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DESIGN OF ECO GREEN WIND TURBIN USING FUZZY LOGIC ON SAHARA DESERT

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Abstract

In development of wind turbine, the government of Libya has assignment Libya electric co. To develop wind turbine in Sahara Desert beginning of 2001. The officer the took a surveying of wind speed and the environment of the Sahara Desert. The surveying has shown that wind speed of Sahara Desert is class 4 and 5. Therefore is suitable to develop wind turbine to produce electrical power for RL (Resistor Load). Based on the argument above, so this research entitled: "Analysis Of Eco Green Wind Turbine Design For Sahara Desert Using Fuzzy Logic". The objectives of this research are: to design and development of eco green vertical axis wind turbines (VAWT) in Sahara Desert, to analysis of suitable eco green vertical axis wind turbines (VAWT) in Sahara Desert using MATLAB and to analysis of how fuzzy logic use in wind turbine design. Research model used input process in Matlab simulation and output is the design and analysis of efficiency wind turbines.

Keywords **:** *Data acquisition system Fuzzy logic*, *Practical measurement*

1. Introduction

In development of wind turbine, the government of Libya has assignment Libya electric co. To develop wind turbine in Sahara Desert beginning of 2001. The officer the took a surveying of wind speed and the environment of the Sahara Desert. The surveying has shown that wind speed of Sahara Desert is class 4 and 5. Therefore is suitable to develop wind turbine to produce electrical power for RL (Resistor Load).[1]

The development wind turbine in Sahara Desert also done by the power has 30 in and the blade has 40 in of length. Thus, wind turbine could produce 2 MW. However, cost maintenance for oil gear is the due to wind is mixing by sands that damage the oil quantity. [2]

Sustainable energy is to provide the energy that meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable energy has two components: renewable energy and energy efficiency. Renewable energy uses renewable sources such biomass, wind, sun, waves, tides and geothermal heat. Renewable energy systems include wind power, solar power, wave power, geothermal power, tidal power and biomass-based power. Renewable energy sources, such as wind, ocean waves, solar flux and biomass, offer emissions-free production of electricity and heat.

An eco green analysis of a wind turbine involves a study of the energy flows over its entire life. This includes the embodied energy associated with the manufacturing process and subsequent replacement and repair of components; the energy required for operation, maintenance and disposal; and the energy generated by the turbine over its entire life. Traditionally, the energy output has been the focus of studies dealing with the life-cycle energy of wind turbines. This may be partly due to conceptual failure in quantifying the life-cycle energy requirements of these systems through underestimating the possible importance of embodied energy. Embodied energy is particularly important due to the complexity of the supply chain. This complexity means that the supply chain has to be modelled for each product and process upstream to the raw materials [3].

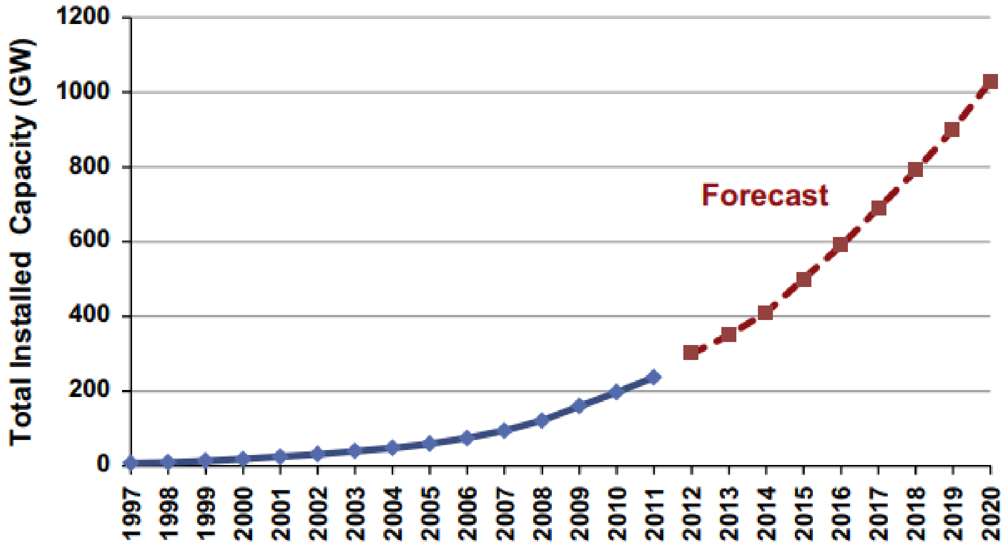


Fig. 1.1. Wind energy: global capacity (blue) and forecast (red) [3]

The development of cleaner and efficient energy technologies and the use of new and renewable energy sources will play an important role in the sustainable development of a future energy strategy. Power generation from wind turbine is a renewable and sustainable energy but in a life cycle perspective wind turbine consumes energy resources and causes emissions during the production of raw materials, manufacturing process, transportation of small and large parts of the wind turbines, maintenance, and disposal of the parts at the end life of the turbines. To determine the impacts of power generation using wind turbine, all components needed for the production of electricity should be include in the analysis including the tower, nacelle, rotor, foundation and transmission. In eco green wind turbine design, the materials are energy intensive with high embodies energy and carbon foot print, the material choice impacts the energy and CO2 for the manufacturing process, the material impacts the weight of the product and its thermal and electric characteristics and the energy it consumes during the use; and the material choice also impacts the potential for recycling or energy recovery at the end of life. The eco aware wind turbine design has two-part strategy: (1) Eco Audit: quick and approximate assessment of the distribution of energy demand and carbon emission over a product's life; and (2) material selection to minimize the energy and carbon over the full life, balancing the influence of the choice over each phase of the life (selection strategies and eco informed material selection) [3].

The problem is Libya wind turbine is not deployment yet, however wind potential has been already in Libya. Its needs some effort to conduct a research of wind turbine analysis in Sahara Desert. Therefore, a deeply analysis is needed to provide information accurately regarding design, installation and development of VAWT that suitable for Sahara Desert environment. An analysis study is conducted to perform this research by using simulation analysis. Choose VAWT than HAWT because it has the advantage of having high torque so that it can rotate at low wind speeds, the generator can be placed at the bottom of the turbine so as to facilitate maintenance and work of the turbine not affected by wind direction.

