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Automated Irrigation by an ANN Controlle[illegible]

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Abstract

Irrigation happens to be the backbone of the civilized society [illegible]e time immemorial. With population increasing at an exponential rate and land areas being curved short accom[illegible]odating thi[illegible]normous population, several new and innovative practices are coming up. The subject of talk in thi[illegible]per theref[illegible] relates to the different techniques of using natural resources. Although many innovative techniques [illegible]e been [illegible]ployed towards Automated Irrigation, they mostly indulge simple On - Off based contr[illegible]. Artificia[illegible]Network can give us a good amount of remedy from the existing problems as it can opera[illegible] valves and actuators connected to the system as and when required. Taking into consideration of the para[illegible]ters [illegible]ay deciding role in irrigation of a particular kind of crop or plantation, we look forward to designing [illegible]N based MATLAB simulated model which does give much better results than the convention[illegible]OFF one[illegible]he system starts from taking signals from various sensors and ends up at giving much better req[illegible]d o[illegible]t from [illegible] Final Control Elements.

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Keywords: Artificial Neural [illegible]utomated Irri[illegible]; Sensor Networks; Evapotranspiration.

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1. Introduction

Studies show that improper irrigation techniques lead to waste of priceless natural resources and also lead to inferior productivity of the crops. Only because of poor irrigation techniques employed in India, the grain productivity rate is about 0.87 kg/m3 whereas in developed countries, it is about 2 kg/m^3. Automation in the field of irrigation and that too, the best one is the need of the hour. It prevents wastage of resources, saves money and also gives better productivity from the same piece of land thus enhancing its efficacy.

2. Control Strategies

We do come across two types of control action, the simple Open Loop Control and the mo[illegible]manding C[illegible]ed Loop Control. The On-Board sensors from the field feed the controller with the data w[illegible]h gets [illegible]pared [illegible] the Controller section and depending upon the set point values, the FCEs are set On[1]. The [illegible]n drawback [illegible]s kind of control action is that it has No Feedback loop refraining it to make a decision w[illegible] to st[illegible]which at [illegible]st times leads to wastage of resources. This type of systems either have to be turned dow[illegible] m[illegible]ll[illegible] a time[illegible]has to be put into place which trips off the FCEs after a predefined time delay.

Closed Loop Control action has an additional feedback network en[illegible]ing [illegible] controller t[illegible] Auto stop the FCEs when the demand for the resource. For proper and the most optimized irrigation p[illegible]edure and to yield the possible results, there are several parameters to be considered, both static ([illegible]) and dyna[illegible]ime dependent) parameters. Some of the fixed parameters at any specific point of time are e[illegible]erated as follows:

- Type of soil (texture)
- Status or stage of growth
- Salinity of the soil (determining the sweating of the soi[illegible]
- Leaf coverage (transpiration and evaporati[illegible]termining [illegible]

Based on the above set of parameter, few input paran[illegible]rs t[illegible]idered are

- Soil humidity level
- Ambient temperature
- Breeze speed
- Radiation

In order to design control l[illegible] all the ab[illegible]mentioned parameters have to be considered and hence the output parameters can be set wh[illegible]

- Opening / Clos[illegible]g of t[illegible]lves and / or fertilizers and adjusting their amounts in combination.
- Switchin[illegible]/ off the en[illegible]ystems (airing, lighting and heat exchanges)
- Openi[illegible] Closi[illegible] of the roo[illegible]n case of Greenhouse agriculture.

