule Based MRAC, on the other hand, has less overshoot but a slower reaction/response. When comparing the Lyapunov rule configuration of MRAC to the MIT rule, the complexity is minimized. As a result, with Lyapunov theory, the physical manifestation of the system under investigation is more possible. It is clear that when the adaption gain increases, the system's performance for both strategies improves (gamma).

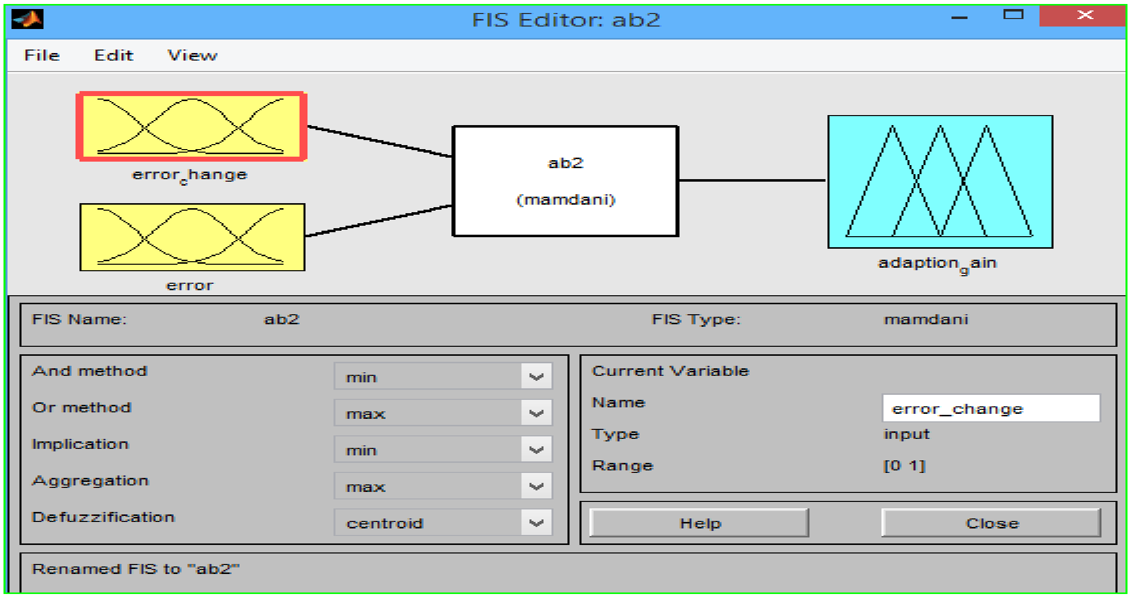
Lyapunov theory, on the other hand, has a faster rate of improvement. For = 0.1, the system response is not oscillatory, but it is quite sluggish. When the adaption gain is increased little, the response becomes oscillatory, and the settling time is reduced slightly. When compared to the MIT rule, the Lyapunov rule has a significant reduction in maximum overshoot. As a result, the Lyapunov rule confirms the system's stability. As a result, the Lyapunov rule confirms the system's stability. In a Model reference controlled system, the Lyapunov rule reduces the time it takes to settle, which enhances the system's speed. It can be concluded that adaption gamma, 0.1 has the best system performance.

5.2 Fuzzy logic controller Design, Simulation of the Results, discussion of controlling wind turbine pitch angle

Fuzzy set without practical, the representation and inference of fuzzy linguistic information, and fuzzy logic rules fuzzy logic rules are the foundations of fuzzy control without practical or proto type, an automated control theory that attempts to mimic human thought and reasoning. The following are some characteristics of fuzzy control: We can utilize fuzzy control rules to describe manipulators' or experts' associated knowledge and experience as linguistic variables, and then apply these guidelines to models of forces that are difficult to accurately build or that are unknown. The fuzzy rule base, defuzzification, inference, and inference are all components of the fuzzy logic controller architecture. MATLAB/Simulink is used to create this controller.

5.2.1 Fuzzy logic controller design of member function

Designed by madman rule member ship function

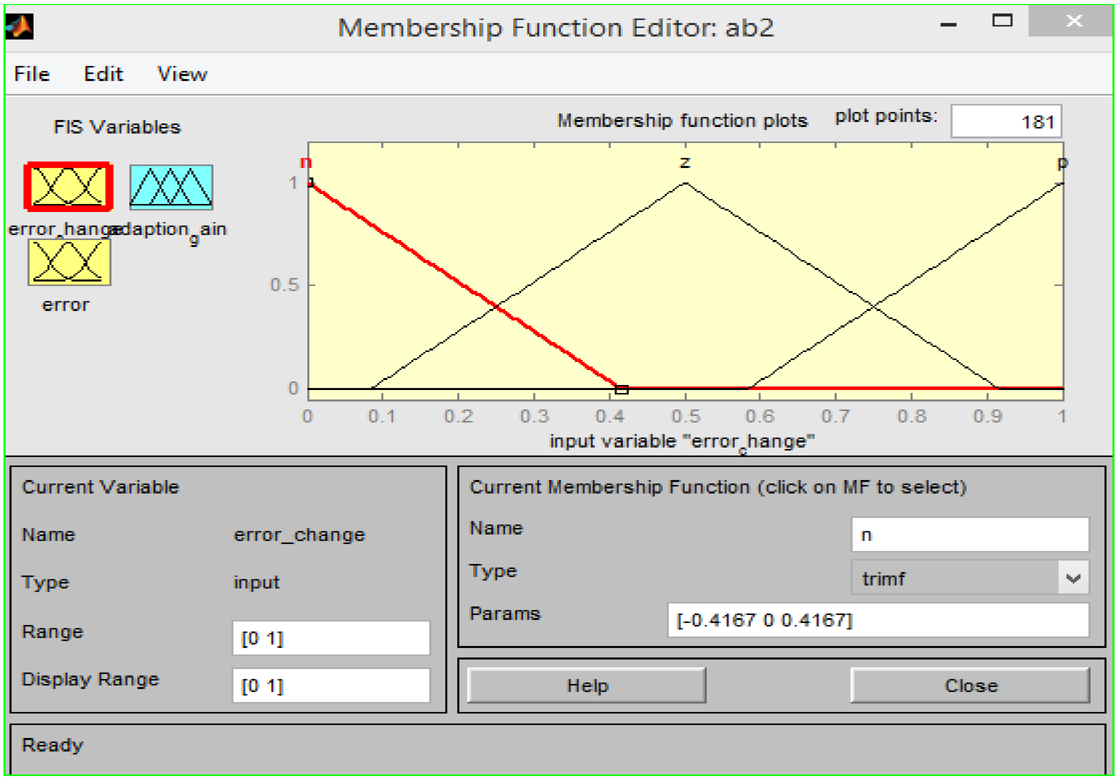


FIS Name: ab2
FIS Type: mamdani

And method: min
Or method: max
Implication: min
Aggregation: max
Defuzzification: centroid

Current Variable
Name: error_change
Type: input
Range: [0 1]

Renamed FIS to "ab2"



plot points: 181

Current Variable

Name error_change

Type input

Range [0 1]

Display Range [0 1]