Impact of the problem is people need electricity in the country of Libya, with a total population of 6 million people, so need repetition. Electricity consumption at 1 KVA = 1,600 VA and 1 MVA = 1,000,000 VA. If 1 family consists of father, mother, and 2 children, the usage used is 1,300 VA or equivalent to 10 KVA with a yield of 2,400 W. Minimum use of 5 MVA using Win Turbine. To overcome the problem above by using software engineering using fuzzy logic methods and MATLAB methods this is the solution.

The objectives of this research are:(1)To design and development of eco green vertical axis wind turbines (VAWT) in Sahara Desert include the capital of wind turbin. (2)To analysis of suitable eco green vertical axis wind turbines (VAWT) in Sahara Desert using MATLAB. (3)To maintain the precision wind turbine design for desert environment.

1. RESEARCH METHOD

In this research will make input data wind speed, after that data environment, corrosion, materials. The process consists of develop VAWT, design, analyze, simulate (MATLAB), mini experience and life cycle analysis. After that the last step is output result of design, analysis, simulation, observation and eco green, after that we can see the efficiency and make conclusion based on the result.

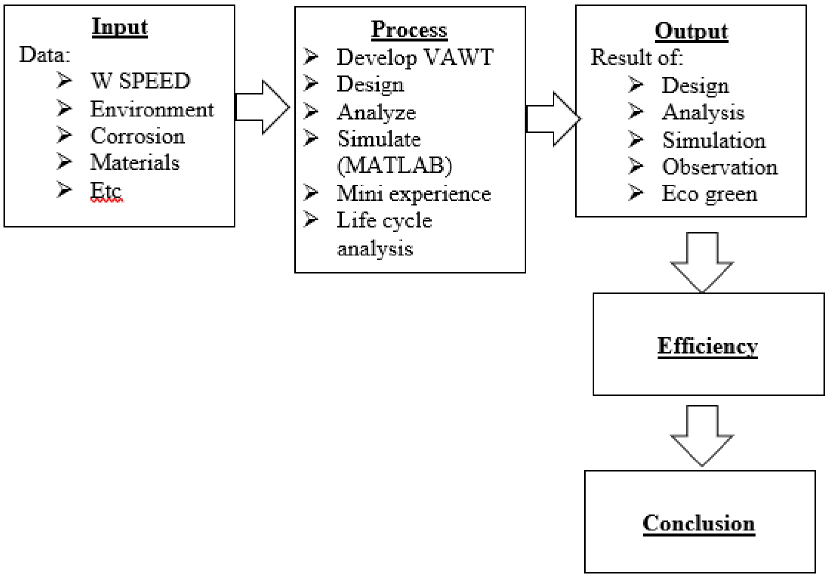


Figure 3.1. System Model/ Proposed Methods

Based on the research model above, it can be say that the input data is W Speed, environment, corrosion, materials and the process is develop VAWT, design, analyze and simulate (MATLAB), make mini experience and life cycle analysis. Output result are design, analysis, simulation, observation and eco green, to reach efficiency and conclusion.

2.1. Tools and materials used

Tools or material used is the simulation of Fuzzy Logic and analysis using Matlab program, the data are about the wind turbine and also the W Speed and mini experience. The specific problems investigated here include diagnosis of critical tool wear in machining of metals via a neuro-fuzzy algorithm, as well as compensation of friction in mechanical positioning systems via an adaptive fuzzy logic algorithm. The results indicate that fuzzy logic in conjunction with conventional algorithmic based approaches or neural nets can prove useful in dealing with the intricacies of control/monitoring of manufacturing systems and can potentially play an active role in multi-modal integrated control systems of the future.

2.2. Research procedure

Wind turbine design is the process of defining the form and specifications of a wind turbine to extract energy from the wind [12]. A wind turbine installation consists of the necessary systems needed to capture the wind's energy, point the turbine into the wind, convert mechanical rotation into electrical power, and other systems to start, stop, and control the turbine. Parameters in this research are W SPEED, environment, corrosion, materials. The process fuzzification are Develop VAWT, design, analyze, simulate (MATLAB), Mini experience, Life cycle analysis. The variables of output are: design, analysis, simulation, observation and eco green. In Figure 3.3, structure of fuzzy control is shown. A fuzzy controller usually contains four main components: Fuzzifier, fuzzy rule base, inference engine and Defuzzifier. The Fuzzifier changes the input (crisp signals) into fuzzy values. The fuzzy rule base consists of basic data and linguistic rules. The engine is the brain of a fuzzy controller which ability to simulate the human decision based on finally, the second transformation converts values into the real values [14].

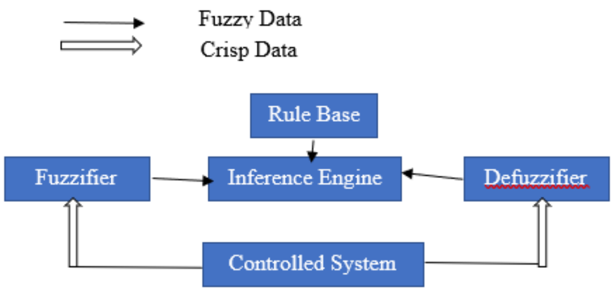


Figure 3.3. Fuzzy inference system

2.3. Methodology

1.Membership Function

Fuzzy sets enter the inference engine which maps the input values using normalized membership functions. The fuzzy-logic inference engine deduces the proper control action based on the available rule base. The fuzzy control action is translated to the proper crisp value through the defuzzifier using normalized membership functions. For implementation of fuzzy values into the models, the fuzzy logic toolbox from MATLAB was used. For prediction of power generation from the wind turbine by using Fuzzy expert system (FES), wind velocity (WV) and chord length of the blade (BC) were used as input parameters and wind power generation (WP) was used as output. For fuzzification of these factors the linguistic variables very low (VL), low (L), medium (M), high (H), and very high (VH) were used for the inputs and output. In this study, the center of gravity (Centroid) method for defuzzification was used because these operators assure a linear interpolation of the output between the rules. The units of the used factors were WV (m/s), BC (m), and WP (W)

2. Rules

The plant control is inferred from the two state variables, error (e) and change in error Δe. The control rules are designed to assign a fuzzy set of the control input u for each combination of fuzzy sets of e and Δe. Table 3.1 shows the rules base. Each pair (e, Δe) determines the output level corresponding [15- 16].