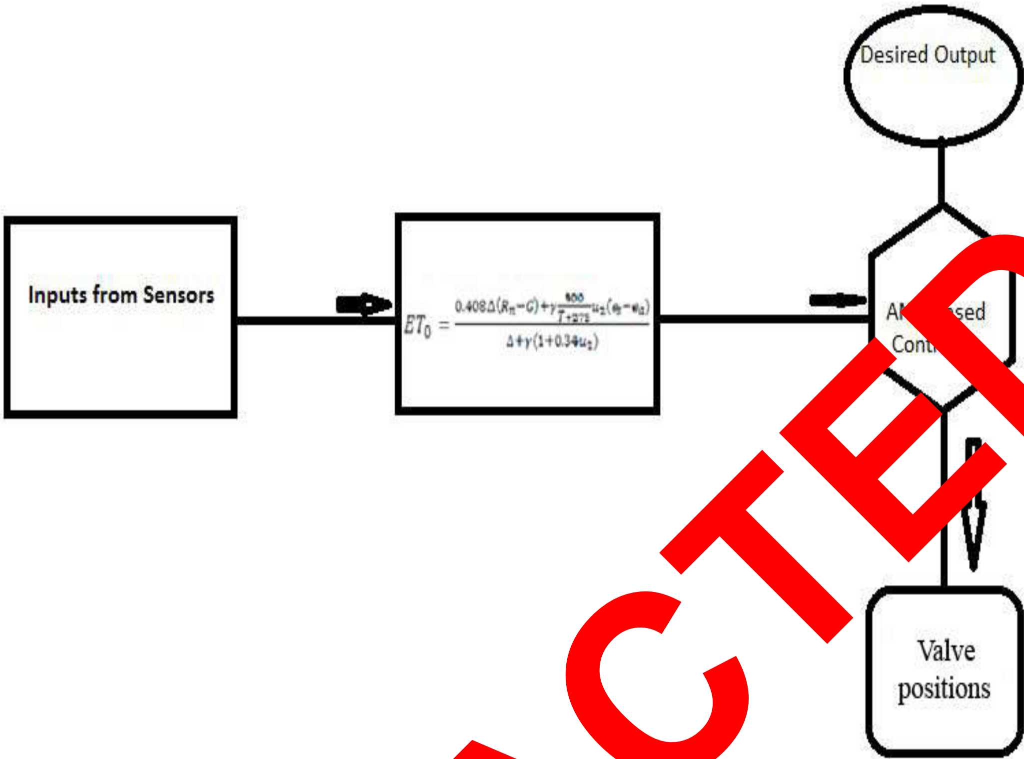

Fig. [illegible] System [illegible]iagram

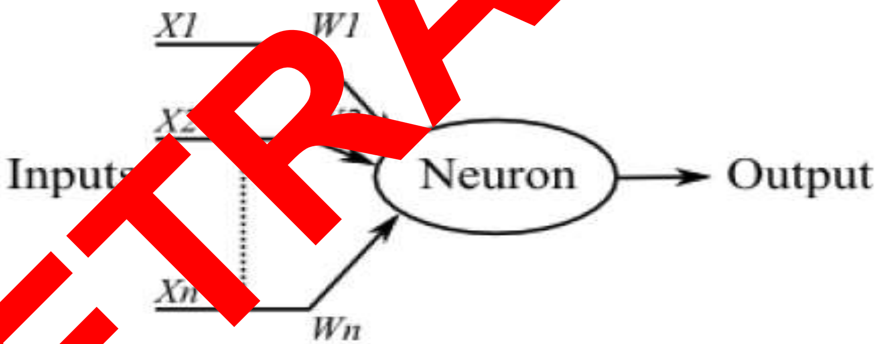

Fig. 2: The block diagram system embedded with ANN controller.

3. F[illegible]on of [illegible]N [illegible]ntrolled Irrigation System

[illegible] we start off with any design techniques employing ANN, we need to know what is ANN and why sh[illegible]e involv[illegible]uch a technique in our work. In simple terms it may be defined as "an artificial neuron network (AN[illegible] a computational model based on the structure and functions of biological neural networks. Information that flow[illegible]rough the network affects the structure of the ANN because a neural network changes - or learns, in a sense - based on that input and output.it processes information using a connectionist approach to computation.

ANNs are considered nonlinear statistical data modeling tools where the complex relationships between inputs and outputs are modeled or patterns are found.

What Are Their Advantages Over Conventional Techniques?

Depending on the nature of the application and the strength of the internal data patterns you can generally expect a network to train quite well. This applies to problems where the relationships may be quite dynamic or non-linear. ANNs provide an analytical alternative to conventional techniques which are often limited by strict assumptions of normality, linearity, variable independence etc. Because an ANN can capture many kinds of relationships it allows the user to quickly and relatively easily model phenomena which otherwise may have been very difficult or impossible to explain otherwise.

Fig 3: (a) Input parameters Graphical representation.

Fig 3: (b) Required soil moisture-graphical representation.

There are four stages connected together to fulfil the requirement.