Current Membership Function

Name n

Type trimf

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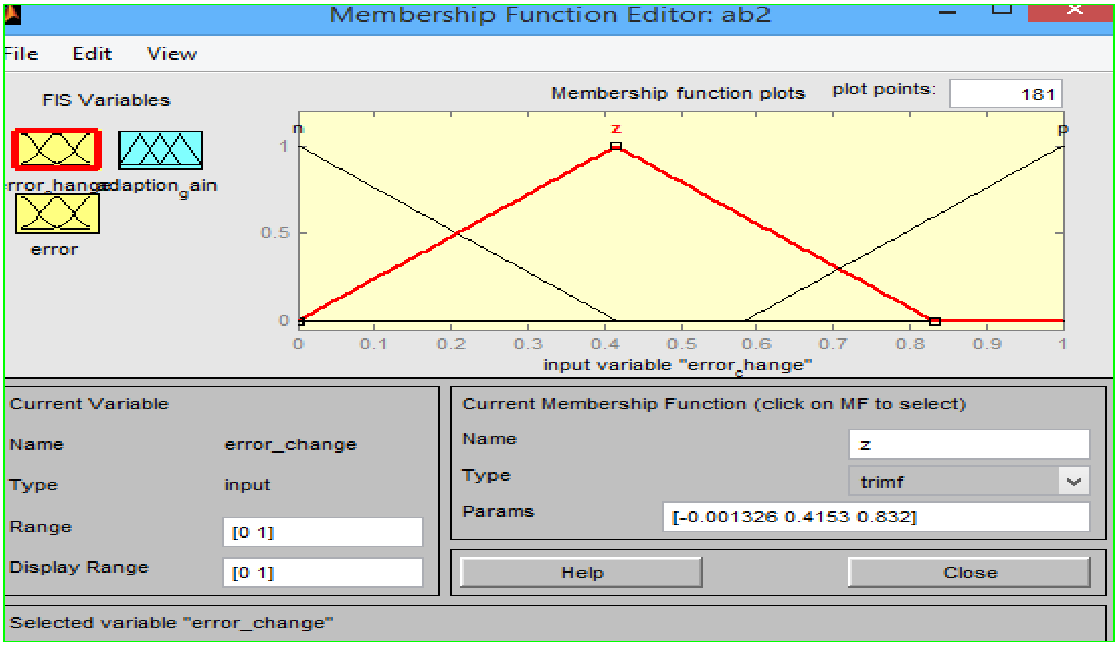
Ready



plot points: 181

Current Variable

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Range [0 1]

Display Range [0 1]

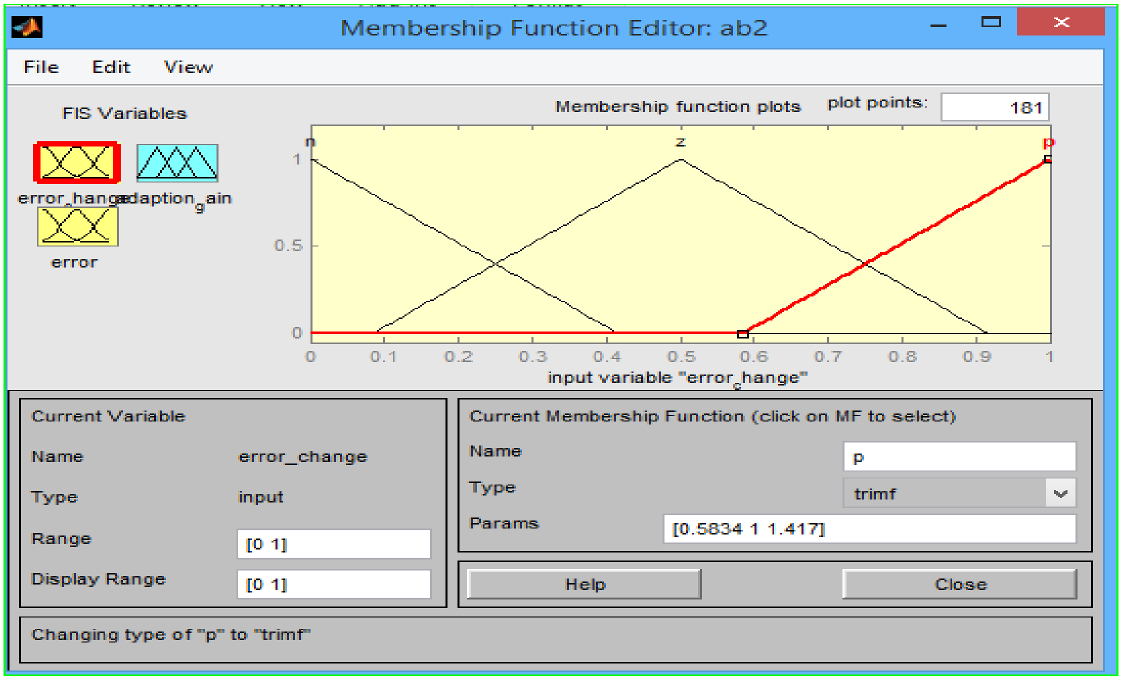
Current Membership Function

Name z

Type trimf

Params [-0.001326 0.4153 0.832]

Selected variable "error_change"



plot points: 181

Current Variable

Name error_change

Type input

Range [0 1]

Display Range [0 1]

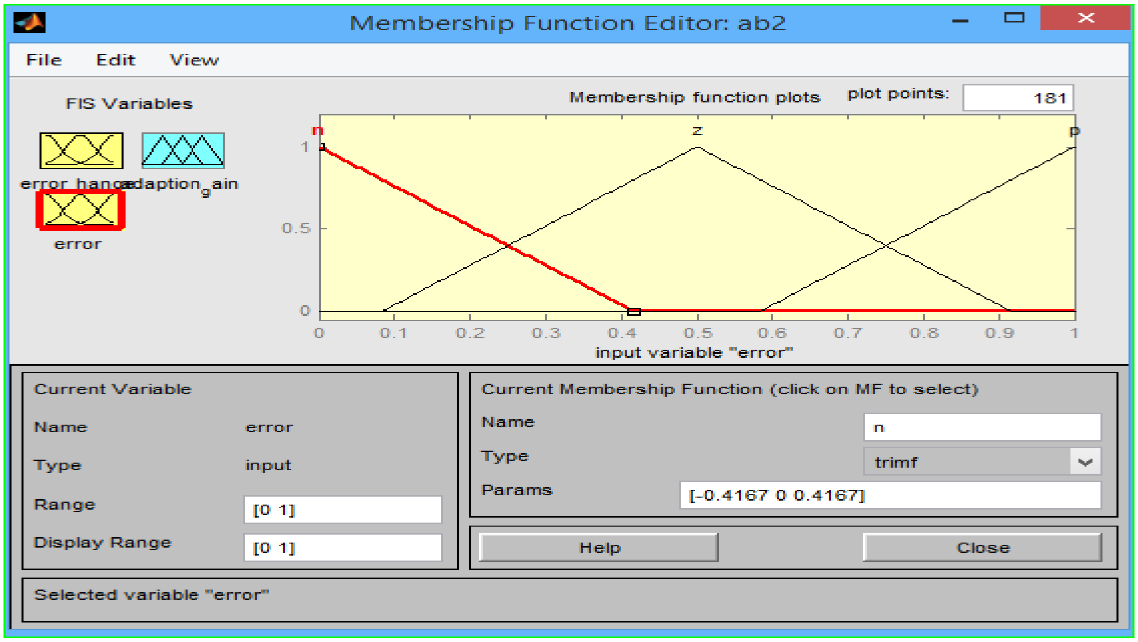
Current Membership Function (click on MF to select)

