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DEVELOPMENT OF A FUZZY LOGIC BASED SMART SOLAR SYSTEM FOR IRRIGATION

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ABSTRACT
A novel concept for fuzzy based switching controlled solar energy powered irrigation system is proposed. It is superior to existing systems, increasing the water output for same PV capacity, while reducing capital cost for same water output. The proposed system improves the total output of water by maximum utilization of available photovoltaic output and maximum utilization of the duration for which solar power is available based on fuzzy logic.

Keywords: Solar Irrigation, Multiple Motor, Intelligent Switching, Fuzzy Logic.

1. INTRODUCTION
In Bangladesh, about 5.0 million hectors of Land need irrigation in dry season. Pumps run by electricity [700-800MW] cover 30% of total land area. Bangladesh faces severe electricity crisis. Energy sources of pumping such as fossil fuels are subsidized by the government for irrigation. Renewable energy presents a better alternative to fossil fuels with greener impact on environment. Since the 1970s photovoltaic-powered pumping systems are being used all over the world [1]. These are inherently low maintenance and high reliability system. But high investment cost and low energy conversion efficiency renders the cost for irrigating per hector of land and cost of per unit energy still very high [2]. There is scope and need for research in this area to lower the investment cost and improve the system design.

2. PRESENT SYSTEM
Solar PV modules produce direct current (DC) power. But alternating current (AC) motor-pumps are generally used for pumping purposes, therefore, a DC-AC converter called 'inverter' is needed to convert power of solar panel from DC to AC. PV power output is non-linear and time-dependent that changes with change in solar irradiance throughout a day, as well as solar cell temperature [3]. The pump runs only when the available photovoltaic (PV) power is sufficient to drive the motor and compensate the loss of the inverters. If the generated PV output falls short of the power requirement by the motor due to a low light condition, the motors of the pumps stall. Since the optimal performance of a pump driven by a motor depends on the PV panel configuration [4], an overcapacity of solar panels is generally maintained, even though it is by far the most expensive component in a PV pumping system. In such a system design, the excess solar power available at times is not generally utilized.

3. PROPOSED SYSTEM
3.1 Solar irradiance at site
Bangladesh is situated between 20.30^0 - 26.38^0 North and 88.04^0 - 92.44^0 East. Dhaka is situated at 23.71^0 latitude and 90.41^0 longitudes. Daily average solar radiation in Dhaka varies between 4 to 6 kWh per square meter, the average being 5.24. Maximum amount of radiation is available on the month of March-April.

Solar radiation energy received on a given surface area in a given time is defined as insolation and generally expressed in kilowatt-hours per square meter per day. The monthly global insolation and daily average bright sunshine hour in and around Dhaka are presented in Tables I and II respectively [5].

Table 1: Monthly Global Solar Insolation in Dhaka

Month	Solar insolation kWh/m^2	Month	Solar insolation kWh/m^2
January	5.47	July	4.18
February	5.91	August	4.60
March	6.00	September	4.94
April	5.85	October	5.44
May	5.23	November	5.34
June	4.55	December	5.38
Average insolation			5.24

Table 1(i): Daily Average Bright Sunshine Hours in Dhaka

Month	Daily Mean	Maximum	Minimum
January	8.7	9.9	7.5
February	9.1	10.7	7.7
March	8.8	10.1	7.5
April	8.9	10.2	7.8
May	8.2	9.7	5.7
June	4.9	7.3	3.8
July	5.1	6.7	2.6
August	5.8	7.1	4.1
September	6.0	8.5	4.8
October	7.6	9.2	6.5
November	8.6	9.9	7.0
December	8.9	10.2	7.4
Average	7.55	9.13	6.03

Irradiance of a site is given by the following relation.

$$Irradiance = \frac{Average\ Insolation}{Average\ daily\ bright\ sunshine\ hours},\ kWh/m^2$$

The irradiance in Dhaka, which can be calculated using the above relation and using data from Tables I and II, is 694.04 watts per m^2.

