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Performance of Dual Axis Solar Tracking System Using Fuzzy Logic Control: A Case Study in Pinarhisar, Turkey

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Abstract

Generating electrical via solar energy is one of the most popular renewable energy source. Modular structured solar panels that work according to photovoltaic principles convert solar radiation into electrical energy. There are some ways of increasing the power produced by the photovoltaic panels. One of the most effective ways is to minimize the angel of rays from sun to panel surface by taking the right position according to the angle of the sun. This paper proposes an intelligent control method for solar tracking. This method uses a fuzzy logic controller applied to the DC motors in solar tracking system (STS). STS is designed and developed as dual axis. Fuzzy logic algorithm used in STS was applied separately in order to control DC motors which determine the azimuth and zenith angels of the system. Position error which is obtained by the help of encoders tied to the motors and error variation were taken as input of fuzzy logic algorithm, applied voltage to the motor was taken as output of fuzzy logic algorithm. Finally, results of the photovoltaic panel on the STS controlled by fuzzy logic are compared to those obtained by the photovoltaic panel system without STS according to instantaneous power performance throughout the day in Pinarhisar, Turkey. Experimental results show that the STS which uses fuzzy logic controller increases the efficiency of energy production from PV.

Key words

Renewableenergy, Solar trackingsystem, Fuzzylogic, Photovoltaic panel

1. INTRODUCTION

Energy is an important factor in industrialization, urbanization and financial growth and social life quality of a country [1]. That is why energy demand worldwide is increasing and this condition is most likely to continue in the future [2,3]. This demand increase lead people towards renewable energy sources such as wind, geothermal, and solar energy sources since fossil fuels are exhaustible. In Turkey, according to final data in 2014, when distribution of renewable sources in total of 69519,8 MW established power is analyzed, shares of wind, geothermal and solar energy are seen to be respectively 3629,7 MW, 404,9 MW and 40,2 MW [4]. In Turkey, %5,86 of the electricity produced is gained from wind, geothermal and solar energy (Figure 1.1). Nevertheless, with the use of renewable energy sources, share of electricity production shows an increasing trend in an annual basis.

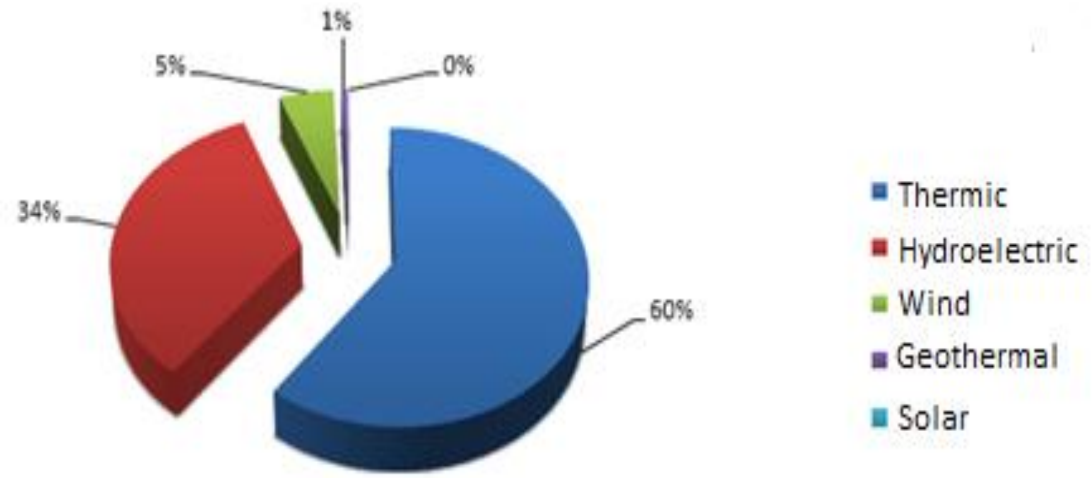


Figure 1. Distribution according to installed power capacity of energy types in Turkey [4]

One of the most important renewable energy sources is surely solar energy. Even though electricity energy produced out of it is lower when compared to other energy sources, thanks to advancements in solar energy industry, with decrease in the initial investment costs and increase in the efficiency, there is no doubt that its contribution rate will be increasing every year. Owing to the geographical position of our country, it can be said that it is in a lucky position in terms of receiving sun when compared to many other countries. Therefore, benefiting from infinite and free solar energy in maximum level will support the interests of our country which is dependent on foreign countries for energy.