Name p

Type trimf

Params [0.5834 1 1.417]

Changing type of "p" to "trimf"



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Current Variable

Name error

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Range [0 1]

Display Range [0 1]

Current Membership Function (click on MF to select)

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Type trimf

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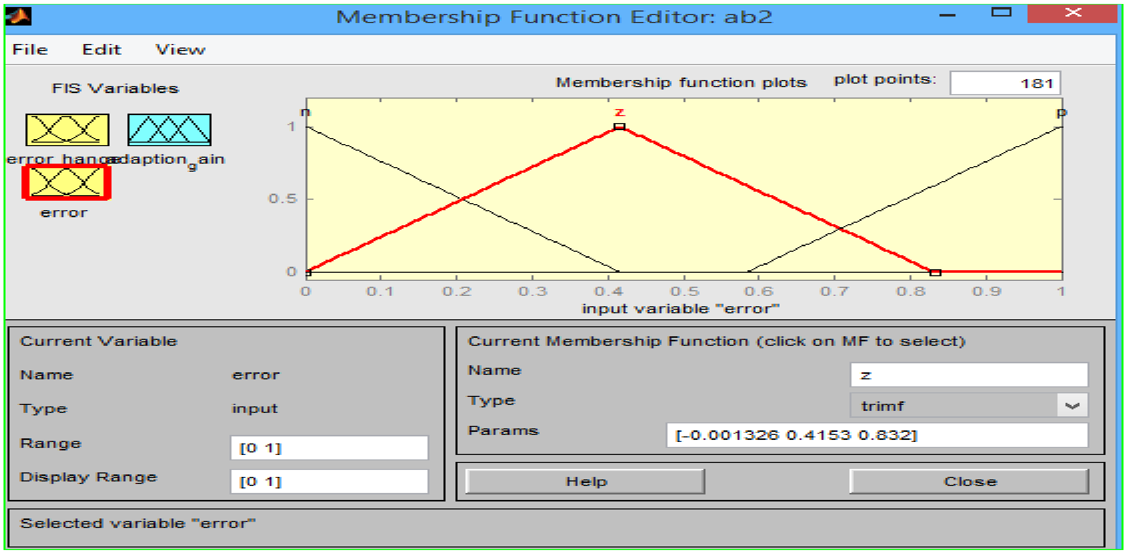


plot points: 181

Current Variable

Name error

Type input

Range [0 1]

Display Range [0 1]

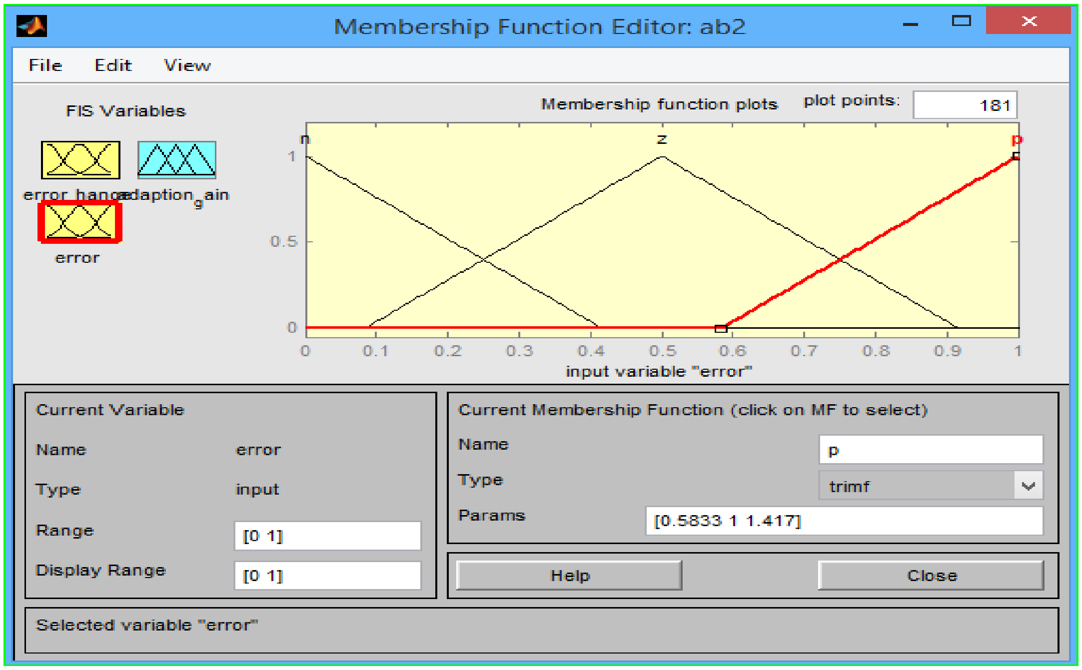
Current Membership Function (click on MF to select)

Name z

Type trimf

Params [-0.001326 0.4153 0.832]

Selected variable "error"



plot points: 181

Current Variable

Name error

Type input

Range [0 1]

Display Range [0 1]

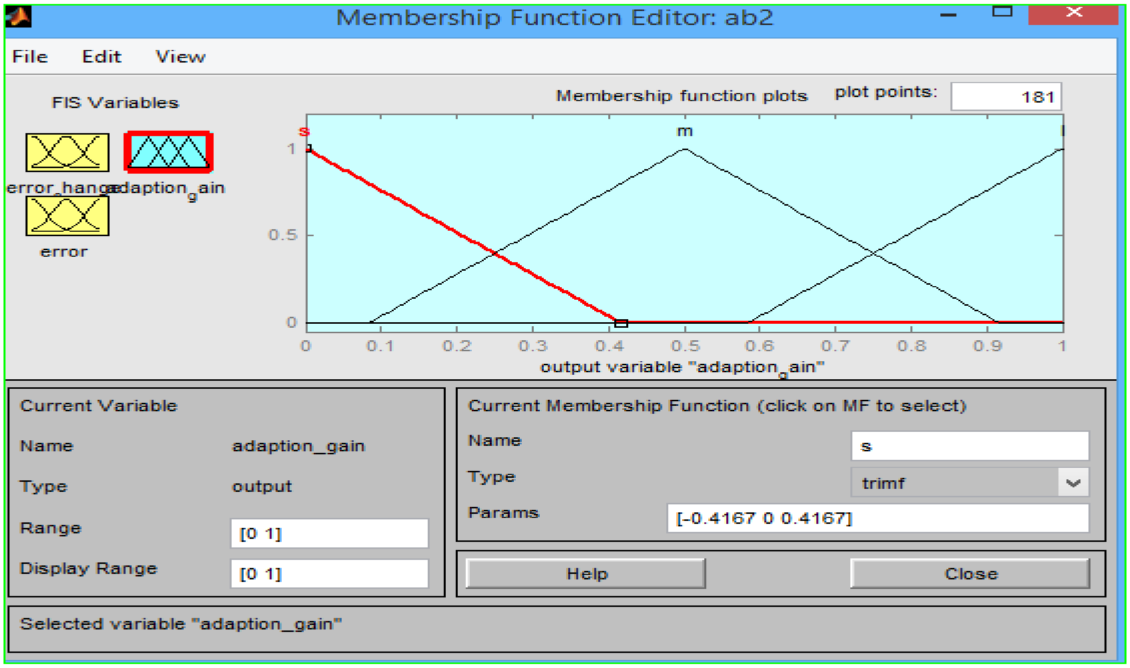
Current Membership Function (click on MF to select)