3.Defuzzification

After determining the parameters, so the next step is to make Defuzzification as follows:

4. Inference

Fuzzy set theory is an artificial intelligence technique that makes use of fuzzy sets and fuzzy 'linguistic' rules to incorporate this uncertainty into the model. Classical set theory can be extended to handle partial memberships, enabling to express vague human concepts using fuzzy sets and also describe the corresponding inference systems based on fuzzy rules. Defuzzification operates on the implied fuzzy sets produced by the inference mechanism and combines their effects to provide the "most certain" controller output (plant input). Then the one output denoted by "WP crisp" can be calculated that best represents the conclusions of the fuzzy controller that are represented with the implied fuzzy sets. Due to its popularity, the "center of gravity" (COG) defuzzification method is used for combing the recommendations represented by the implied fuzzy sets from all the rules

2. RESULTS AND ANALYSIS

3.1. Calculation Wind Turbine of Sahara Dessert using Fuzzy Logic

Table 3.1. Data

1.	Population	6.800.000
2.	Consumption	10020 MW
3.	Production	4350 MW
4.	Production deficit	5500 MW
5.	Turbine production approx.	12 KW

Knowing that 1 MW is enough for 300 to 400 homes

1) How much does one house consume?
1 MW you run home 300 to 400 homes
$\frac{1.000.000\ W}{350\ homes} = 2857\ W = 2860\ W$ for every home
2) How many home in Libya?
As each home consumes 2860 W and the total consumption 10020 MW.
$\frac{10.020.000\ W}{2860\ W} = 3.503 = 3.504.000$ homes
3) How much do we need a wind turbine to produce 1 MW ?
A single turbine yields about 12 KW
$\frac{1.000.000\ W}{12.000\ W} = 83,3 = 84$ turbine
4) How much wind turbine we need in case of overload?
The average output per turbine is approximately 8KW.
$\frac{1.000.000\ W}{8000\ W} = 125$ turbine
125 – 84 = 41 extra turbine
5) How much land do we need to install wind turbine?
1 turbine need around 100 m^2 so 125 turbine will need 12.500 m^2 of land.
Data: Turbine output rate from electricity:
100% : 12KW
50% : 8 KW
30% : 6KW

3.2. Result

Based on the model of research shown in Figure 3.1 and data input shown in Table 4.1 until table 4.3

Table 4.1. Data Input

Parameter Input		
Material	**Temperature (T)**	**Humidity (H)**
Iron	30	10
Steel	20	15
Fiber	10	20
Carbon	15	25

Table 4.2. Data Input

Parameter Input	
Type	**Size**
Manual	Small
Manual	Medium
Electric	Big

Table 4.3. Rules

INPUT		OUTPUT	
Gearbox	Transmission	Materials	VAWT
Manual	V-Belt	Steel	STABLE
Manual	V-Belt	Iron	BAD
Manual	V-Belt	Aluminum	GOOD
Electric	V-Belt	Steel	FAIR
Gearbox	Transmission	Materials	VAWT
Manual	V-Belt	Steel	STABLE
Manual	V-Belt	Iron	BAD
Manual	V-Belt	Aluminum	GOOD
Manual	V-Belt	Aluminum	GOOD
Manual	V-Belt	Iron	GOOD
Electric	V-Belt	Steel	FAIR
Electric	V-Belt	Steel	VAWT
Electric	V-Belt	Iron	FAIR
Electric	V-Belt	Steel	VAWT
Manual	V-Belt	Aluminum	GOOD

The Fuzzy Logic Toolbox is a collection of functions built on the MATLAB numeric computing environment. It provides tools to create and edit fuzzy inference systems within the framework of MATLAB, or integrate fuzzy systems into simulations with Simulink. This toolbox relies heavily on graphical user interface (GUI) tools, and provides three categories of tools: Command line functions, Graphical interactive tools, and Simulink blocks and examples. There are five primary GUI tools for building, editing, and observing fuzzy inference systems in the Fuzzy Logic Toolbox: the Fuzzy Inference System or FIS Editor, the Membership Function Editor, the Rule Editor, the Rule Viewer, and the Surface Viewer as demonstrated.

3.2.1.MF (Membership Function)

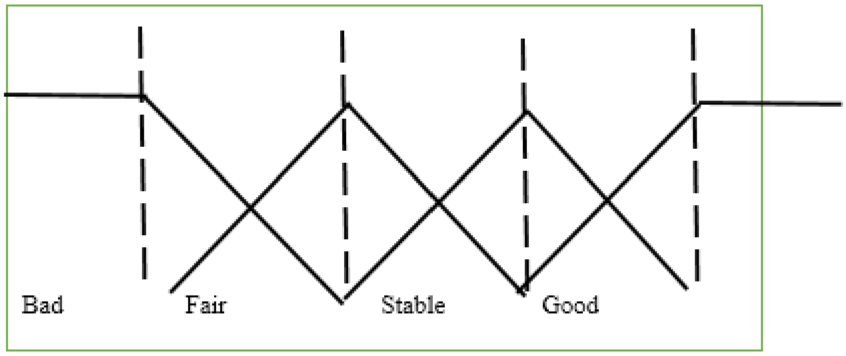


Figure 4.1. Membership functions of the two entries: $Input_1$, input2, and the output, with three sets of linguistic variables

It is propose that the membership functions of the inputs and output be defined in terms of a set of language variables:

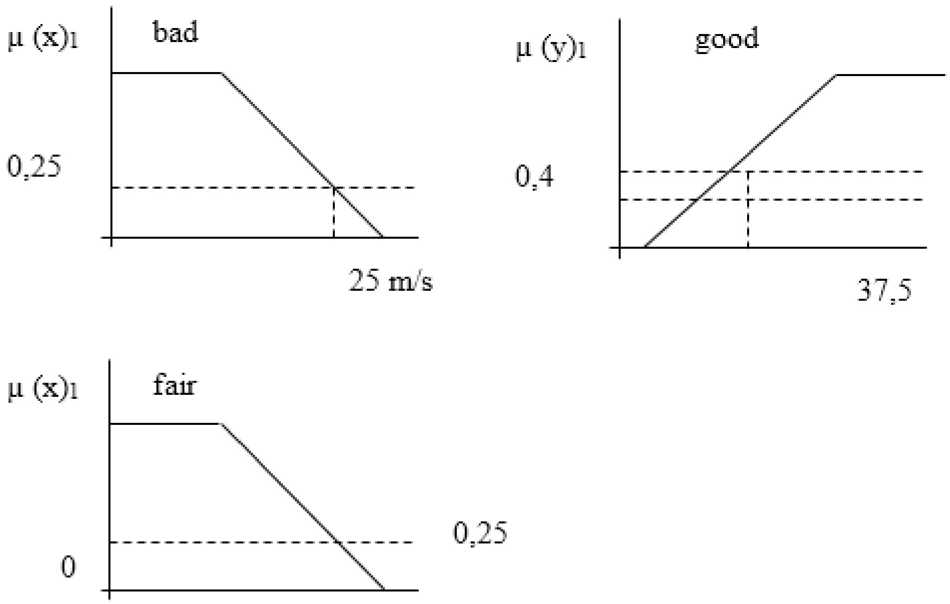
1. $Input_1$: T: Temperature, H: Humidity, M: Materials.
2. $Input_2$: G: Gearbox, Tr: Transmission,V:V-Belt.
3. Output: B: Bad, F: Fair, G:Good.