Photovoltaic systems enable solar power to turn into electricity energy. Power that these systems produce depend on a variety of factors including the amount of energy they receive from sun rays. In order to increase the efficiency of photovoltaic systems, scientists and engineers have made many researches. In general, there are three ways to increase the efficiency of photovoltaic systems. First method is to increase power production efficiency of solar cells [5,6]. Second one is related to increasing the effectiveness of control algorithm for energy conversion systems that include maximum power point tracking [7,8]. Third approach is to use solar tracking system in order to make maximum use of solar energy [9].

There are a number of works proposed by many researchers to solar tracking. In their work, Sefa et al. have done the design and application of PC-based one axis solar tracking system. The reason why they have used one axis is that they thought system's total weight of 3500 kg would make double axis tracking harder [10]. M.J. Clifford and D. Eastwood have designed a one axis solar tracker that is, in other words, appropriate for use only in Ecuador regions [11]. Tiberiu and Liviu have used one-axis solar tracker and opted to manually adjust the other axis throughout the year with regular intervals [12]. WafaBatayneh et al. designed dual-axis solar trackers which are driven by a DC motor for each axis of tracking. They presented a fuzzy logic based controller for controlling the DC motors. They used four small PV cells as sensors to find solar position. [13]. While choosing the mechanical system of solar tracking systems, its cost analysis should be made. Cost of the tools to be used in the system and power consumption should be taken into consideration.

In this study, the effect of solar tracking system, which is controlled with fizzy logic at Kirklareli University Pinarhisar Vocational School, upon the performance of solar panels have been put under the scope. A comparison is made between the daily energy productions of fixed positioned PV panels and PV panels that are positioned on solar tracking system.

2. MATERIALS AND METHODS

2.1. Page Layout Sun Tracking System Design and Control

In the electro-mechanical system of solar tracking system, there are 2 DC motors, 2 reducers, 2 encoders, 1 double channel motor driver, daq card and a computer. In the mechanical structure of STS, PV panels have the motion ability with two double axis, and are positioned with direct current (DC) motors. By providing the revolution of panels in Azimuth and Zenith angles, sun can be tracked in a way that enables sunrays to fall onto panels with vertical angle.