Name p

Type trimf

Params [0.5833 1 1.417]

Selected variable "error"



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Name adaption_gain

Type output

Range [0 1]

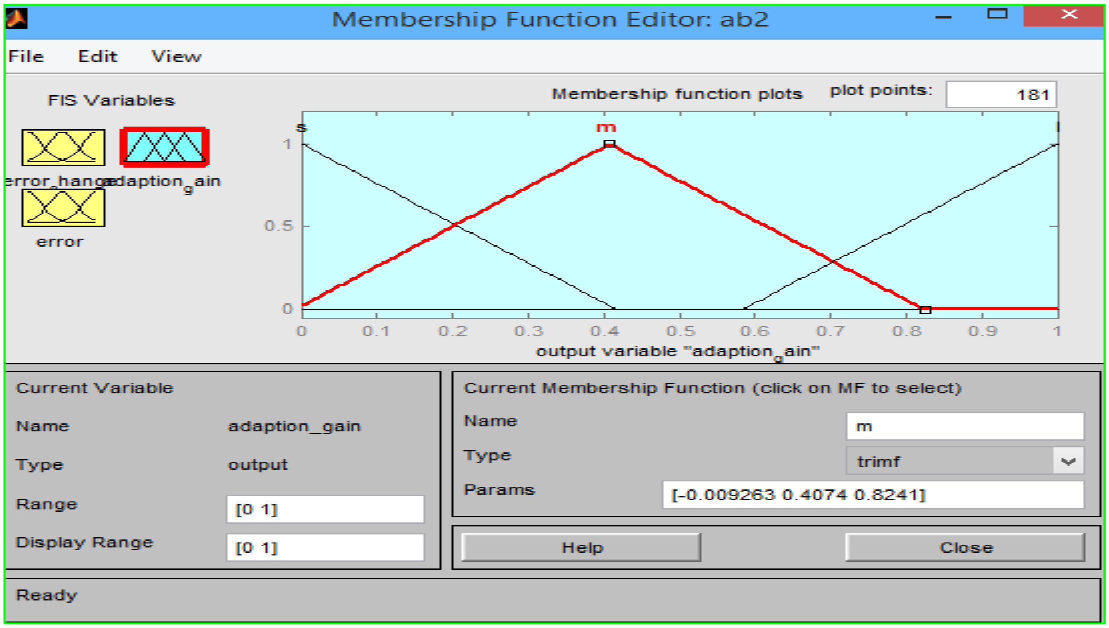
Display Range [0 1]

Name s

Type trimf

Params [-0.4167 0 0.4167]

Selected variable "adaption_gain"



plot points: 181

Name adaption_gain

Type output

Range [0 1]

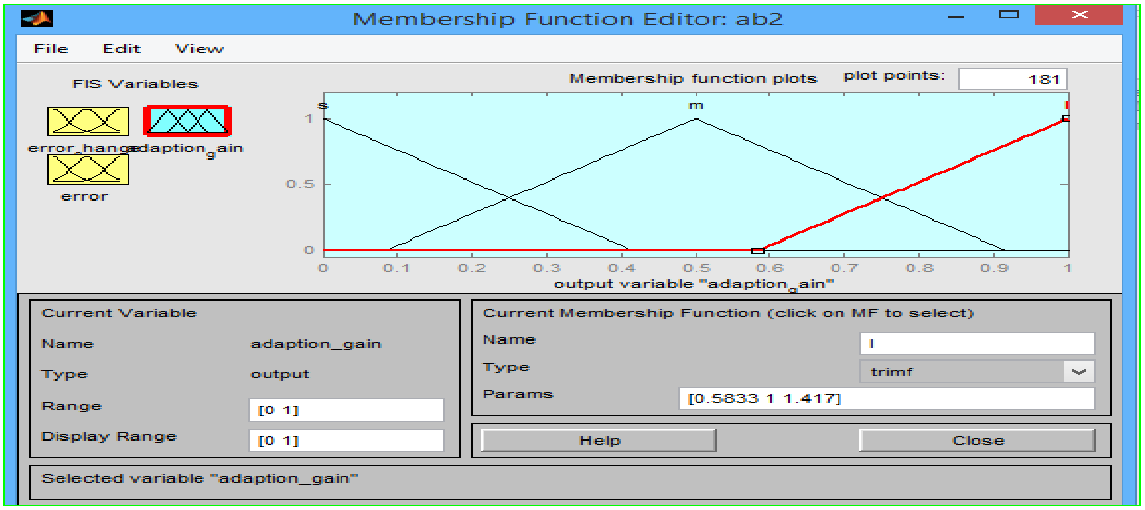
Display Range [0 1]

Name m

Type trimf

Params [-0.009263 0.4074 0.8241]

Ready



plot points: 181

Current Variable

Name adaption_gain

Type output

Range [0 1]

Display Range [0 1]

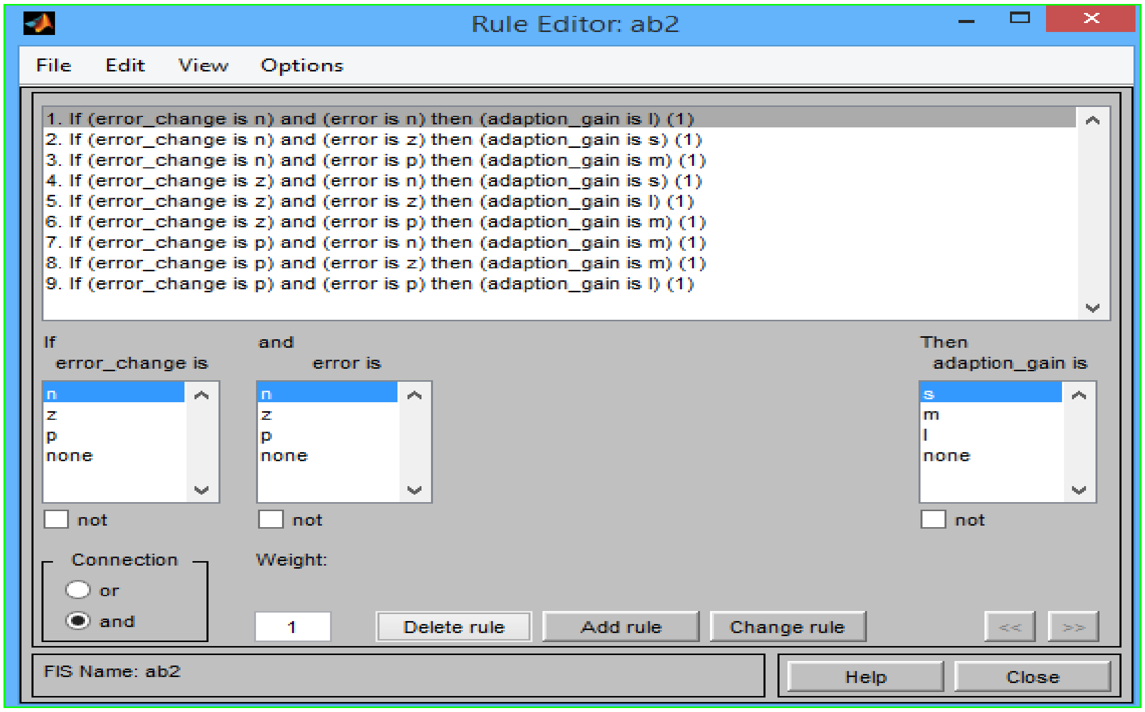
Current Membership Function (click on MF to select)