- Sensor Input: temperature, air humidity, soil moisture, wind speed and radiation are collected.
- Evapotranspiration Model: This block converts four input parameters into actual soil moisture.
- Required Soil Moisture.
- ANN Controller: compares the required soil moisture with actual soil moisture and decision is made.

3.1. Modeling of System Parameters

Inputs Parameters: There are four factors (Temperature, air humidity, wind speed and radiation) by which evapotranspiration is influenced.

3.1.1. Temperature:

- A sine wave with amplitude of 5 ºC;
- A frequency of 2pi/T=2pi/24. 24 hour time period.
- A constant bias (offset) of 30 ºC;

3.1.2. Air humidity: It is modeled as:

- A sine wave with amplitude of 10%;
- Bias of 60% (constant);
- A frequency of 2pi/T=2pi/24. 24 hour time period.

3.1.3. Wind speed:

- A sine wave with amplitude of 1 Km/h;
- Bias of 3.5 Km/h (constant);
- A frequency of 2pi/T=2pi/24. 24 hour time period.

3.1.4. Radiation: It is modeled as maximum possible radiation at earth's surface (Rmax).

- A sine wave with amplitude of 2MJ/m2
- Bias of 112MJ/m;
- A frequency of 2pi/T=2pi/24. 24 hour time period.

3.2. Soil Moisture

It depends on plantation, type of growth, period and type of soil. The required soil moisture is calculated according to the above mentioned factors, an assumed graph is shown in figure 3.

3.3. Evapotranpiration Model

Penman-Monteith equation is an equation accepted as a scientifically sound formulation for estimation of reference evapotranspiration (Eto). It is a combined function of radiation, temperature, humidity and wind speed. Updated by FAO in May 1990, the Penman Monteith equation[6,7] is written as the following:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \tag{1}$$

$$\Delta = \frac{4098e^0(T)}{(T + 273.3)^2} \tag{2}$$

$$e^0(T) = 0.6108\exp\left(\frac{17.27T}{T + 273.3}\right) \tag{3}$$

$$\gamma = \frac{C_pP}{\varepsilon\lambda} \tag{4}$$

ET0 = Reference evapotranspiration [mm day-1],
Rn= Net radiation at the crop surface [MJ m-2 day1],
G = Soil heat flux density [MJ m-2 day-1],
T = Mean daily air temperature at 2 m height [°C],
U2= Wind speed at 2 m height [m s 1],
es= Saturation vapor pressure[kPa],
ea= Actual vapor pressure [kPa],
es-ea= e0(T) =Saturation vapor pressure deficit [kPa],
D = Slope vapor pressure curve [kPa °C-1],
g = Psychrometric constant [kPa °C 1].
P = Atmospheric pressure [kPa],
z = Elevation above sea level [m],
e0(T) = Saturation vapour pressure at the air temperatureT [kPa],
λ = Latent heat of vaporization, 2.45 [MJ kg-1],
Cp = Specific heat at constant pressure, 1.013 10-3 [MJkg-1 °C-1],
ε = Ratio molecular weight of water vapour/dry air =0.622.

3.4. Control Unit

The control unit consists of Artificial Neural Network based controller. This controller interfaces the required soil moisture and measured soil moisture. The main function of this stage is to keep the actual soil moisture close to the required soil moisture. As a result the output of this stage is control input for valve which supervises the amount of water which should be supplied in order to optimize the whole system. The block diagram of ANN based control system is shown in figure 4.

In the proposed method Dynamic Artificial Neural Network is used. Dynamic Networks [illegible] werful than static networks because dynamic networks have memory, they can be trained to lear[illegible]quential [illegible] time varying patterns [2,3].

The controller has two inputs i.e. required soil moisture and calculated soil moi[illegible]e from eva[illegible]ration model and there is only one output of controller also called control input for Va[illegible] positi[illegible]t makes [illegible]e system configuration very simple and straight forward[4,5].

