# Plant Irrigation System Using ARM Processor with Solar Power for Agricultural Applications

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***Abstract-*** **Indian agriculture is dependent on the monsoon seasons which are not reliable source of water. Therefore there is a need for irrigation system in the country which can provide water to the farms according to their soil types. This paper presents the prototype design of microcontroller based automatic irrigation system which will allow irrigation to take place where water is required, there by supplying required quantity of water depending on the soil moisture indicated by different plants. This project presented here waters your plants regularly whenever it is required. The circuit comprises of sensor parts built using Gypsum blocks which is controlled by a LM324 IC comparator. Two stiff copper wires are inserted in the soil to sense whether the soil is wet or dry. This project is designed with ARM7TDMI processor. Depending upon the various processes its corresponding details will be read by the LPC2148 controller unit. The LPC2148 are based on a 16/32 bit ARM7TDMI CPU with real time emulation and embedded support, together with 128/512 kilobytes of embedded high speed flash memory. With a wide range of serial communications, they are also very well suited for communication gateways, protocol converters, embedded soft modems as well as many other general applications. The use of pesticides dosing and sprinkling system makes an added advantage to the irrigation system by sprinkling the pesticide mixture in required proportion to the plants without human control.**

***Key Words:*** **ARM7TDMI LPC2148 controller, Gypsum embedded sensors, LM324 comparator, DC sprinkler motors, Relays.**

## I. INTRODUCTION

Solar energy has emerged as a viable source of renewable energy over the past decades, and is now widely used for a variety of industrial and domestic applications. Solar energy systems are based on solar collectors, which are designed to collect the sun's energy and to convert into their electrical power. Living in this modern world, we are blessed with abundance of innovative technology. Thus watering your plants effectively by using automatic plant irrigation system has become a very easy task. Too much water in your farming will go waste, too little water will cause malnutrition to your plants. Agriculture is one of the most important aspects in our life. It is the only field which maintains human life to survive on the Earth. In this scientific world we can able to automate each and every process in order to reduce the manual work load and also the time consumption. It will be more useful if we introduce automation in these agricultural applications.
Here we are going to reduce the human work load due to irrigation through embedded systems.

The project presented here waters your plants regularly. The circuit comprises sensor parts which are supported by using op-amp LM324 comparator. The comparator monitors the sensor and when sensor sense the dry condition then the project will switch ON the motor and it will switch OFF the motor when sensor is wet. The comparator does the above work it receives the signal from the sensors. Each zone will be activated in sequence so as not to create any excessive water wastage. In this project we make use of micro controller for controlling the whole process. A program is developed in embedded C by using keil micro vision software to control the pesticide unit i.e. the pesticide automatically mixes with water or solvent and sprays without manual work.

## II.ARM PROCESSOR

The ARM7TDMI (Advanced RISC Machine Thumb Debug Multiplier IC hardware) is a general purpose 32-bit microprocessor, which offers a very high performance and a very less power consumption. The ARM architecture based on RISC (reduced instruction set computing) and the instruction set and related decode mechanism are much simpler than those of micro programmed Complex Instruction Set Computers (CISC). A RISC (reduced instruction set computer) is a microprocessor that is designed to perform a smaller number of types of computer instruction so that it can operate at a very high speed and perform more million instructions per second in a less time.

This type of simplicity results in a high instruction throughout the process and impressive real time interrupt response from a small and cost effective processor core. Pipeline techniques are employed so all parts of the processing and memory systems can operate continuously, i.e. while one instruction is being executed, its successor is being decoded i.e. second instruction, and a third instruction is being fetched from memory. The ARM7TDMI processor also employs a unique architectural strategy known as Thumb, which makes ideally suited for high volume applications with memory restrictions. The key point behind Thumb is that it reduces instruction set optimized for code density from C code, improve performance from narrow memory level.

*A.LPC2148 controller*

The LPC2148 microcontroller are based on a 16/32 bit ARM7TDMI with real time emulation and embedded support, that combine microcontroller with embedded high speed flash memory ranging from 32kb to 512kb. A 128 bit wide memory interface and unique accelerator architecture enable 32bit code execution at the maximum rate. For critical code size applications, the 16bit thumb process reduces code by more than 25% with minimum performance penalty. Due to their small size and less power consumption, LPC2148 are ideal for applications where as miniaturization is a key requirement. Serial communication interfaces ranging from a USB.2 full speed device, multiple UART's to 12C-bus and on chip Static RAM of 8kb to 40kb, make these devices very well suited for gateway communications and protocol converters, soft modems, voice recognition and low end imaging providing both large buffer size and high processing power.