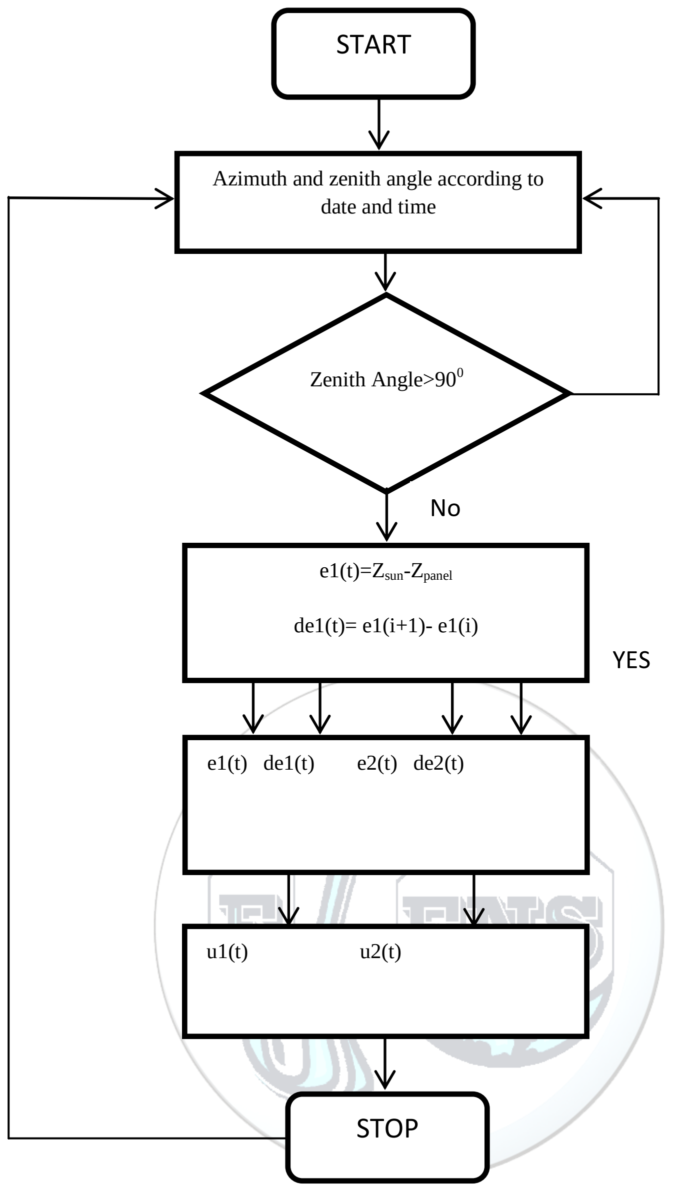


Figure2. Flow chart of the fuzzy controller

As shown in Fig 2, Azimuth and Zenith angle of Sun is calculated according to time/date and geographical information. If the Zenith angle is more than 90 degrees, sun is set. Running solar tracking system is needless. In the other condition, pulse signals coming from the encoder bound to motors, and consequently the errors and rate of changes of errors are calculated. For each motor, error (e) and change of error (de) are applied to Fuzzy Controller as input. The output of the fuzzy controller will be the motor's speed needed to move the panel.

2.2. STS using Fuzzy Logic

Fuzzy logic controller, which was first created in 1965 by Zateh [14], is a system defined via fuzzy rules and created by the professional experience. It is a system that includes the linguistic variables instead of the mathematical model of a dynamic system. It has four main parts: (i) Fuzzification (ii) Rule base, (iii) Inference (iv) Defuzzification interface The proposed system for two DC motors in this study consist of two input variables: error (e) and change of error (de), and one out variable: duty ratio (u), as shown in Fig. 3

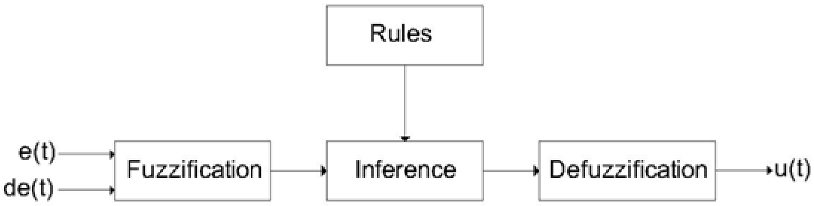


Figure3. General diagram of a fuzzy controller

Fuzzification

In the fuzzification process, membership function values are assigned to the linguistic variables. In order to carry out this process, the input variable range is transformed to the convenient universal cluster and by this way the input values are transformed to the convenient verbal values. In this study have five fuzzy subsets: NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big). In the fuzzification process various membership functions are used. In this study, triangle function is used as the membership function.

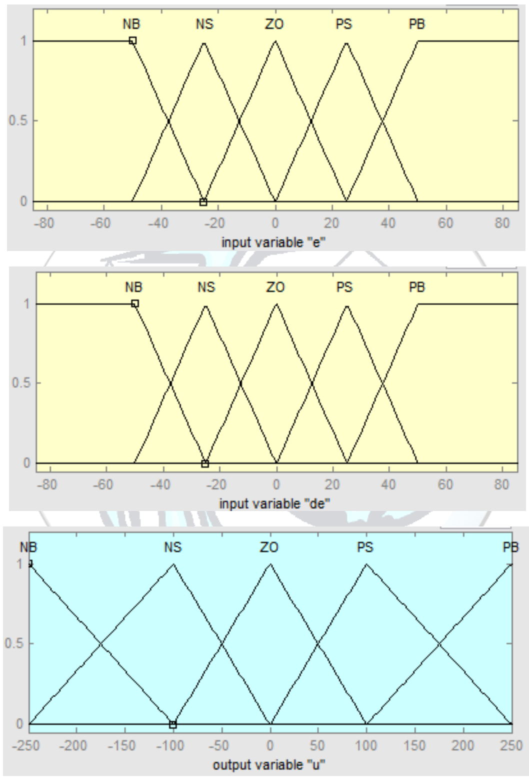
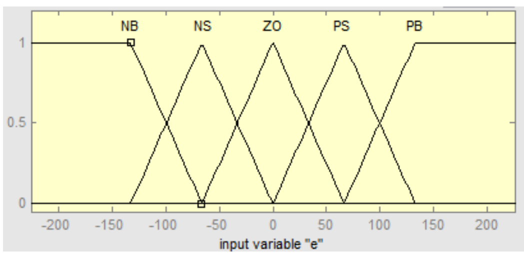


Figure4. Fuzzy logic membership functions for inputs and output variable of zenith angle.