Name l

Type trimf

Params [0.5833 1 1.417]

Selected variable "adaption_gain"



1. If (error_change is n) and (error is n) then (adaption_gain is l) (1)
2. If (error_change is n) and (error is z) then (adaption_gain is s) (1)
3. If (error_change is n) and (error is p) then (adaption_gain is m) (1)
4. If (error_change is z) and (error is n) then (adaption_gain is s) (1)
5. If (error_change is z) and (error is z) then (adaption_gain is l) (1)
6. If (error_change is z) and (error is p) then (adaption_gain is m) (1)
7. If (error_change is p) and (error is n) then (adaption_gain is m) (1)
8. If (error_change is p) and (error is z) then (adaption_gain is m) (1)
9. If (error_change is p) and (error is p) then (adaption_gain is l) (1)

If error_change is: n, z, p, none — ☐ not

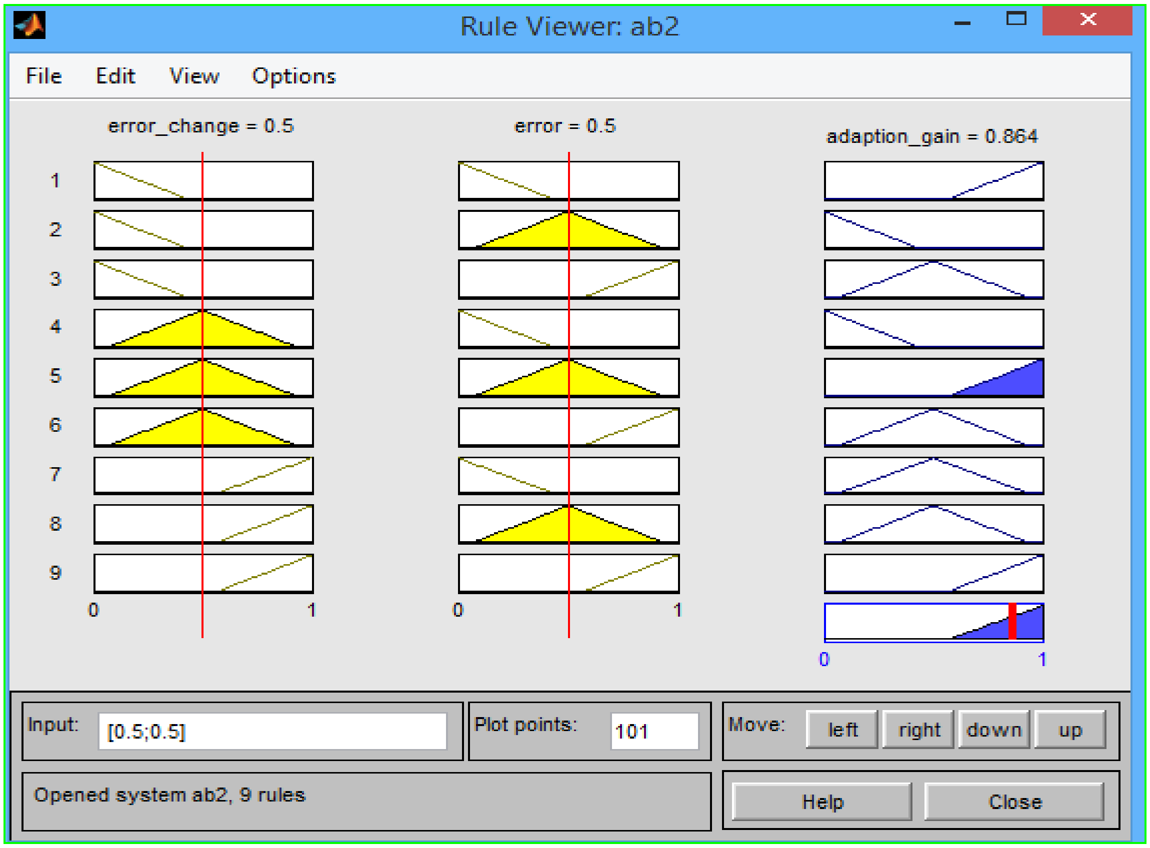
and error is: n, z, p, none — ☐ not

Then adaption_gain is: s, m, l, none — ☐ not

Connection: ○ or ● and

Weight: 1

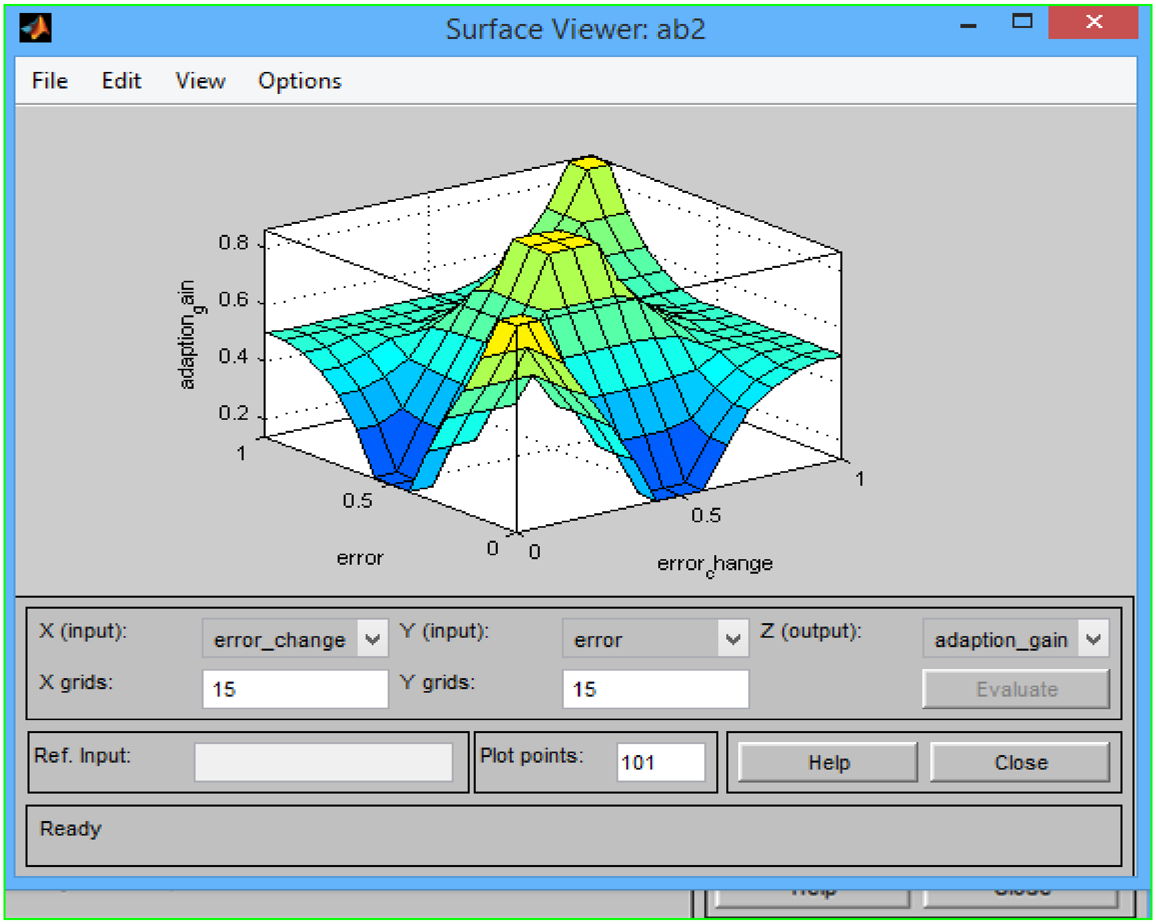
FIS Name: ab2



Input: [0.5;0.5]