The real values of input1, input2, and output are multiplied by a scaling factor for inputs. The input scaling factor was conceived in this framework as follows:

- $Input_1$ values are between 0 and25 → wind speeds
- $Input_2$ values are between 25 and 50 → wind speeds
- Output values are between 50 and 75 → wind speeds

The Inference Method

After evaluation of an exhaustive number of input variables combinations and evaluation of the corresponding outputs, and recommendation of inference rules for judgment. The inference methods as follows:



Inteference methods
STEEL:
R_1 If steel wind speed < 25 and heuredity < 50% then bad
R_2 If steel wind speed < 25 and heuredity < 50% then fair
R_3 If steel wind speed < 50 and heuredity < 25% then fair
R_4 If steel wind speed < 75 and heuredity < 50% then good
IRON:
R_1 If steel wind speed < 25 and heuredity < 50% then bad
R_2 If steel wind speed < 25 and heuredity < 50% then fair
R_3 If steel wind speed < 50 and heuredity < 25% then fair
R_4 If steel wind speed < 75 and heuredity < 50% then good
FIBER:
R_1 If steel wind speed < 25 and heuredity < 50% then bad
R_2 If steel wind speed < 25 and heuredity < 50% then fair
R_3 If steel wind speed < 50 and heuredity < 25% then fair
R_4 If steel wind speed < 75 and heuredity < 50% then good

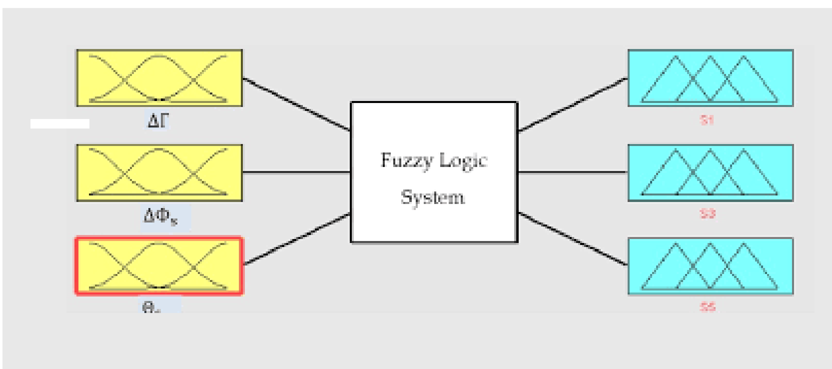


Figure 4.2. MATLAB representation of the fuzzy logic controller

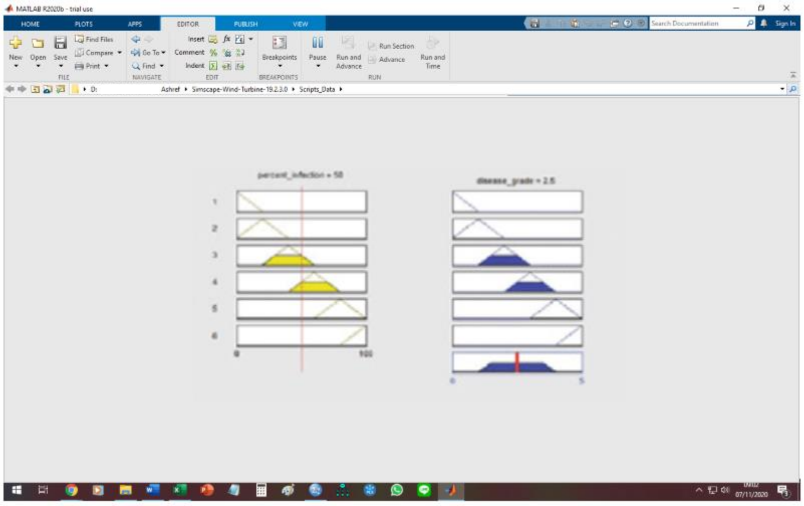


Figure 4.3. Output values depending on possible combinations of Input variables;

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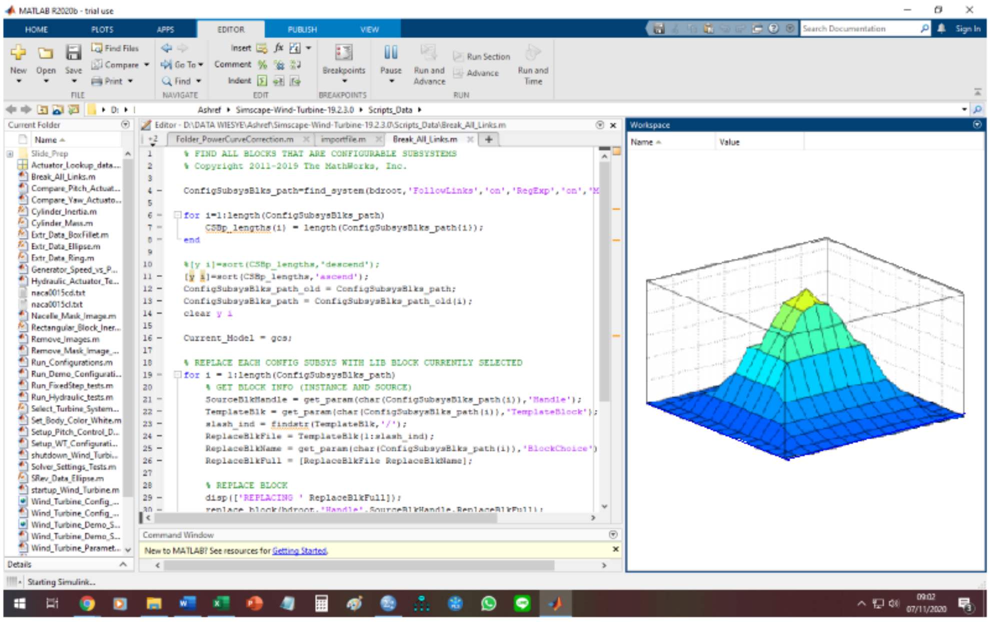