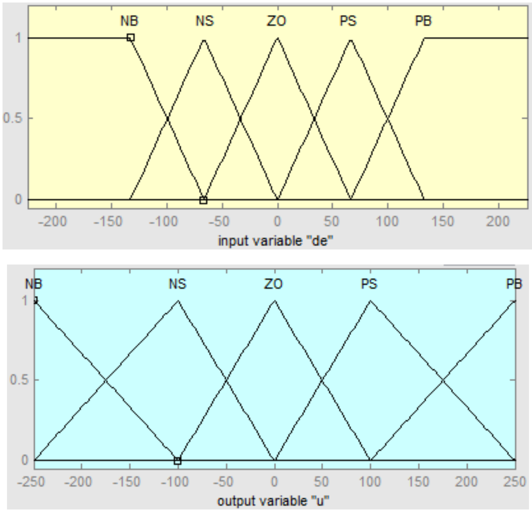


Figure5. Fuzzy logic membership functions for inputs and output variable of azimuth angle.

Rule base

Rule base, holds the knowledge in the form of a set of rules, of how best to control the system. In this study, 25 number "if-in that case" rules have been created. The result of rules and motor PWM values are determined. In table 1, a part of rule table which is created for the input variables takes place.

Table 1.Fuzzy controller rules

e/de	**NB**	**NS**	**ZE**	**PS**	**PB**
NB	NB	NB	NB	NS	ZE
NS	NB	NB	NS	ZE	PS
ZE	NB	NS	ZE	PS	PB
PS	NS	ZE	PS	PB	PB
PB	ZE	PS	PB	PB	PB

Inference

The data coming to system in the blurring rule base are processed by the inferring mechanism after they are ready to be processed. In this study, Mamdani method, which is one of the inferring method, has been used. While the threshold values of rules are measured in Mamdani inferring method, firstly " and (intersection)" then "or (combination)" processors are used.

Defuzzification

In the defuzzification process, the process of transforming the fuzzy set obtained in the fuzzy inferring motor to a definite value is carried out. In order that the obtained fuzzy set is to be applied the real life, there must be a numerical value. In this study, center of gravity method has been used. The center of gravity of the inferred cluster, which has been created via this method, is found and the value coming to this center as a definite value is assigned.

3. RESULTS AND DISCUSSION

In this study, a dual axis solar tracking system based on fuzzy logic controller, which simultaneously carries four number of 120 W panels, has been designed. According to the researches, before deciding to use solar following systems, the first thing that must be done is to take into account the initial investment cost and energy waste. In order to decrease the initial investment cost, two number of DC motor instead of servo motor have been used in order to move panels in azimuth and zenith angles. Angle position information of panels has been found with pulse signals read with the help of reed sensor instead of industrial encoder. Again in order to decrease the cost, Arduino Mega 2560 model has been chosen instead of industrial daq card.

We use fuzzy logic to control the speeds of the two motors based on date/time aiming at increasing the efficiency of the solar panels. Two different fuzzy logic algorithms have been applied to two motors that control Azimuth and Zenith angles (Figure 6). In both algorithms, the number of rules was 5 and fuzzy logic membership function parameters were determined with the help of experiences.

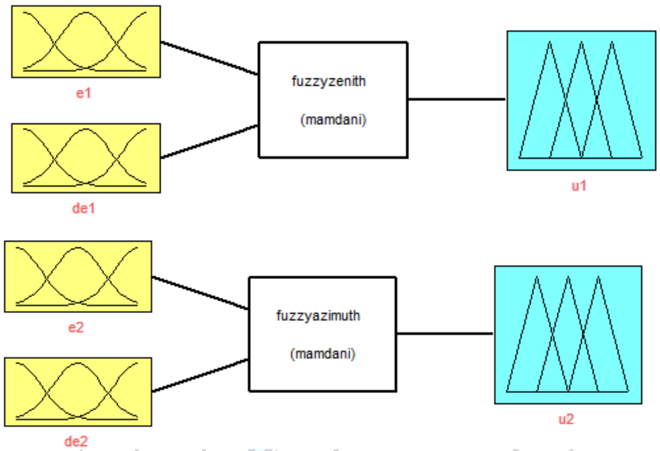


Figure 6.Fuzzy logic controller.