Plot points: 101

Opened system ab2, 9 rules



X (input): error_change

Y (input): error

Z (output): adaption_gain

X grids: 15

Y grids: 15

Ref. Input:

Plot points: 101

Ready

Figure 5.5 fuzzy logic design member ship system

Where the linguistic variable n = negative, z = zero, s= small = positive, m = medium and l= large.

The range of adaptation gain is determined by the stability circumstances, as well as the transient and steady-state responses. The adaptation gain was tweaked in the simulation using fuzzy logic to provide a decent response while minimizing the mistake.

5.2.2 Table for linguistic variable and adaption gain parameters of the fuzzy logic controller design

	ec(change error)	e(error)
N(negative)	-0.4167 0 0.4167	-0.4167 0 0.4167
Z(zero)	-0.00126 0.4153 0.823	-0.00126 0.4153 0.823
P(positive)	0.5834 1 1.417	0.5833 1 1.417

Table 5. 3: Range of linguistic variable

	Adaption gain
S(small)	-0.4167 0 0.4167
M(medium)	-0.00926 0.4074 0.8241
L(large)	0.5833 1 1.417

Table 5. 4: Range of adaptation gain

The input to fuzzy controller is e and $\frac{de}{dt}$.the membership functions are given

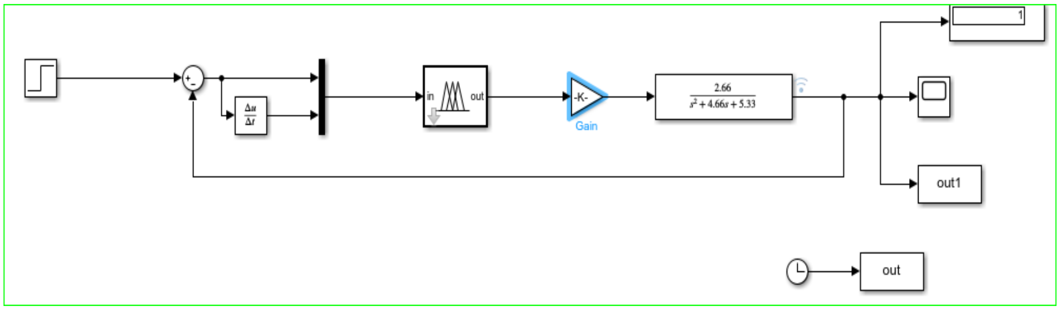


Figure5.6. design and model of system fuzzy logic controller of the plant.

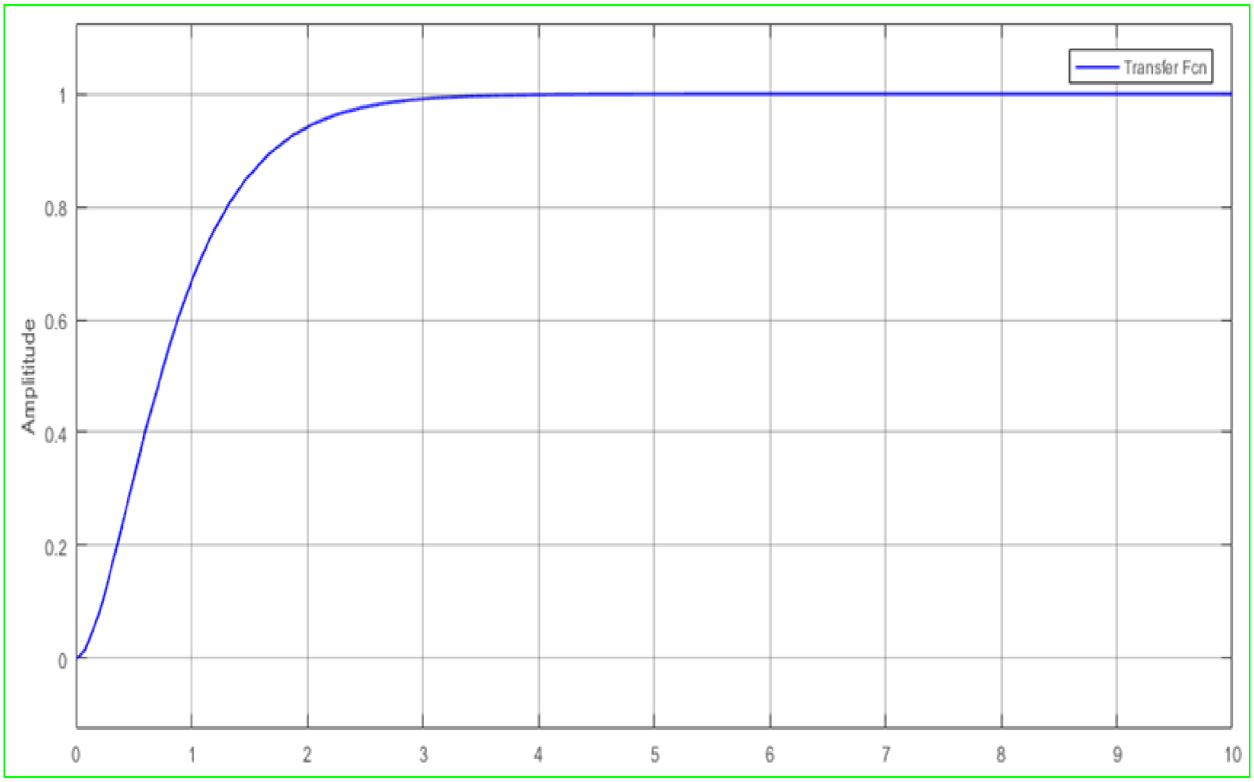


Figure 5.7. Simulation plot of system fuzzy logic controller of the plant

The most popular approach of control is fuzzy logic control. As a result, the wind turbine blade pitch angle has been successfully regulated utilizing the fuzzy controller. As a result, output power stability and aerodynamic braking are successfully achieved.

We favor the fuzzy controller because it is effective at adjusting to system changes. As a result, any changes to the system parameters that may occur during this time will have no effect on the control system's performance. Furthermore, the disadvantages of fuzzy controller compensate for nonlinear system-related control challenges or it was always updates when starts working and the result stability of the system and error reduction is not good. Because more over shoot and more settling time.

Fuzzy logic controllers are listed in the following table.

1	Raise time	1.4843
2	Settling time	2.5741
3	Settling minimum	0.91600
4	Setting maximum	0.2977
5	Over shoot	0
6	Under shoot	0
7	Peak	0.91600
8	Peak time	10
9	Steady state error	0

Table 5. 5: Shows the time domain specifications for input with a wind turbine pitch control fuzzy logic controller.