Figure 4.4. The Surface Viewer of output Matlab

3.2.3. Rules

There are rules, as follows:

R_1 : IF size is small and weight is small THEN quality is bad, also
R_2 : IF size is small and weight is small THEN quality is medium, also
R_3 : IF size is small and weight is small THEN quality is medium, also
R_4 : IF size is small and weight is small THEN quality is also, also
R_1 : IF size is small and weight is small THEN quality is bad, also
R_2 : IF size is small and weight is small THEN quality is medium, also
R_3 : IF size is small and weight is small THEN quality is medium, also
R_4 : IF size is small and weight is small THEN quality is also, also
R_1 : IF size is small and weight is small THEN quality is bad, also
R_2 : IF size is small and weight is small THEN quality is medium, also
R_3 : IF size is small and weight is small THEN quality is medium, also
R_4 : IF size is small and weight is small THEN quality is also, also
R_1 : $h_1 = \min(\mu_{small}(2), \mu_{small}(25)) = \min(0.8, 0.75) = 0.75$
R_2 : $h_2 = \min(\mu_{small}(2), \mu_{small}(25)) = \min(0.8, 0.75) = 0.25$
R_3 : $h_3 = \min(\mu_{small}(2), \mu_{small}(25)) = \min(0.2, 0.75) = 0.2$
R_4 : $h_4 = \min(\mu_{small}(2), \mu_{small}(25)) = \min(0.2, 0.75) = 0.2$
R_1 : $h_1 = \min(\mu_{small}(2), \mu_{small}(25)) = \min(0.8, 0.75) = 0.75$

R_2 : h_2 = min (μ_{small} (2), μ_{small} (25)) = min (0.8, 0.75) = 0.25
R_3 : h_3 = min (μ_{small} (2), μ_{small} (25)) = min (0.2, 0.75) = 0.2
R_4 : h_4 = min (μ_{small} (2), μ_{small} (25)) = min (0.2, 0.75) = 0.2
R_1 : μB_1 = min (μ_{small} (h_1, μB_1(y)) = min (0.75, μ_{bad} (y))
R_2 : μB_2 = min (μ_{small} (h_1, μB_1(y)) = min (0.75, μ_{medium} (y))
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R_3 : μB_3 = min (μ_{small} (h_1, μB_1(y)) = min (0.75, μ_{medium} (y))
R_4 : μB_4 = min (μ_{small} (h_1, μB_1(y)) = min (0.75, μ_{good} (y))
R_1 : IF size is small and weight is medium THEN quality is bad, also
R_2 : IF size is small and weight is bad THEN quality is medium, also
R_3 : IF size is small and weight is small THEN quality is medium, also
R_4 : IF size is small and weight is good THEN quality is also, also
R_1 : IF size is small and weight is good THEN quality is bad, also
R_2 : IF size is small and weight is medium THEN quality is medium, also
R_3 : IF size is small and weight is medium THEN quality is medium, also
R_4 : IF size is small and weight is bad THEN quality is also, also
R_1 : IF size is small and weight is good THEN quality is bad, also
R_2 : IF size is small and weight is medium THEN quality is medium, also
R_3 : IF size is small and weight is medium THEN quality is medium, also
R_4 : IF size is small and weight is bad THEN quality is also, also
R_1 : IF size is small and weight is good THEN quality is bad, also
R_2 : IF size is small and weight is medium THEN quality is medium, also
R_3 : IF size is small and weight is medium THEN quality is medium, also
R_4 : IF size is small and weight is bad THEN quality is also, also
R_1 : h_1 = min (μ_{small} (2), μ_{bad} (25)) = min (0.8, 0.75) = 0.75
R_2 : h_2 = min (μ_{small} (2), μ_{bad} (25)) = min (0.8, 0.75) = 0.25
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R_2 : h_2 = min (μ_{small} (2), μ_{good} (25)) = min (0.8, 0.75) = 0.25
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R_2 : μB_2 = min (μ_{small} (h_1, μB_1(y)) = min (0.75, μ_{medium} (y))
R_3 : μB_3 = min (μ_{small} (h_1, μB_1(y)) = min (0.75, μ_{good} (y))
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R_2 : μB_2 = min (μ_{small} (h_1, μB_1(y)) = min (0.75, μ_{bad} (y))
R_3 : μB_3 = min (μ_{small} (h_1, μB_1(y)) = min (0.75, μ_{medium} (y))
R_4 : μB_4 = min (μ_{small} (h_1, μB_1(y)) = min (0.75, μ_{good} (y))

