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Control of PV Water Pumping System Water levels

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Abstract. Solar pumps are used on small farms, private homes, orchards, etc. It is most economical to power the pump directly from the PV array, store water in a tank, and then distribute it. The test bench installed at the research unit of Ghardaia URAER is used to test and characterize different PV pumping systems and the results of this characterization are presented in this paper. A novel method of water consumption management through a Photovoltaic water pumping system, installed on real well has been studied. The method consists of controlling the water usage via the storage tank level and the consumption. The main purpose is to adapt the variation of the water consumption by an end user. The designed control system is based on the control of water supply from a submersible solar powered pump according to the variation of water demand. Taking into account the permanent solar energy supply and the availability of the water. The control design is satisfied by a Fuzzy Logic Controller (FLC), that senses the varying level of water in the storage tank and the end user requirement, so that the storage tank or a reserve tank is filled up, for its satisfactory performance. The Through different environmental condition recorded, the proposed system design has been simulated and validated by Matlab toolbox. The obtained results averred a very high controlling effectiveness of both the water management and the PV pumping system operation.

Keywords: *PV water pumping, water level, fuzzy logic, Storage.*

1. Introduction

Solar water pumping is done all over the world and greatly enhances the quality of life of people's living in rural and remote communities. Solar PV water pumping systems are reliable, and very cost-effective and can replace manual pumps, if used in the right location. A solar water pumping system does not have to use batteries to provide the power as the pump will operate during the day by pumping water into a tank for use at night.

Groundwater is an important source of water and the dominant source for domestic supply in many areas, especially in dry areas where surface of water is scarce and seasonal. Besides, it is an important source for the agricultural and the industrial sector. The solar photovoltaic water pumping has been recognized as suitable for grid-isolated rural locations in poor countries where there are high levels of solar radiation. Sometimes, the quantity of the water pumped doesn't meet the need of the user, due to the weak solar radiations, during cloudy days. Thus, to tackle this problem a control system needs to be integrated, that can maintain the rate of extraction of ground water at an optimal level as per the user's requirement.

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Fuzzy logic approach has been successfully applied for wide range of control problems beginning from the introduction by Zadeh in 1965 of fuzzy-set theory and its applications. Recent researches and studies on water level used the Artificial Neural Networks (ANN) and Fuzzy Logic Controller (FLC) to control the water management [5]. Among the problems faced are the wastage of water due to overflow of tanks and the cumulative water for long time, which has also been investigated [2]. The rule – based Fuzzy Neural Networks are also used in auto-control of pumping operations [3]. The most important objective served by the recent proposed system is that it maintains the extraction rate of ground water at the optimal level sustaining the water resources in the environment as well as meeting the demand of consummator [4].

The proposed prototype consists of solar powered submersible pump Grundfos model (900 W), water supply control unit with sensors and storage tank with maximum 50 m3 capacity as shown in Figure1. Objective of this study is to design a system with optimal control to satisfy the need of the citizens in the remote regions, taking into consideration the insufficient solar radiations when the sky is cloudy. The study is carried out including the water compensation during the different days. These constraints have been simulated, applied and tested for its outcome in the proposed prototype which includes a fuzzy controlled water supply through a solar powered submersible pump.

2. Stationary PV pumping system

The stationary PV water pumping lab installed at URAER/Ghardaïa site consists of a complete test bench assembled by the following parts:

Stainless steel tank (artificial well), type acerinox 1.4301 2B / 034DC7, completed by hydraulic system which involve two flow meters, two pressure sensors and control valve to adjust the

- pumped water pressure.
- MPPT (300W) for low power
- DC/AC inverter for three phases pumps.
- Electrical panel display which displays the following parameters: Q (m3/h), I(A), V(V),E(W/m2), TMH(m).
- Connexion box to select the different configuration (DC pump, three phase pump or DC pump via the MPPT).
- Data acquisition connected to PC
- PV generator composed of 25 Isofoton (110 W/24V) PV modules, implemented about 40 m away from the lab, direction full south, with optimal inclination angle of 32°.
- Earth installation.