*B. Seven Basic Operating Modes of ARM:*

- User: Mode under which most tasks run.
- FIQ: Entered when a high priority (fast) interrupt is raised.
- IRQ: Entered when a low priority (normal) interrupt is raised.
- Supervisor: Entered when a Software Interrupt instruction is executed.
- Abort: used to handle memory access.
- Undef: Used to handle undefined instruction sets.
- System: mode using the same registers as user mode.

The below circuit diagram tells about the micro controller pin connections to the Relays, LCD, Comparators, and to the switching transient for pesticide dosing

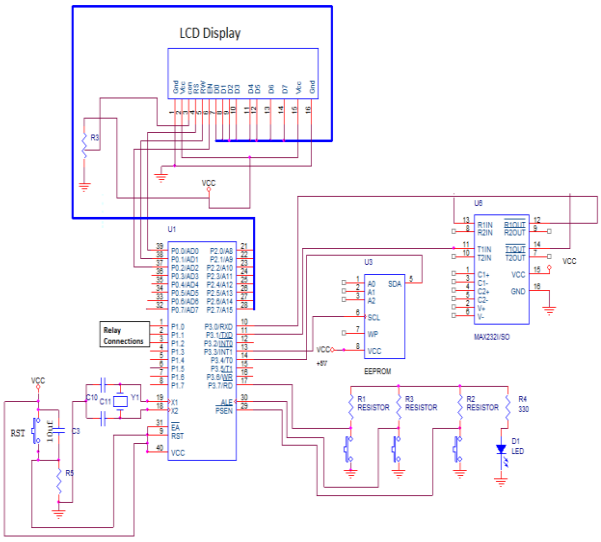


Figure 1: Microcontroller design layout

*C. ARM Board Technical Specifications:*

| | |
|---|---|
| Processor | : LPC2148 |
| Clock speed | : 11.059 MHz / 22.118 MHz |
| Real time Clock | : DS130 on i2c Bus battery |
| Data Memory | : 24LCxx on I2c Bus |
| LCD | : 16x2 backlight |
| LED indicators | : Power |
| RS-232 | : +or - 9V levels |
| Power | : 8-15V AC/DC @ 500 mA |
| Voltage Regulator | : 3.3V |

The main aim of using this ARM7TDMI LPC2148 controller because of following advantages

- High speed flash memory in all modes of operations.
- Very wide range of serial communications.
- Very well suits for communication gate ways.
- Less power consumption.
- Reduced instruction set computing technology

## III. BLOCK DIAGRAM

The below block diagram shows the complete picture layout of the automatic plant irrigation, the input to the technology is solar power and the four relays which controls the four tanks which is connected to the four dc sprinkler motors, and the moisture sensor is placed to detect the soil condition which is controlled by a LM324 comparator and finally the ARM controller which controls the whole process with a high efficiency. The working of major components used in this technology is explained below.