3.2.4. Output Values

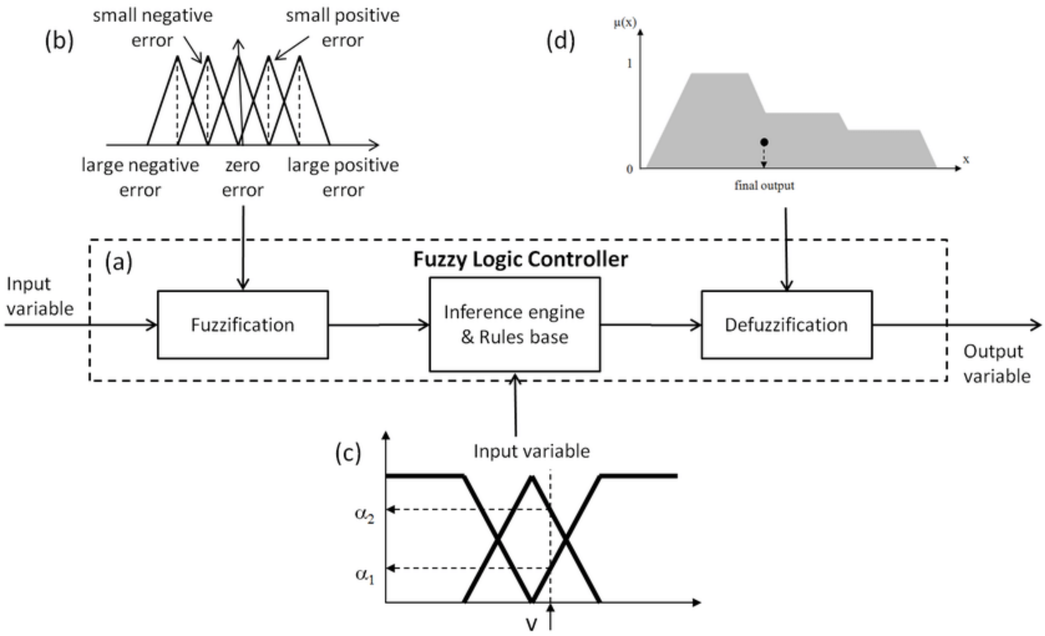


Figure 4.5. Output Values – Fuzzy Logic Controller 1

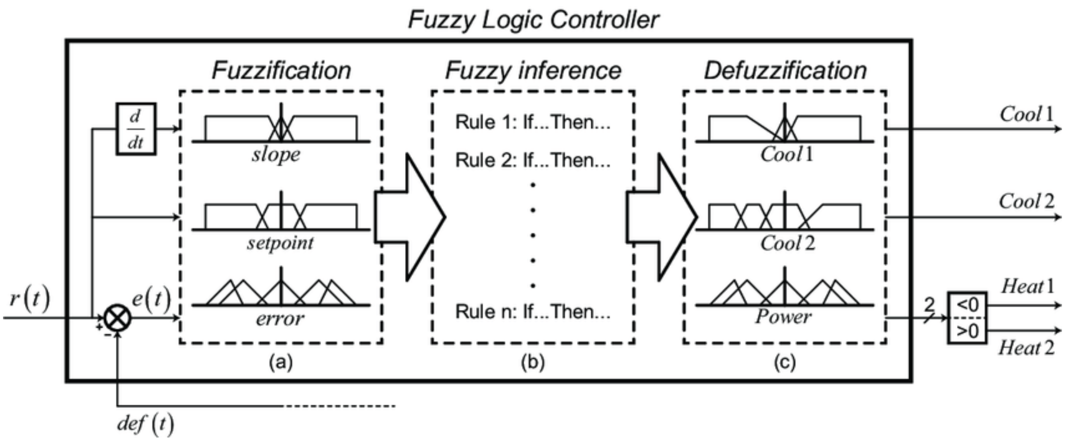


Figure 4.5. Output Value - Fuzzy Logic Controller 2

From the fuzzy logic controller and rules, so the output value as follows:

Simulations were carried out with a 3kW PMSG-based WECS which has the optimal power coefficient Cpmax=0.48 and the optimal tip-speed ratio λ=8.1. Control performances of both PI and FUZZY Controllers are compared in parallel.

Both of the two methods track the output reference adequately. The FLC provides better tracking than the PI controller. Two important factors show the efficiency of the power conversion: the power coefficient maintenance and the tip-speed ratio maintenance under wind speed fluctuations. The FLC shows better performances better than PI controller in optimizing the power conversion. The PI controller stays oscillating around optimal values. The FLC keeps the optimal power coefficient and tip-speed ratio values constant after transient time. It is clear that the maximum power extraction control works very well where the value of power coefficient was kept at optimum value of power coefficient Cp-opt which equals 0.48 with varying wind speed.

3.2.5. Fuzzification

The table below shows the data Fuzzification of this research:

Table 4.4. Data Fuzzification

0	0	0	0
0	0	0	1
0	0	1	0
0	1	0	0
0	1	0	1

0	1	1	1
1	0	0	0

After determining the parameters, so the next step is to make Defuzzification as follows:

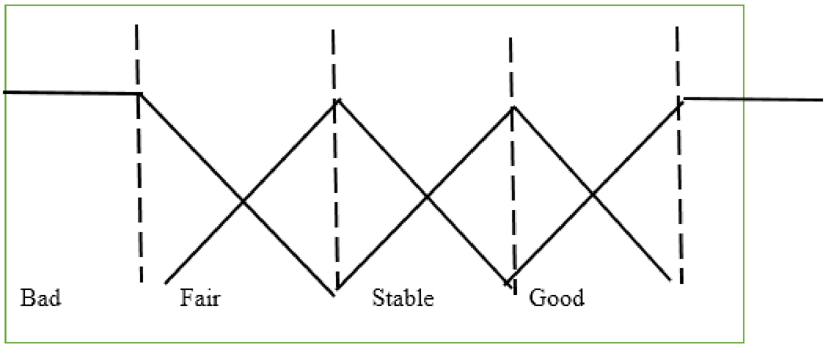


Figure 4.8. Defuzzification

Defuzzification The criteria: Bad < 25, Fair <50, Good > 75.

3.3.Design and development of eco green vertical axis wind turbines (VAWT) in Sahara Desert.

A. Overview

The tests were conducted outside, in a 4 m wide, and approximately 50 m long road between a three and a four building. The location, which constitutes something like an outdoor wind tunnel. Flow visualization tests indicated a nearly unidirectional flow at the test site.

B. Power and efficiency

In this section, the experimental results will be shown as original and non-dimensional data. The load had to be pre-set, and the wind speed could not be controlled. This means that every test run contains a multitude of conditions. In order to identify the main system characteristics, it was therefore decided to show not just power out against wind speed and efficiency against non-dimensional blade speed, but also the relationships of actual and non-dimensional parameters. the power generated as a function of wind speed for both geometries. For wind speeds of more than 3 m/s, the power generation for Geometry 2 is twice as high as that for Geometry 1. The efficiency graphs confirm the better power conversion for higher wind and runner velocities. The efficiencies for Geometry 2 reach 0.48 for a wind speed of 1.4 m/s, 0.40 for 2.5 m/s and 0.2 for 5 m/s. Fig. 3 shows the power output as a function of the blade to wind speed ratio. Geometry 2 indicates a marked increase in power as well as a shift of the point of maximum power from wind speed ratios of vB/vw ¼ 0.8 to 1.

The initial tests, which were conducted with only friction torque applied, resulted in a maximum blade to wind speed ratio of 1.5. The gap between blade and axis was found to be an essential detail of the system. The results from a three blade rotor without gap between blades and axis reported in the literature may also have been influenced by this effect. Numerical work where a larger gap existed, indicated a maximum (free wheeling) blade to wind speed ratio of 5.4, substantially higher than the ratio of 0.44. This supports the argument for the necessity of the gap, although a speed ratio of 5.4 appears to be very high.