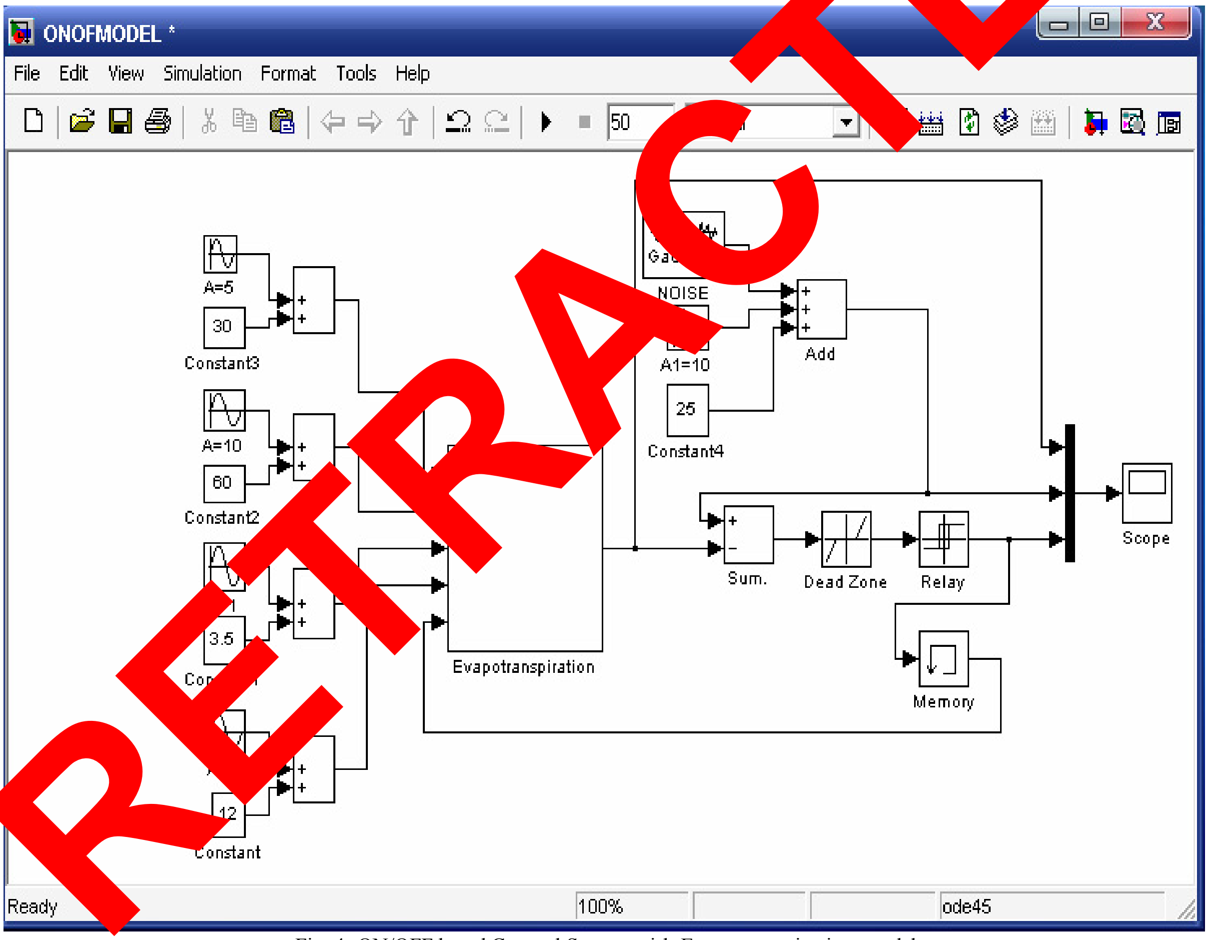

Fig. 4: ON/OFF based Control System with Evapotranspiration model

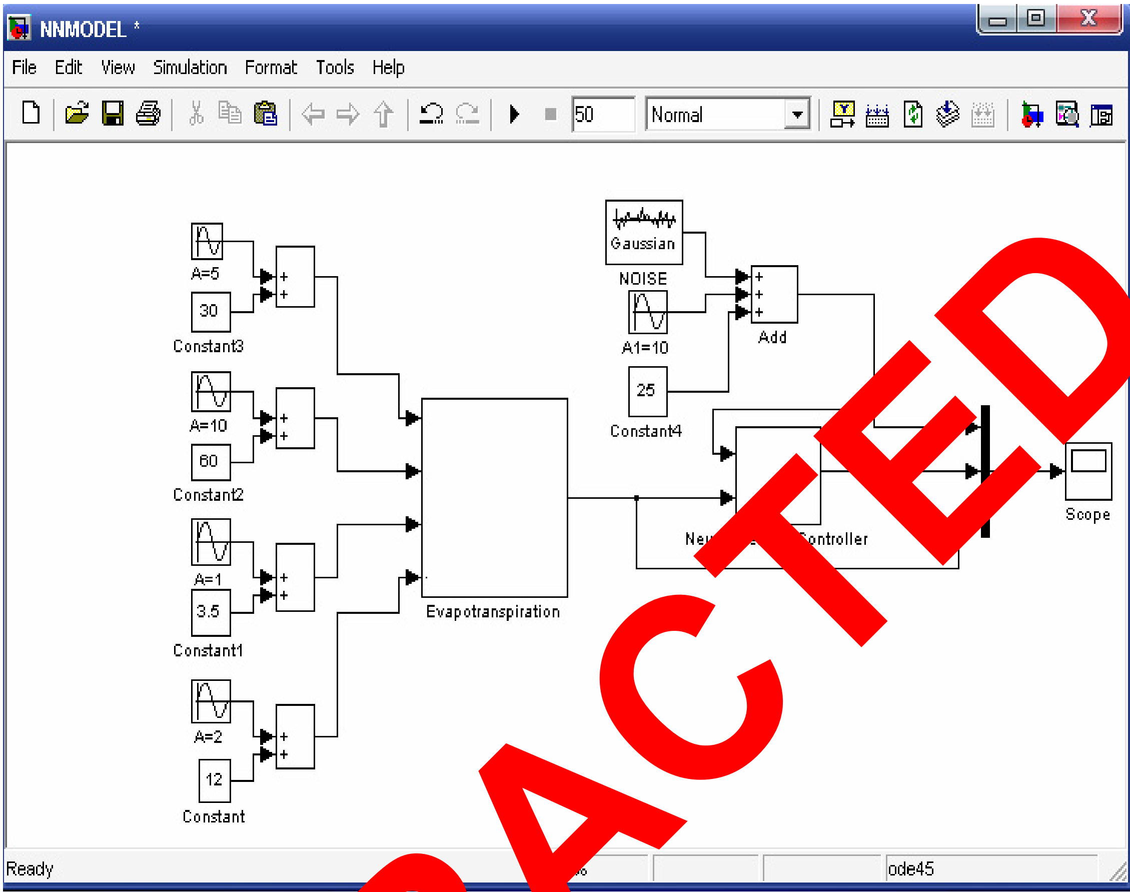

Fig. 5: A[illegible] based [illegible]ntrol sy[illegible] with evapotranspiration model

4. ANN Controller Archite[illegible]e

ANN Controller is i[illegible] using the [illegible]owing:

- Topology: Distributed [illegible] Delay Neural Network is used ;
- Trainin[illegible]nction: Bayes[illegible]egulation function is used for training.
- Perf[illegible]nce: S[illegible]m squared error is taken as performance measure.
- Go[illegible]he s[illegible]oal is 0.0001.
- Learn[illegible]te: The [illegible]ning rate is set to 0.05. (Fig 6)