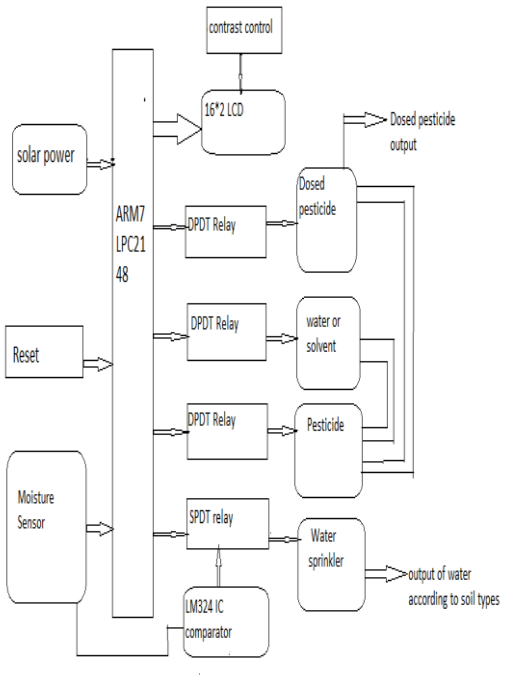


Figure 2: Block diagram

## IV. HARDWARE DESCRIPTION OF MAJOR COMPONENTS

### *A.Power supply unit and its description*

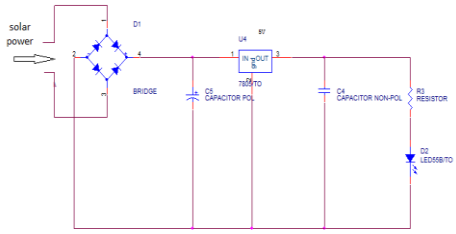


Figure 3: Power supply unit circuit

The input to this technology is solar power, The Solar multi-crystalline 10 watt panel which has 36 solar cells which is made up of silicon materials, each cell produces approximately 0.6volts according to the multi-meter reading. The overall voltage produces around 20 volts approximately. The output of the solar is fed to the 12volts lead acid battery to store the power in case of any break down of power from the input. From the battery the power is fed to bridge rectifier, as the basic definition of bridge rectifier is to convert AC into pulsating DC, in this project our input is DC still we have used rectifier because it is a normal practice to provide bridge at incoming power because bridge rectifier protects the circuit from DC polarity miss match. However the power connector polarity orientation in the bridge yields correct polarity to the circuit with a good stability. The output from bridge rectifier is sent to capacitive filter, it removes the ripples from the output of rectifier and smoothens the DC output received from the rectifier is constant until the mains voltage and load is maintained constant. However if either of the above two is varied DC voltage received at this point changes, therefore a Regulator applied at the output stage. The regulator name itself implies it regulates the input applied to it.It is to maintain the constant voltage.

This technology uses 5volts (i.e.7805 regulator) and 12volts (i.e.7812 regulator) are used for constant voltages according to our requirements. Here the 5volts regulator supply is given to the ARM microprocessor board, for the 16*2 LCD and for reset ratio button purpose only we require 5v and for rest of the parameters such as oscillators, LPC2148 controller we require only 3.3volts as a input, so in order to fed the require power to the controller we have placed a 3.3 fixed voltage regulator as a input to the controllers, this shows the major advantage of this system because the power consumption is less by using ARM7TDMI LPC2148 controller.

### *B. Relays:*

A relay is electrical controllable switch. In this system it uses four relays to control four dc sprinkler motors, among four relays three relays are DPDT i.e. double pole double throw relays and remaining one is a SPDT relay, i.e. single pole double throw relay. The SPDT relay is to control the water sprinkler motor, the input power to SPDT is 12volts from the 7812 regulator because, it consist of LM324 comparator which controls the sensor parts.

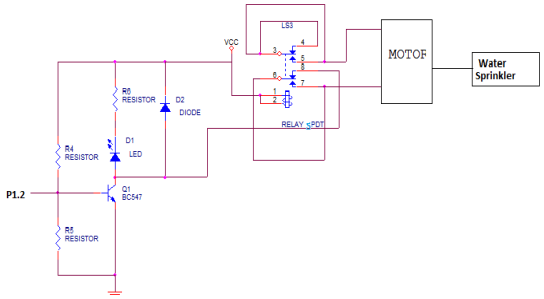


Figure 4: SPDT Relay connection to the motor

In SPDT relay Current will flow between the movable contact and one fixed contact when the coil is de-energized and current flow between the movable contact and the alternate fixed contact when the relay coil is energized. The figure 4 shows the SPDT relay connection to the water sprinkler motor, which is connected to the moisture sensors, whenever the sensors sense the soil types the motor will work accordingly.

DPDT relay stands for Double Pole Double throw relay. It operates like the SPDT relay but has twice as many as contacts. There are two completely isolated sets of contacts in DPDT relay. In this technology total three DPDT relays to control the pesticide dosing process, the figure 5 shows the connection to the 3 motors which is used for pesticide dosing purpose

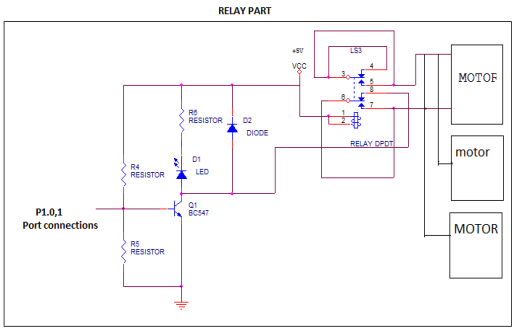


Figure 5: DPDT relay connections to the motor

### *C. Sensors and LM324 comparator:*

Modern impedance dew point sensors are typically constructed using state of the art thin and thick film techniques which are built using Gypsum blocks. Gypsum blocks consist of two parallel electrodes embedded in blocks. They have a pair of wires connected to the electrodes that are two meters long from the circuit. These gypsum blocks acting as sensors are buried in the soil to achieve a good contact with the soil. It has measuring range of 100% for 0 to 150kpa.