The results of this characterization laying the day of 24 December 2013 for a height H = 12m, are presented in the following figures

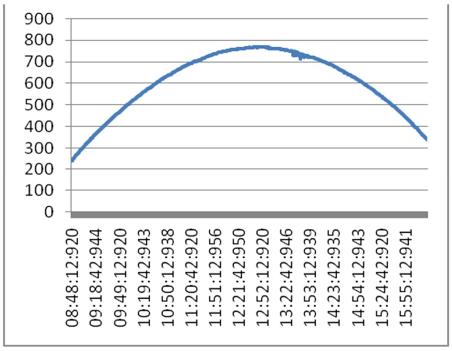


Fig.1 Irradiance

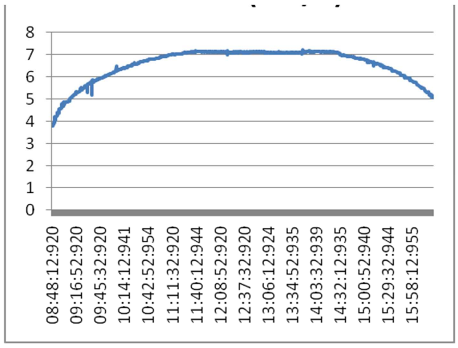


Fig.2 Flow

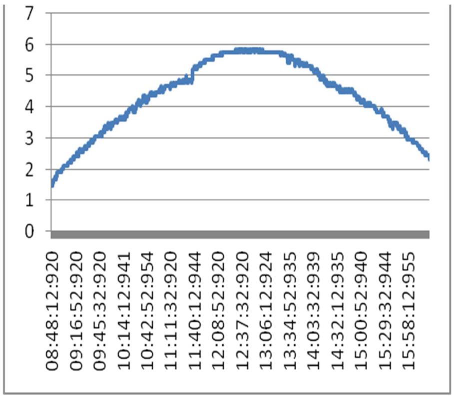


Fig.3 Current

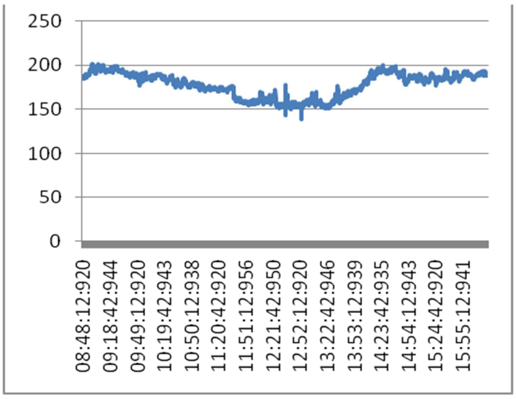


Fig.4 Voltage

3. System configuration

The system consists of solar powered submersible pump, water supply control unit with sensors, two valves, storage tank and reserve tank as shown in Figure1. There are three sensors positioned at different locations. One sensor is present in the bore well to sense the ground water level. The second sensor, with multi sensing elements at different vertical positions, is put in the tank being used for storing the pumped water. The third sensor is responsible for sending the feedback about load i.e. consumption pattern (rate).

If the Storage tank is full of water then the valve 1 is closed and the valve 2 is opened to fill the reserved water. The reserved water tank is then used to supply water for the users, when the Storage tank has an insufficient quantity caused by damage in the system or insufficiency of solar energy. The concluded purpose means that the the opening and closing of the valves V1 and V2 depends on the water-level in the storage tank and the water consumption. This process is auto-controlled by the output signal of (FLC).

4. fuzzy logic controller (FLC)

In fuzzy logic approach the Boolean logic is extended to handle the concept of partial true which implies the true takes a value between completely true and completely false. The notion of fuzzy sets has to be introduced, which is the collection of the objects that might belong to the set to a degree, taking all values between 0 (full non-belongingness) and 1 (full belongingness), instead of taking crisp value. The indication of intensity of belongingness is expressed in membership function, assigning to each element a number from the unit interval.

Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensor or other inputs, such as switches, thumbwheels, and so on, to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value. To implement fuzzy logic technique to a real application requires the following three steps:

1. Fuzzification – convert classical data or crisp data into fuzzy data or Membership Functions (MFs)
2. Fuzzy Inference Process – combine membership functions with the control rules to derive the fuzzy output
3. Defuzzification – use different methods to calculate each associated output and put them into a table: the lookup table. Pick up the output from the lookup table based on the current input during an application [13].