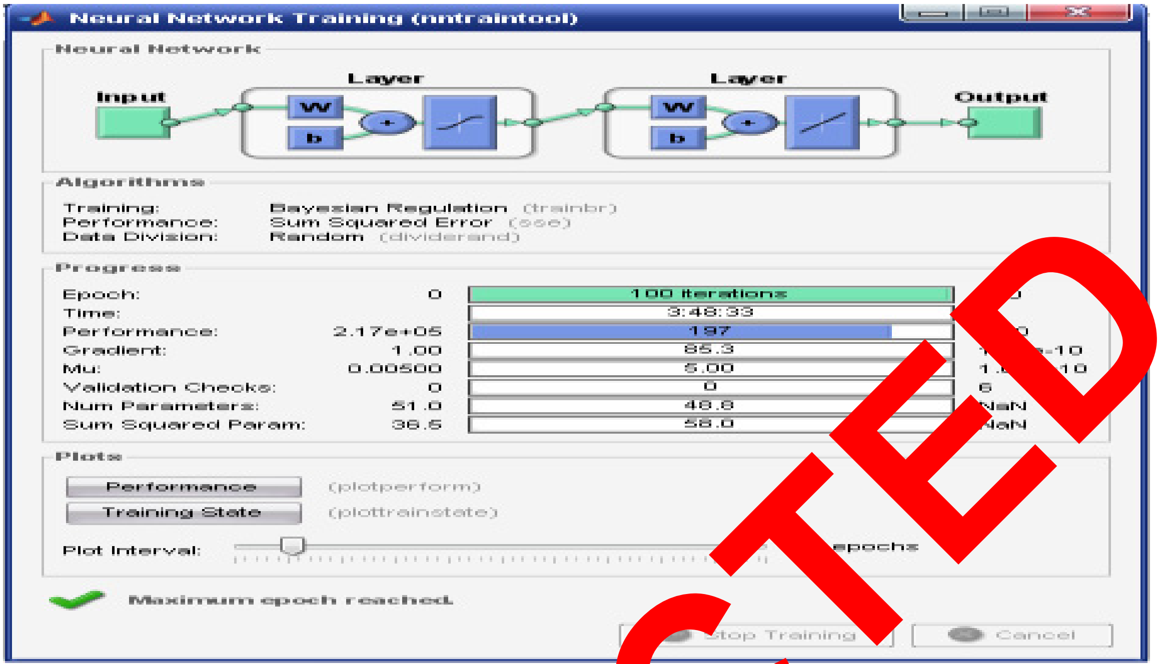

Fig 6: Neural Network Training

The block diagram of ON/OFF controller is shown in figure. In this configuration the valve is opened when the required soil moisture exceeds the measured soil moisture and it is closed otherwise.