5.3 Simulation of fuzzy based adaptive controller design

The output fuzzy value is converted to a crisp value using the defuzzification process. Using a reference model, expected results for the plant under management. Taking measures to correct for system disturbances and changes leads to system performance. The fuzzy based adaptive controller/ fuzzy based MRAC simulation is as follows:

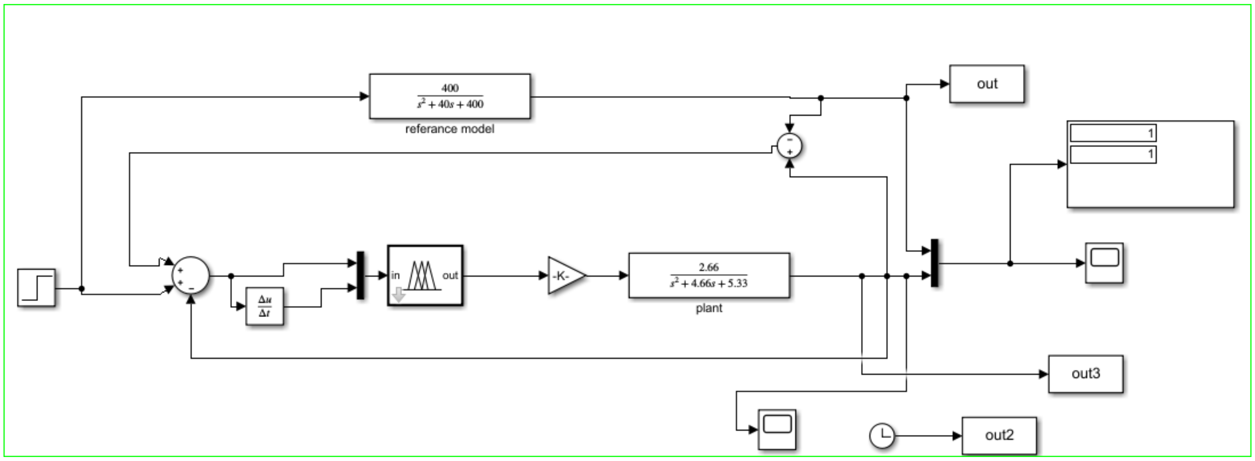


Figure 5.8 Design fuzzy logic based adaptive controller of wind turbine pitch angle control(reference and plant transfer function)

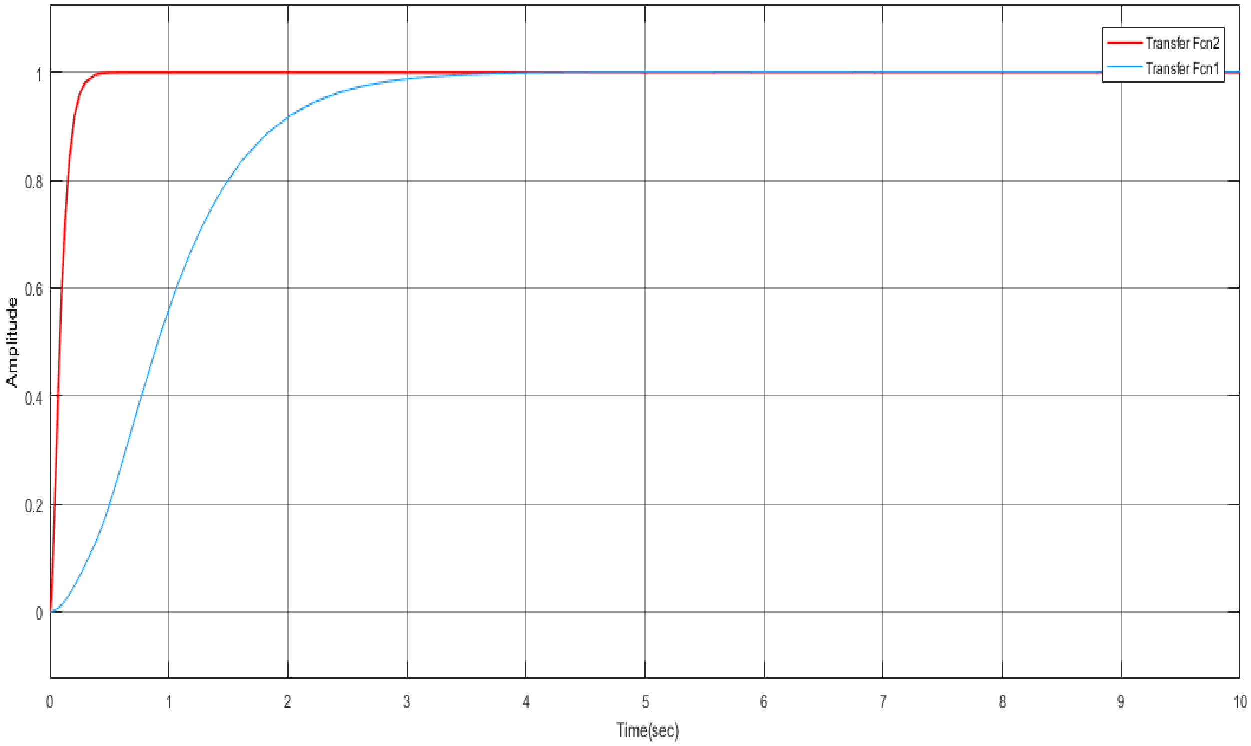


Figure 5.9 .Simulation plot of system fuzzy logic based adaptive controller of the design

The goal of this study/simulation result aims to create a Model Reference Adaptive Controller that is based on a Fuzzy Logic Controller (FLC). It consists of a Model Reference Versatile Control (MRAC) plot and a Fuzzy Logic Controller (FLC). The objective is to run the plant using MRAC and a suitable one reference model. while also controlling it using FLC. The controller in a traditional MRAC scheme is meant to ensure that plant output converges to reference model output based on a linear plant. This approach is for effectively regulating a linear plant with unknown parameters. As result, it is difficult to manage a nonlinear system in real time using the MRAC technique. To solve the difficulty, it is proposed in this thesis to include an FLC in the MRAC system. The total of the outputs of MRAC and FLC is used as the control input. Simulations demonstrate the effectiveness of the proposed control mechanism. The suggested FLB-MRAC can significantly improve the system's behavior by forcing it to follow the reference model and minimizing the model-to-plant output error.

Fuzzy logic-based adaptive controller are shown in the following table.

1	Raise time(sec)	1.4800
2	Settling time(sec)	2.5725
3	Settling min	0.9100
4	Settling max	1.0000
5	Over shoot	0
6	Under shoot	0
7	Peak	1.0000
8	Peak time(sec)	10
9	steady state error	0

Table 5. 6: specifies the time domain requirements for a fuzzy logic-based adaptive or fuzzy logic-based model reference adaptive controller for wind turbine pitch control.

5.4 Comparison of wind turbine pitch angle control by MIT, Lyapunov, fuzzy logic controller and fuzzy based adaptive controller

Figure 9 and table 5.5 depicts the unit step response of a wind turbine pitch control system. The reaction graphs reveal time domain specifications, which are reported in Table 9. We found that the Fuzzy based adaptive controller has a shorter settling time (2.5725 sec), settling minimum less time(0.9100), and a faster rise time in seconds (1.4800) of the stable the system or controlling the system. On the other hand, there is not one of them superior to each other and the same nonlinear system to linearize. Fuzzy based adaptive controller the better to control is called fuzzy logic based adaptive control.