In this work, a Fuzzy Logic Controller (FLC) is used to control the pump operation in stand-alone PV pumping system installed in a remote desert farm in accordance to the water flow rate consumption and the water level in the storage tank. The synoptic of the design is represented in the following [5]:

The procedures in making the control designs are setting the constraints, assigning the linguistic variables and setting the rules for the controller. The water-consumption and the Level (quantity) of water present in the storage tank are the inputs [6]. The control of valves is the operation-time of the submersible pump, is the output of the system. Since these input parameters represented by membership function are to be fuzzified, equation (1), the max-min method of fuzzification, [7],[8] is used to set the fuzzy rules of the controller.

$$\mu = (\alpha 1 \wedge \mu 1) \vee (\alpha 2 \wedge \mu 2), \qquad (1)$$

Similarly, since the valve control unit cannot respond directly to the fuzzy controls, [9] the fuzzy control sets generated by the fuzzy algorithm have to be converted to crisp values by using the method of defuzzification. Subsequently, the approximate centre of gravity (COG) method, supposed to be the most accurate method to get a crisp value is used for the defuzzification, as shown in equation (2).

$$\mu = COG = \sum wi\ \mu(i))/\sum \mu i\ , \qquad (2)$$

Where, μi = action dictated by the ith rule , $\mu(i)$= truth value of rule

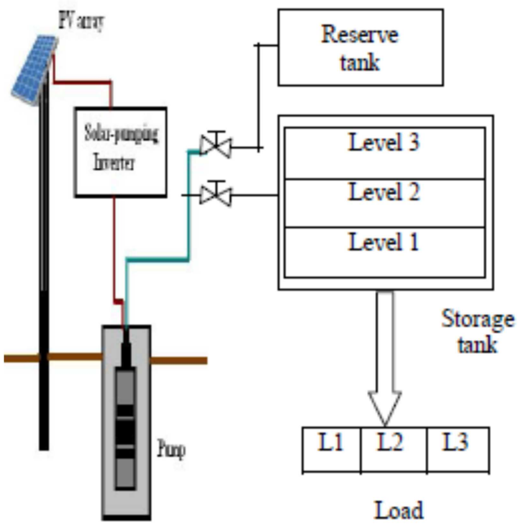


Fig.5 Configuration pumping system used

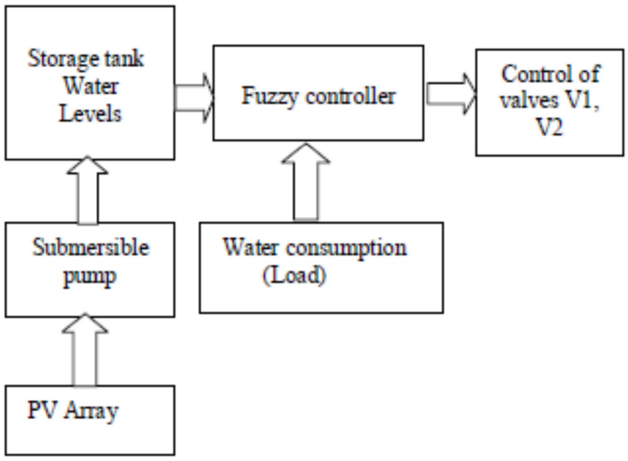


Fig.6 A proposed model of water management

5. The procedure

A. Input variable

Load : Level1: trim f (0 10 20)
Level2: trim f (15 25 35)
Level3: trim f (30 40 50)

ST: Level1: trim f (0 10 20)
Level2: trim f (15 25 35)
Level3: trim f (30 40 50)

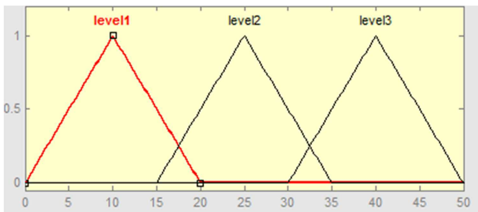


Fig7. Membership functions for Load (water consumption)

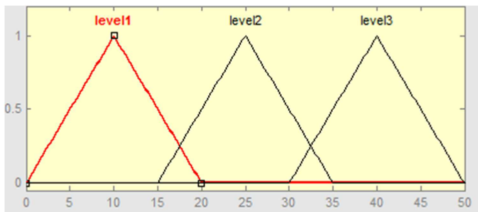


Fig8. Membership functions for storage tank

B. Output variable:

Control valves: V1: trapmf (0 0 20 40)
V2: trapmf (25 45 50 50)