3.2 The proposed system

Performance of a solar PV system is affected by availability of solar radiation. The available solar radiation is a function time of the day and the site selected. Optimal performance of a solar PV system depends upon how well these two factors are considered while designing the system. The hourly variation of insolation at a site is represented by a bell shaped curve as shown in Figure 1.

The proposed system uses multiple pumps of different dimensions, and utilizes intelligent switching to operate the pump motors so that the photovoltaic output of solar panel is utilized to the maximum. The water flow rate from the system for both conventional and the proposed concept is shown in Figure 1.

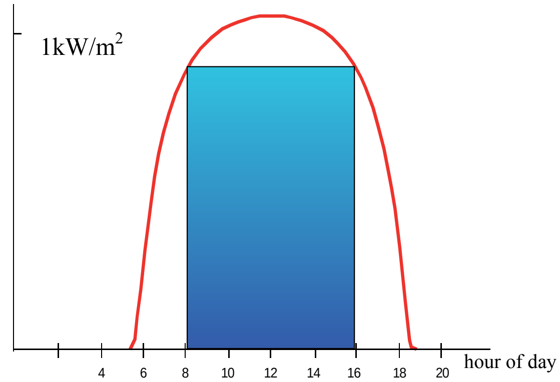

Fig 1a.. Comparison of performance from conventional pumping system and proposed pumping system

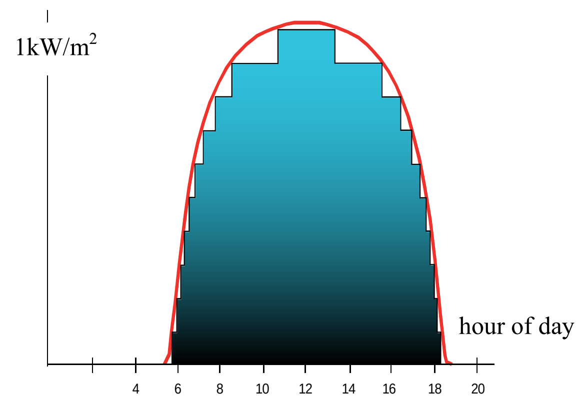

Fig 1b. Comparison of performance from conventional pumping system and proposed pumping system

For the novel system, gain in pumped water output at single day for same amount of solar illumination is estimated to be about 37.85%. For a cloudy day, the gain in pumped water output is estimated be 55.55%. In turn, the cost of solar powered pumps will be reduced almost by same percentage.

4. SYSTEM SETUP

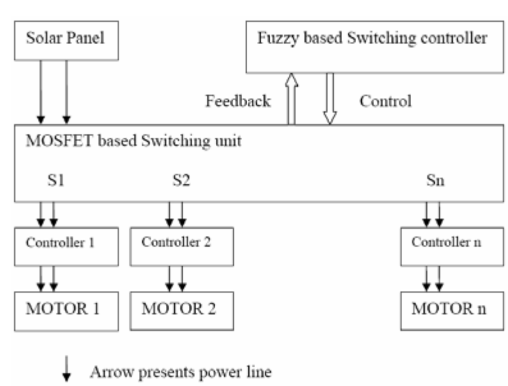

Fig 2.System Architecture

5. FUZZY BASED SWITCHING CONTROLLER

Fuzzy theory is a science closely related to our lives. Because it describes things with language, it is easy to accept. In real life, most descriptions are fuzzy. For example, when we say “sweet fruit” or “drive fast” sweet and fast are not accurate values but simply a description of the degree. However, people can easily understand the meaning from the description.

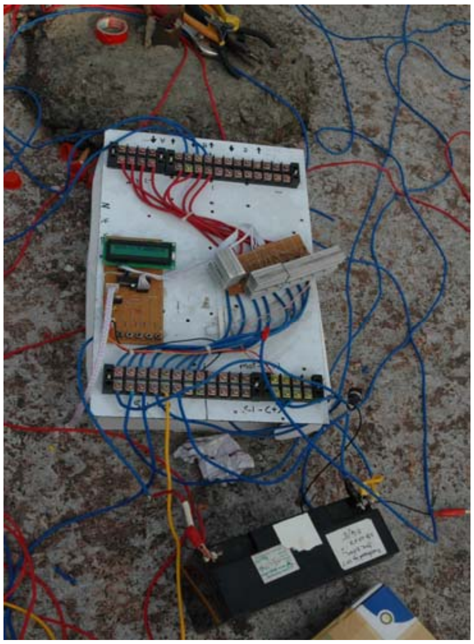

Fig 3. Microcomtroller based control system.