The dual axis solar tracking system presented here is tested experimentally. The experimental study is realized at Pinarhisar Vocational High School in Kirklareli, Turkey. STS has the capacity of carrying four panels, but measurements have been made over a 120 W panel. For performance evaluation, a comparison has been made between all-day productions of fixed panel and the panel positioned on STS. Installation angle of fixed panels have been determined as 38 degree south by considering the latitude angle of Kırklareli University Pinarhisar Vocational School taking into account that they will be used in summer and winter conditions.

Performance analysis of STS located at Kirklareli University Pinarhisar Vocational High school and fixed panel was made on the 17.09.2015.

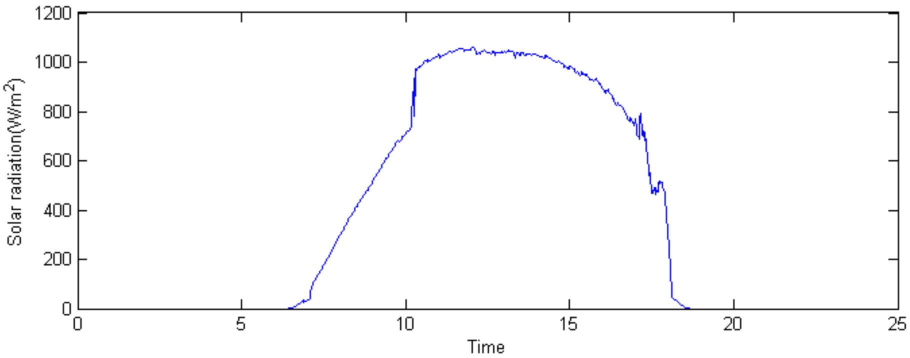


Figure 7. The results solar radiation amount on the 17th of September 2015.

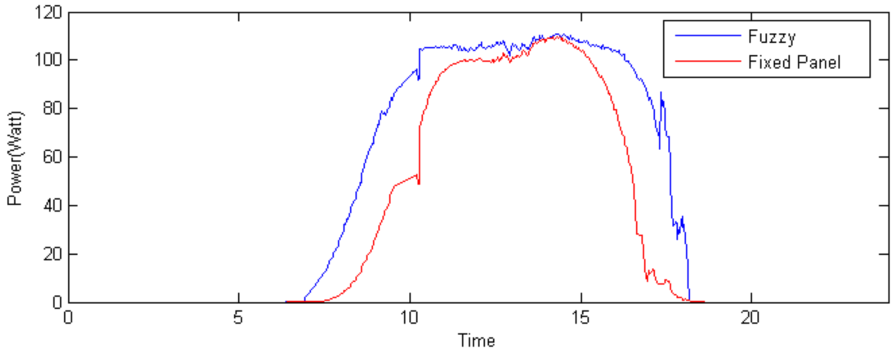


Figure 8. Power output values seems of the fixed panel and the PV panel using STS in Pinarhisar, Turkey. The results presented are on the 17th of September 2015.

It can be seen that throughout the whole day, the PV panel on STS has the highest power output due to highest solar irradiance exposure. The fixed PV panel has a lower output power compared to the panel on STS due to low solar irradiance. In Pinarhisar on the specified date it was found that the daily output power of the STS used with Fuzzy logic was 35.6% higher than the fixed PV panel

4. CONCLUSIONS

In this paper the speed of DC motors in dual axes solar tracking system is controlled using fuzzy logic controller. Results of the photovoltaic panel on the STS controlled by fuzzy logic are compared to those obtained by the photovoltaic panel system without STS according to instantaneous power performance throughout the day in Pinarhisar, Turkey. Experimental results show that the STS which uses fuzzy logic controller increases the efficiency of energy production from PV.

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