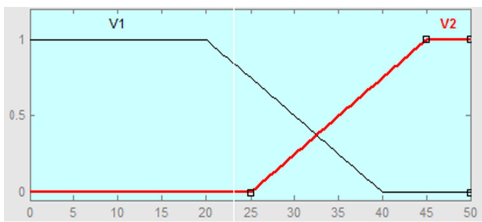


Fig.9 Membership functions output

C. Fuzzy rules:

Knowledge based decisions, according to the input conditions of storage tank level and load (water consumption), have been formulated as a fuzzy rule base as shown in Table 1. The simulated results of a case study on a typical day are shown below. The rules that explain the working principle of our system based on the fuzzy control algorithm are represented in Table 2:

TABLE I: FUZZY RULE

ST level / Load	level1	Level2	Level3
Level1	V1	V2	V2
Level2	V1	V2	V2
Level3	V1	V1	V1

TABLE II: IF THEN INFERENCE RULES

R1	If ST is Level1 And Load is level1 Then V1 is ON
R2	If ST is Level1 And Load is level2 Then V1 is ON
R3	If ST is Level1 And Load is level3 Then V1 is ON
R4	If ST is Level2 And Load is level1 Then V2 is ON
R5	If ST is Level2 And Load is level2 Then V2 is ON
R6	If ST is Level2 And Load is level3 Then V1 is ON
R7	If ST is Level3 And Load is level1 Then V2 is ON
R8	If ST is Level3 And Load is level2 Then V2 is ON
R8	If ST is Level3 And Load is level3 Then V1 is ON

6. The simulation result

The software implementation of the proposed system is done using the fuzzy tools of MATLAB ver7.9. A few simulation results have been shown in the figures 10, 11, 12,13,14,15 and 16.