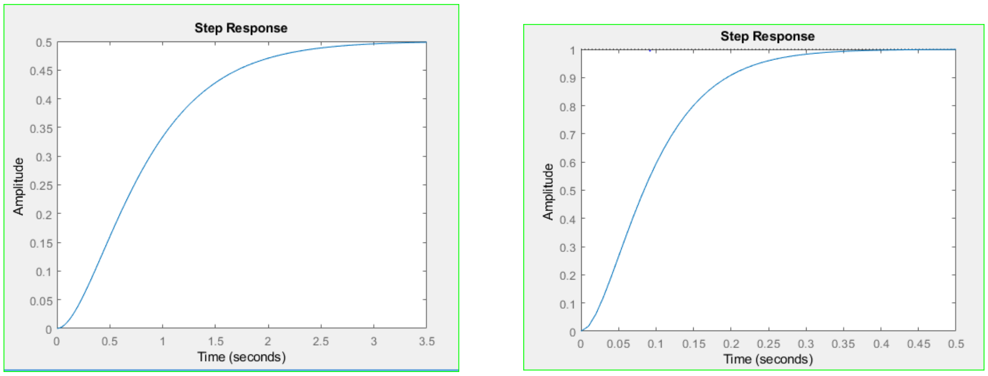
We get more energy from wind energy when the wind speed and time are varied for the reduction error.

		MIT	Lyapunov	FLC	FLBAC
1	Raise time(sec)	25.4559	0.177	1.4743	1.4800
2	Settling time(sec)	39.0522	0.2968	2.5741	2.5725
3	Settling min	0.9012	0.9402	0.91600	0.9100
4	Settling max	1.00	1.004	1.00	1.000
5	Over shoot	0	0.037	0	0
6	Under shoot	8.639e-75	0	0	0
7	Peak	1	1.004	1	1
8	Peak time(sec)	80	6.9859	10	10
9	persistent steady state error	0	0	0	0

Table 5. 7: Comparison MIT, Lyapunov, fuzzy controllers: fuzzy logic and fuzzy based adaptive

The following graphs from the matlab software specify the frequency, pole, damp, and time constant domains for unit step input without a FLC and an FLBAC for the model and the plant.

```
num=[2.667];                                  num=[400]
den=[1 4.667 5.333];                            den=[1 40 400];

sys=tf(num,den)                                sys=tf(num,den)

sys=                                           sys=

2.667/s^2+4.667s+5.333                                  400/1s^2+40s+400

Continuous time transfer function                        continuous transfer function

step(sys)                                               step(sys)
```



a) plant/process b) reference model

Figure 5.10 The r/n between reference model and plant/process

Damp(sys)

a)plant				b) reference model			
Pole	Damp	Frequency	Time constant	Pole	Damp	Frequency	Time constant
-2.00e+oo	1.00e+00	2.00e+00	5.00e-01	-2.00e+oo	1.00e+00	2.00e+00	5.00e-01
-2.67e+oo	1.00e+00	2.67e+00	3.75e-01	-2.00e+oo	1.00e+00	2.00e+00	5.00e-01

Table 5. 8: The relation between reference model and plant/process.

From table 5.8 by mat lab plot graphs the model reference better than plant /pitch control of the system. Because, the model reference is more stable before controlling showing the graph. an other hand ,plant/pitch control system have nonlinear ,there no unit step response and reference model have better unit step response/good linearity known.

5.5. Wind Turbine Power probability, power coefficient, and Curve and Their Applications in Wind Based Energy Systems

A wind turbine's power curve shows the relationship between output power and hub height wind speed, and is an important feature of the turbine. The power curve is used for energy assessment, warranty for. Simulation, and turbine performance monitoring. The power curve depicts a WT's power response to different wind speeds. Curve models that are accurate are valuable in a variety of wind energy applications. From chapter 3 and 4 the dynamic modeling control curve power program for the variable speed. With time varying shown chapter 5 with simulation.

CHAPTER 6

6 .Conclusion and future work

6.1 CONCLUSIONS

The dynamic performance of the mechanical, electrical, and aerodynamic components of an unique variable pitch, variable speed wind turbine outfitted with a permanent magnet synchronous generator and motor was researched or simulated using MATLAB/Simulink to validate 1 MW wind turbine. The MIT rule and Lyapunov rule based FLC and FLB MRAC for wind turbine pitch angle controller are designed in this thesis. When the wind's velocity fluctuates between cut in and cut out, I used a pitch angle controller to control the turbine's power output. I look at types of these controllers in this thesis better selected FLBMRAC. In In order to enhance the wind energy conversion system's performance and stability.

Whereas the FLBMRAC-pitch angle controller is designed and compared to a fuzzy logic controller/as explained controllers of pitch angle, the FLBMRAC- The stability of the output power may be better maintained using a pitch angle controller and has enhanced dynamic characteristics. I examined the answers for unit step using MIT, Lyapunov, fuzzy logic controllers and adaptive controllers using fuzzy logic in terms of time domain requirements and It oscillates with a zero peak overshoot during the rising time, adding the product to the system's performance. The FLBRMAC pitch angle controller is used to increase the stability of the energy conversion system for wind turbines. Based on our findings, we believe that the FLBMRAC controller has a relatively fast response time and that this technique is far superior for pitch system management and ensuring wind turbine output power stability.

Future work

Nuero fuzzy adaptive or ANFIS will be used in the future to control the wind turbine systems' pitch angle and evaluate their performance with the FLBAC/FLBMRAC controller. Also, the use of the grid side converter control and individual pitch control techniques to enhance the system's overall performance. and Together with the other FLBAC controllers, this controller's hardware WECS implementation can improve the system's overall performance.

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Appendix

1. Parameters of Wind Turbine

Require material with symbol	Measurement and used for design parameter	Parameters unit
Power rating for generators, Pg	1Mw	Watts
Generator speed, Wg, when rated	1500 rpm	Revolution per minutes
Rated turning speed of rotor, Wt	20 rpm	Revolution per minutes
Wind turbine blade radius , R	50m	Meters
Reference pitch angle, βd	0 to 90 deg	Degree
Rate of change of pitch angle , $d\beta/dt$	0.6 deg/sec	Degree per second
Control accuracy of pitch angle, (β_d-β)	0.30 degre	Degree
Damping coefficient, B	2 N.m/rad/sec	Newton product of metres and radius pr second
Drive train inertia ,Jt	0.75 N.m^2	Newton per meters square

2. the parameters used to model the drive train are listed.

Parameter	Description	Parameter	Description
J_T	Wind turbine inertia (kg. m^2)	W_T	Wind turbine shaft speed, (rad/sec)
G_T	Generator inertia, (kg. m^2)	Wg	Generator shaft speed ,(rad/se)
Ks	Stiffness coefficient N.m/rad	θ_T	Wind turbine shaft angle ,(rad)
B	Damper coefficient, (N.m/rad/sec)	θ_g	Generator shaft angle,(rad)
T_T	Wind turbine torque,(N.m)	$1:n_{gear}$	Gear ratio
T_G	Generator electro machine torque,(N.m)	β	Pitch angle
Pm	Mechanical power		
. λ	The tip speed ratio		
P	the power of the wind		