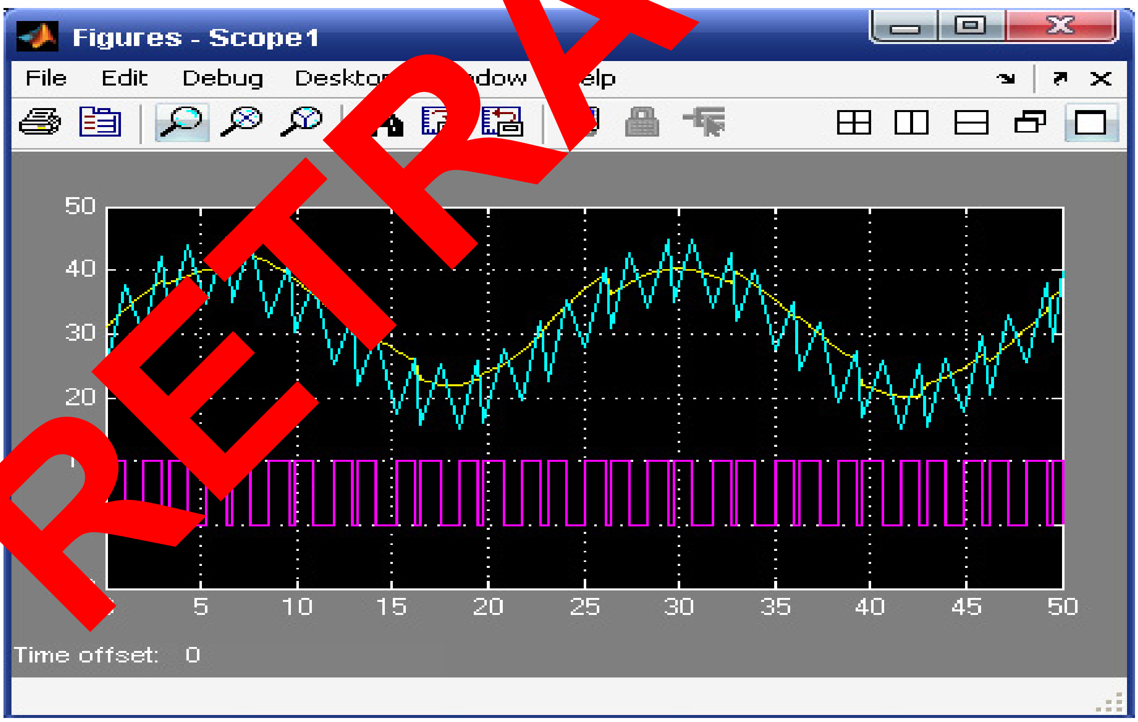

Fig. 7: Simulation Results of ON/OFF control based System

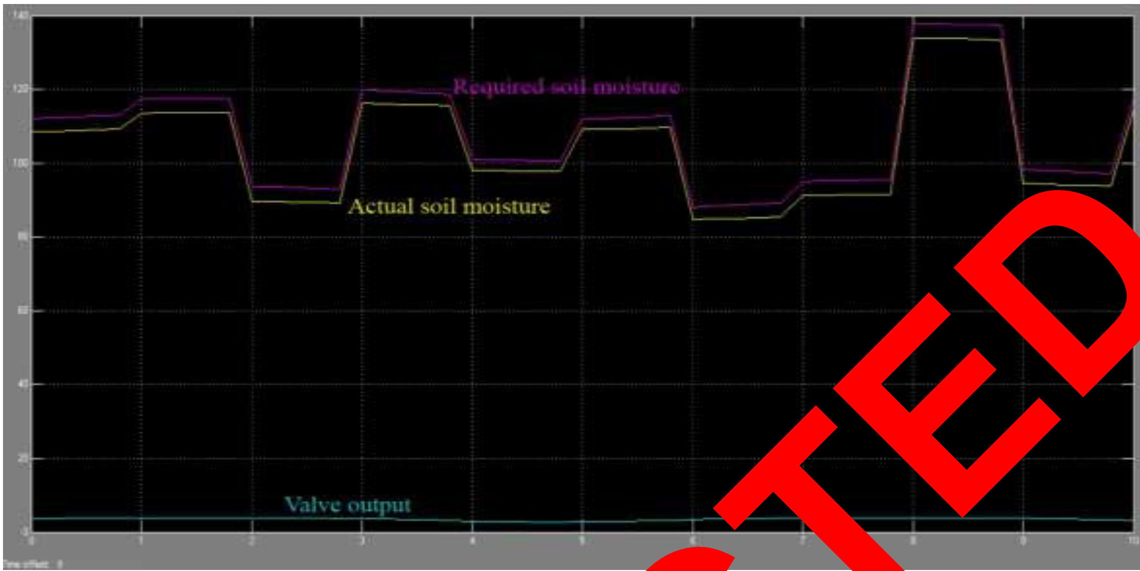

Fig. 8: Simulation Results of ANN b... control System

5. Simulation Results

Once the neural network is trained, it can be us... ct controller in cascade with the Evapotranspiration model. The control target is to b... actual soil moisture as close as possible to required soil moisture and to optimize the resources like water and energy.

Keeping the aforementioned re... ent in ... behaviour of ANN controller is noted for reference (Required) Soil moisture. The Respons... AN controller is compared with ON/OFF controller implemented with the same evapotranspiration model... s is shown in figure 7-8.The important facts that can be extracted from the simulations are:

5.1. ON/OFF Controller

The legends of figure ... are:

- Yellow ...gnal – ...quired Soil moisture
- Blue ...al-...al soil moisture.
- Light R... nal – v... output.

In .../OFF c... based system, the actual soil moisture tracks the required soil moisture but there are co...uous oscillations around the required soil moisture.
...ous oscillation at the output shows that the ON/OFF control based system is not stable.

In O...FF controller the valve is opened and closed continuously at the extreme points (0 and 10).Due to this, lot of energy and water are consumed which is undesirable.

5.2. ANN Controller:

The legends of figure 7 are:

- Yellow signal-Required Soil moisture
- Light Red signal-Actual Soil moisture
- Green-Valve output.

The actual soil moisture tracks the required soil moisture without any oscillations.

1. The error (difference between required and actual soil moisture)is steady and reasonable (l[illegible]%)
2. In ANN controller the ON/OFF of the valve and energy system is very low and henc[illegible] of en[illegible] and water can be saved.

The main goal of designing the cost-effective and result oriented Irrigation Contro[illegible]stem ha[illegible]en a[illegible]ved by using ANN Controller.

6. Conclusions and future work

This paper has described a simple approach towareds Irrigatio[illegible]ol problem[illegible] ANN Controller. The proposed system is compared with ON/OFF controller and it is s[illegible]wn th[illegible]N/OFF Controller based System fails miserably because of its limitations. On the other hand ANN based a[illegible]ach has resulted in possible implementation of better and more efficient control. These con[illegible]do not requ[illegible] prior knowledge of system and have inherent ability to adapt to the changing condition[illegible]nlike conventional methods. It is noteworthy that ANN based systems can save lot of resources (energy and w[illegible]r) and can [illegible]ovide optimized results to all type of agriculture areas.

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