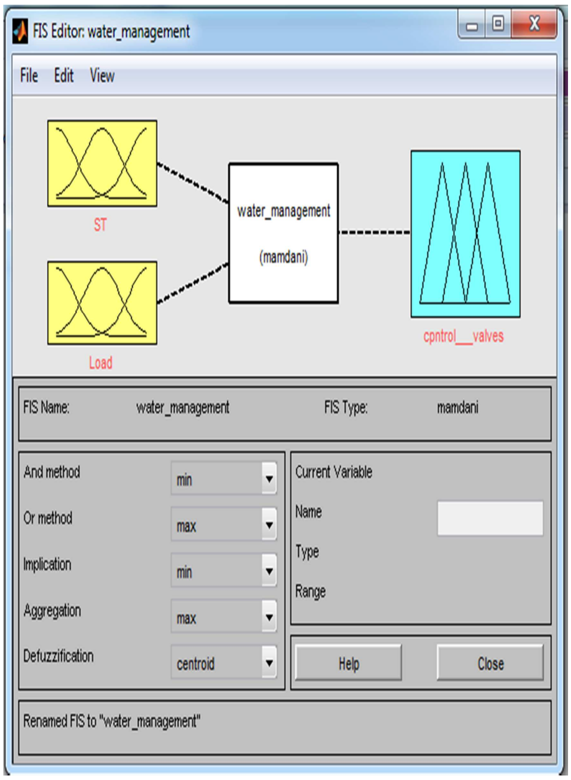


Fig. 10 Fuzzy inference system editor

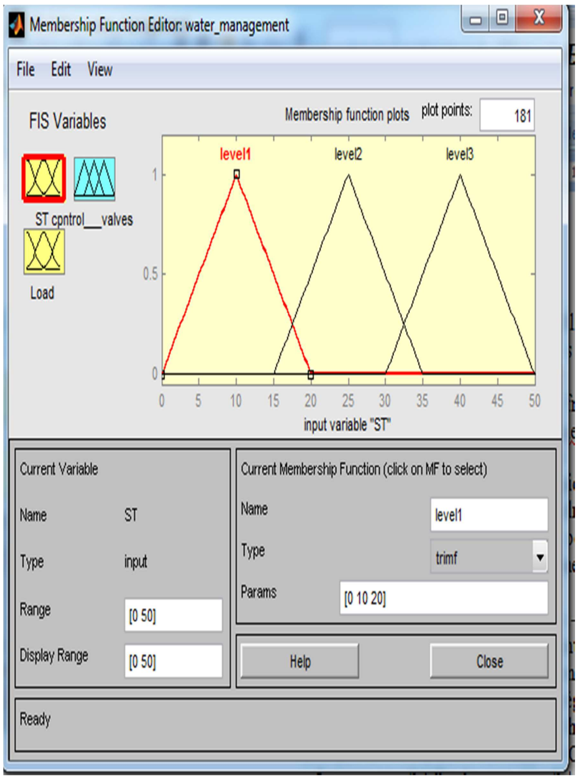
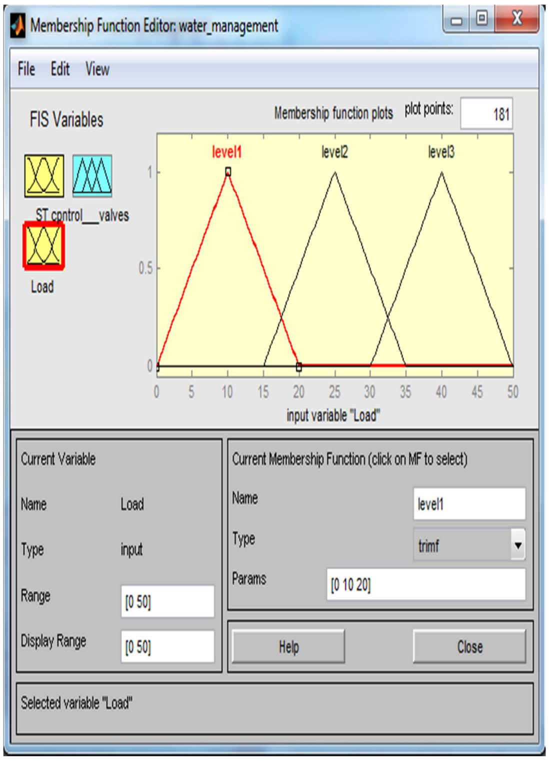


Fig. 11 Membership function for the storage levels (ST)



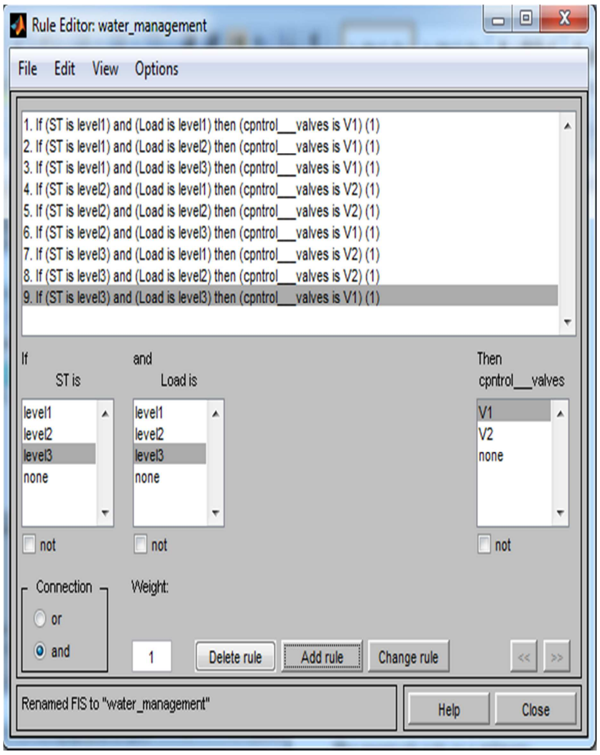


FIG.12 MEMBERSHIP FUNCTION FOR THE LOAD (LOAD)