Tests were conducted in strong time constraints, only half an afternoon and one morning of wind tunnel time was available to the team. In the tests, the strong horizontal oscillations were noticed, but could not be followed up. The efficiencies in the wind tunnel tests were very low, as were the maximum blade to wind speed ratios with a ratio of 0.3 in the wind tunnel, and 1.5 in the initial outside experiments. This led to the conclusion that vortex shedding and dynamic response occurred in the wind tunnel. The highly variable wind speeds in the outside tests did not allow this effect to develop. So, the more regular and controlled conditions created a condition where unexpected fluid dynamic effects dominated the environment and consequently the measurements. If the results from the outdoor tests had not been available, and if the specific characteristics of the model had not created a visible dynamic response, then these effects would probably have gone unnoticed, and the interpretation of the results may have been misleading

It had been decided to conduct experiments in a narrow channel between two buildings since the costs for tests in a wind tunnel were too high. The disadvantages of outside tests are mainly the variable and unpredictable wind speed, and the uncertainty about wind direction. To some extent the latter factor could be balanced by choosing an appropriate site with temporary unidirectional flow conditions. The measurement system was designed accordingly so that wind speed, runner speed and friction force could be measured simultaneously. The tests resulted in efficiencies 0.45 to 0.5 for wind speed ratios of around 1 to 1.8, and a maximum blade to wind speed ratio of 2.5. This indicates the effect of the deflector, which funnels the air flow into the operating section. The efficiency is however not just a function of the applied torque blade speed ratio, but also of the actual wind speed, reaching a maximum for lower wind speeds and reducing to 0.4 for a wind speed of 5 m/s. This indicates that wind speed related turbulent losses are present. Geometry 2 with a downstream shroud led to a significant improvement of the performance. With efficiencies of up to 0.5, the values from the tests reported here are significantly larger than those reported in the literature (0.15). The experiments reported in the literature were however all conducted in wind tunnels, so that vortex shedding and the associated detrimental effects cannot be excluded. In addition, the effect of a downstream shroud to avoid counteracting forces on the rotor was not considered. In the numerical models it appears that the effect of downstream separation was not included either, which must lead to lower efficiencies.

Operational conditions in a natural environment may affect the performance of a wind turbine. Two aspects, the effect of cross winds or wind components normal to the prevailing wind direction and the effect of wind speeds exceeding the design wind speed will be discussed here briefly: Cross winds or wind vector components normal to the turbine axis can have negative effects on HAWTs, leading e.g. to additional dynamic loadings on the turbine blades. The VAWT described in this article is expected to tolerate large wind vector angles of up to 45 to the rotor channel without additional effects, apart from a reduction in power output. The wind can enter the rotor channel from the deflector side for an angle of 45, from the rotor channel side at even larger angles. Here, the reduction in power would be more significant since a vector component of the air flow points against the direction of rotation. This may need to be addressed by a slight change in geometry.

The turbulence associated with cross winds should not have any significant effect on power generation since the VAWT relies on resistance drag conversion rather than aerodynamic effects. The rotor speed is limited by the design speed of the generator. An further increase of the wind speed above design speed could theoretically be compensated by the rotor speed remaining constant, so that the blade speed ratio and the efficiency reduces. However, say for a 20% wind speed increase the available power would increase by 73% whilst the efficiency only drops by 4%. Reducing the rotor speed further to match the power rating at a lower speed would overload the generator. A solution for this problem could be to turn the shroud, the external hull, slightly out of the wind direction. This will reduce the wind energy input, so that the effective power generated by the rotor and its speed can therefore remain constant. Contrary to HAWT's, stall does not occur for resistance type wind turbines. It can be expected that the turbine will remain operational for wind speeds significantly higher than the design wind speed. The effect of an increased wind speed and an oblique wind angle on flow induced vibrations will need to be assessed in wind tunnel experiments. If the flow induced vibrations are linked to the flow through the rotor, then it may be necessary to shut down operation by turning the outer shroud into the wind direction. In general, the authors expect that the resistance-type VAWT has a wider operational range of wind speeds than airfoil-type VAWTs and HAWTs.

With mechanical efficiencies of 0.5, the resistance VAWT is in interesting alternative to propeller type turbines. A 6 m diameter, 10 m high rotor could produce approximately 30 kW electrical energy for the wind speed of 12.5 m/s. Since the resistance type machines do not rely on aerodynamic uplift, stall e i.e. the sudden loss of uplift under high air flow velocities/high angles of incidence cannot occur. Operation in higher wind speeds may be possible by turning the rotor channel slightly out of the wind as described in the previous section. Also, it can be expected that the effect of turbulence will be small, making the application in built-up areas easier. All these aspects require further investigation. The original System wind mills were built for wind coming from just one direction. The modern VAWTs are envisaged to have a movable outer shroud, which can turn the opening into the prevailing wind direction. Contrary to current propeller type HAWTs, the runner will not have to be moved, reducing structural complexity

C. System Code

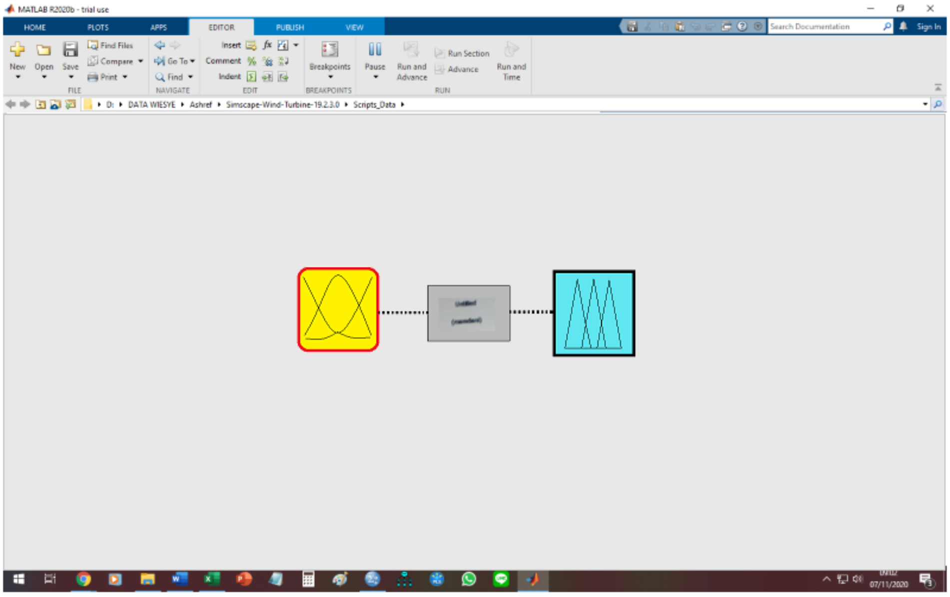
As found in the Literature Review, success of any project begins with a well- defined plan of action. A combination of flow chart and input-output diagram were used to design and develop the integration plan. This ensured that the model was designed to succeed from the start. Although new parameters were added along the development, proper system planning was greater significant to the savings of development time. Parameters could be easily identified and observed for quick theory checks using display nodes. See the appendix B for the system mapping charts and I/O design. In addition, a data acquisition model was constructed to log the data at various nodes in the system to a MATLAB array file called ‘Results’. Using a ‘Data2XLS’ function, the results of the array are written to a Microsoft Excel file at the final time (= 12). This allowed for the data to be collected and represented more easily. The data could be displayed in charts, plots, and graphs that are not easily made in MATLAB. Also, the use of excel as a statistical software would be used to quantify and compare the data. Figure 4.6 provides a visual of the complete Simulink model. Close attention was paid to the look of the model to match the transfer system created in the planning phase. Along with the input-output mapping, the creation of the model was found to be more simplistic by knowing what parameters are necessary for the computation in each component model. The use of display blocks, shown in provide a quick check to assess the functionality of the system by following the air cycle. From the concept design, the temperature of the air should be seen to increase from atmosphere through the heat chamber, decrease through the evaporator and heat back up through the condenser. The values displayed during simulation matched this concept.