Fig 4. Multiple switched motor.

Fig 5. Turnable stand with solarpanel.

5.1 Fuzzy Logic Controller Structure

The basic fuzzy based switching controller is shown in figure-6.

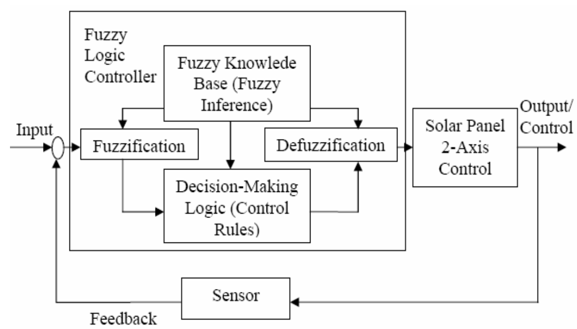

Fig 6. Fuzzy Based Switching Controller

5.2 Fuzzification Interface

The input of a common controller is a specific numeric value, but the knowledge base for fuzzy control is expressed with language. The system must turn numeric values into language and corresponding domains to allow the fuzzy interface engine to interface. This transformation is called fuzzification.

5.3 Knowledge Base

Knowledge base is the inference basis for fuzzy control. It defines all relevant language control rules and parameters. The knowledge base (including the database and rules base) is the core of a fuzzy control system.

5.4 Fuzzy Interface Engine

As the most important part of fuzzy control, the fuzzy inference engine performs the actual decision-making process. The basic theory of the fuzzy inference engine is an approximate inference. The engine has two key inference methods: generalized modus pones (GMP) and generalized modus tollens (GMT). GMT is object-oriented inverse fuzzy theory, but GMP is forwarding linking inference modus. In GMP, when data is input, the output can be inferred according to rules; GMP is applicable for a fuzzy control inference mechanism. Its operation includes the following three calculations:

- Perform an AND operation for all propositions of an antecedent of the triggered rule to obtain the antecedent fit.
- Perform an AND operation for all of the propositions of the consequent corresponding to the antecedent fit of the triggered rule to determine how strongly true the rule is.
- Perform an OR operation for all consequents of all triggered rules.

5.5 Defuzzification

The reverse of fuzzification, defuzzification transforms the fuzzy inference engine's output values into equivalent assured values, making the assured value comply with the input signals of the controlled system. This process gives output control signals to the controlled system.

5.6 Implementation

Our controller design takes the measured value of the light strength received by the sensor as the feedback and implements control using many rounds of modifications.

6. COST ANALYSIS

To emphasize on the cost reduction, we consider the solar pumping system implemented by Rahimafrooz Bangladesh Ltd. The system consists of a 11.9 KW solar powered irrigation system, which can serve up to 50 beneficiaries. The water irrigation covers about 20 acres area. The discharge capacity of the pumping system is 5 lac litres per day (92 GPM). Submersible centrifugal multistage pump is used in the project, with motor capacity of 10 hp. The installation depth is 65 feet below ground level. For the required shaft power of the pump, a 7.5 kW inverter is used. A 4.4 kW of overcapacity of solar panel is used, which is the most expensive component of the entire system. At present per watt installation cost of solar panels is 3-4 USD. In the proposed system, using variable output capacity motors, over capacity of solar panels is completely eliminated. Thus savings from installed PV capacity in the proposed system will be 13,200–17,600 USD.

The cost of DC-DC converter in proposed system is comparable with the cost of inverter used in the existing system.

7. CONCLUSIONS

The costs for irrigating per hector of land and cost of per unit energy still are very high in Bangladesh. By implementing the concept for fuzzy based switching controlled solar energy powered irrigating system, capital cost for same water output can be reduced; which is proposed in this paper.

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