FIG.14 IF-THEN RULES FOR THE PROPOSED SYSTEM

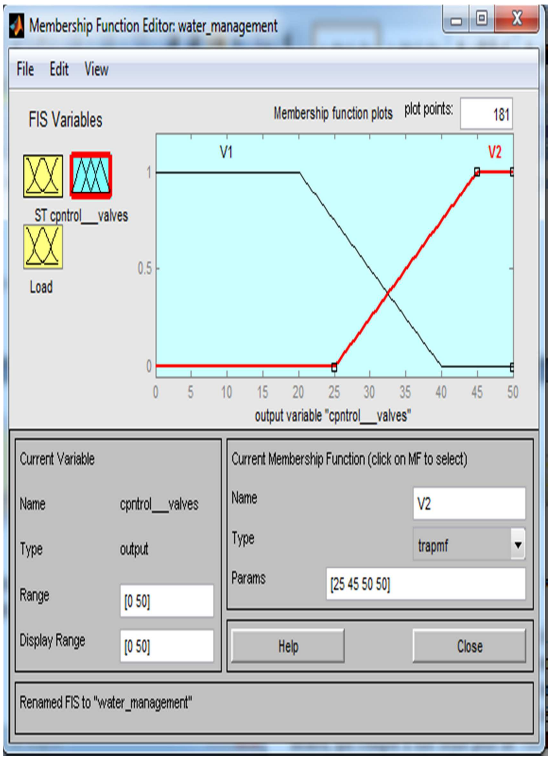


Fig.13 Membership function for output

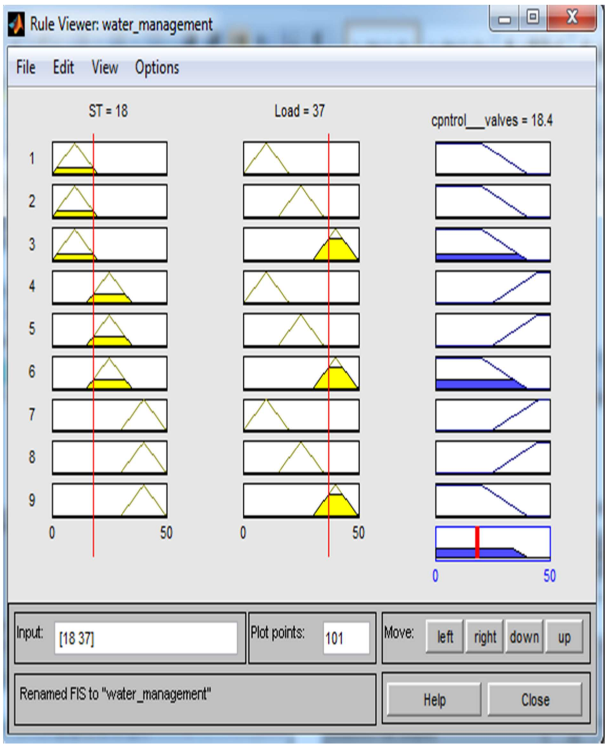


Fig.15 Rule viewer

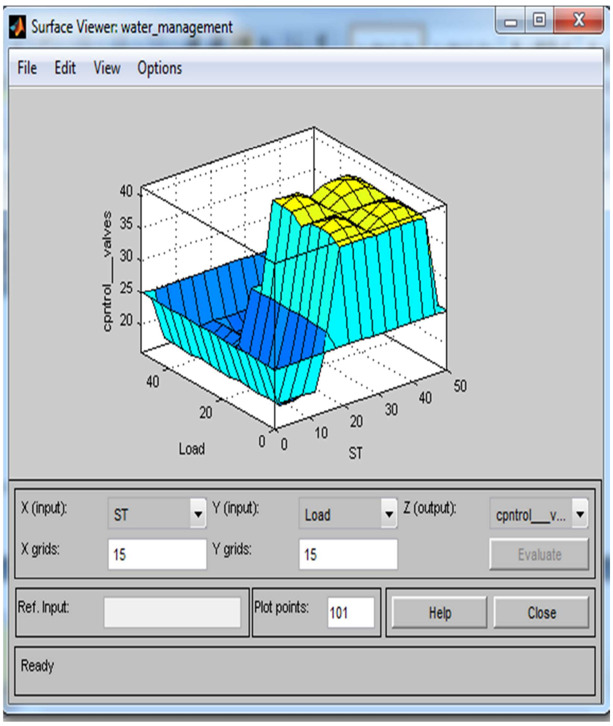


FIG.16 SURFACE VIEWER

7. conclusion

The Fuzzy Logic Controller (FLC) was successfully applied for controlling management for water levels of storage tank and water consumption, in a photovoltaic pumping system. In this way, we are satisfying the need of water for the citizens in the remote regions, taking into consideration the insufficient solar radiations when the sky is cloudy. The advantages of intelligent controllers are in their robustness and ability to reproduce the centralized behavior of control actions by using the easily measurable local information.

7. References

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