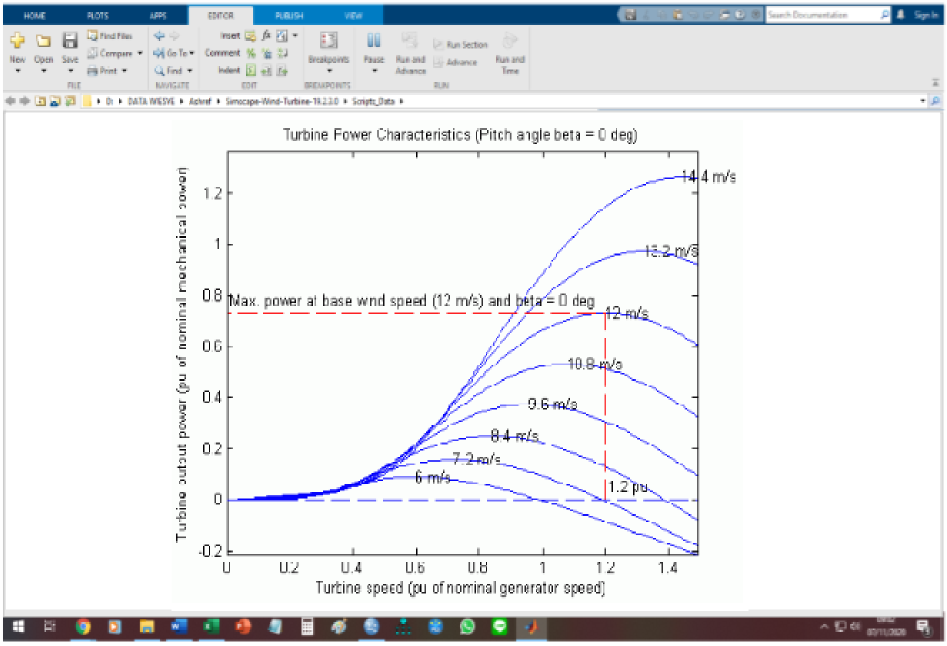
```
% Fit to curve for dynamic interaction
Irradiance = 1000 *sin((1/24)*(Time*2)*pi);

 %Conver to english units
Sun_power = Irradiance * W2Btuph(1)/m22ft2(1);

if Temp <= 1
    %Assume the atmoshper temp to follow the solar radiation
Temp_atm = (Sun_power/10)*sin((1/24)*(Time*2)*pi) + 50;
else
    %If user input data, curve to 12 hour cycle with peak at noon
Temp_atm = (Temp/2)*sin((1/24)*(Time*2)*pi) + (Temp/2);
end

%Get the entalpy of the air at temp and pressure
[H] = refpropm('H','T',F2K(Temp_atm),'P',psi2kPa(Pressure),'AIR.PPF');
offset = 10;
enthalpy = (H * J2Btu(1)/kg2lbm(1))/ offset;

%Use entalpy to find relative humidity
[Temp_atm, w, RH, enthalpy,Tdp ,v ,Twb] = Psychrometricsnew
('tdb',Temp_atm, 'h', enthalpy,'p',Pressure);
%Offset the relative humidity from 40 percent
phi = RH ;%

%Normalize phi to 100
if phi > 100
    phi = 100;
elseif phi < 20
    phi = RH + 20;
end

%Pass out data for next system block
data = zeros(4,1);
data(1) = Sun_power ; data(2) = Temp_atm; data(3) = phi; data(4) =
enthalpy;

y = data;
```

3.3.1. Analysis of how fuzzy logic use in wind turbine design.

Simulations were carried out with a 3kW PMSG-based WECS which has the optimal power coefficient Cpmax=0.48 and the optimal tip-speed ratio λ=8.1. Control performances of both PI and FUZZY Controllers are compared in parallel.

Both of the two methods track the output reference adequately. The FLC provides better tracking than the PI controller. Two important factors show the efficiency of the power conversion: the power coefficient maintenance and the tip-speed ratio maintenance under wind speed fluctuations. The FLC shows better performances better than PI controller in optimizing the power conversion. The PI controller stays oscillating around optimal values. The FLC keeps the optimal power coefficient and tip-speed ratio values constant after transient time. It is clear that the maximum power extraction control works very well where the value of power coefficient was kept at optimum value of power coefficient Cp-opt which equals 0.48 with varying wind speed.





The illustration below shows the mechanical power P_m as a function of generator speed, for different wind speeds and for blade pitch angle β = 0 degrees. This figure is obtained with the default parameters (base wind speed = 12 m/s, maximum power at base wind speed = 0.73 pu (k_p = 0.73), and base rotational speed = 1.2 pu).

3. CONCLUSION

The conclusion is the effect of cross winds or wind components normal to the prevailing wind direction and the effect of wind speeds exceeding the design wind speed will be discussed here briefly: Cross winds or wind vector components normal to the turbine axis can have negative effects on VAWT, leading e.g. to additional dynamic loadings on the turbine blades. Two important factors show the efficiency of the power conversion: the power coefficient maintenance and the tip-speed ratio maintenance under wind speed fluctuations. The FLC shows better performances better than PI controller in optimizing the power conversion. The PI controller stays oscillating around optimal values. Through the design of eco green of wind turbine in Sahara desert can overcome the problem that faced by the Libyan government to achieved the optimal solution for electricity power.

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