Operation of the sensor depends upon the absorption of water into a porous non-conducting sandwich between two conductive layers built on top of a base ceramic substance. The active sensor layer and the porous top conductor, that allows transmission of water into the sensor. Therefore the sensors respond very rapidly to the changes in the moisture.

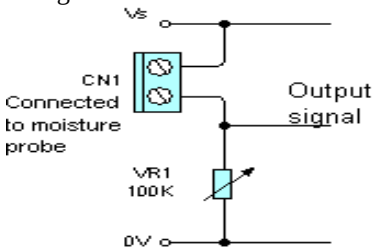


Figure 6: Moisture Sensor circuit

In this technology a simple low cost moisture probe made from a small piece of strip board with leads connected to a pair of the copper strips embedded with gypsum blocks is constructed. When the probe is dry there is a very low voltage and high resistance between the strips. When it is wet the water reduces the sensor probe's resistance and voltage increases. The moisture sensor forms a potential divider whose output voltage is determined by the upper and lower parts of the circuit. The moisture sensor is connected to the circuit by wires connected to a terminal block mounted on LM324 comparator, the comparator which controls the moisture sensors according to their soil types whether to send or stop the water.

LM324 is a 14 pin IC consisting of four independent op-amps, these are high gain voltage amplifiers with a differential output with a good stability which acts as comparator. This LM324 comparator receives the signal from sensor, which sends the signal to the microcontroller and acts accordingly by using relay to ON or OFF the motor according to the soil types.

*D. DC sprinkler motors*

High pressure water pump built in thermal protector, fully automatic demand pumps can be used as a portable sprinkler pump as well. Small size, light weight and stable performance. Special valve for water inlet and outlet. Low noise with excellent resistant to chemical corrosion. Working voltage is 12Vdc.

*E. Switch interfacing for pesticide dosing*

The coding is developed in Embedded C language by using Keil micro vision software, according to the requirement of the project to control the whole process, the proportion mixing of the pesticide with water in the dosed pesticide tank is controlled by ARM processor. To enable this process the push buttons are placed which acts as switch to perform the desired task. CPU accesses the switches through ports of the controller. Therefore these switches are connected to a microcontroller. This is connected between supply and ground terminals. Microcontrollers implements interfacing of switch between hardware and software. When the switch is open, the total supply i.e. Vcc appears at the port pin P2.0= 1, When the switch is closed i.e. when it is pressed, the total supply path is provided to ground. Thus the voltage value at the port pin P2.0 will be zero.P2.0 = 0.

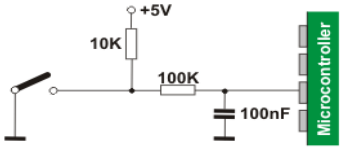


Figure 7: Switch interfacing to the microcontroller

A pesticide dosing ratio are set in the coding as 1:2 and 1:4, when the switch is pressed, 1 percent of pesticide and 2 percent of water will mix by itself with no human control and same as for 1:4 also and finally sprinkles the product into the farm

## V.EXPERIMENTAL SETUP

The technology automatic plant irrigation using solar power with ARM7TDMI PROCESSOR and LPC2148 Controller was designed such that the solar powered input with load of dc sprinkler motors, microcontroller and relays. This system automatically senses the moisture content in the soil whether it is dry or wet by using LM324IC comparator, which will allow irrigation to take place where watering is required by using moisture sensor parts, Water is a good conductor of electricity if more water present in the soil the lower the resistance to electricity passing through it, i.e. when soil is wet, water flow to the soil will be stopped because of low resistance. As soil dries, Water is drawn from the block and resistance between the electrodes increases.

Here the relays will acts as switch whenever the sensors sense the soil wet or dry, for example if soil is in dry condition the sensors will send signal to comparator and relay will close the switch, to ON the dc sprinkler motor to water the farm.

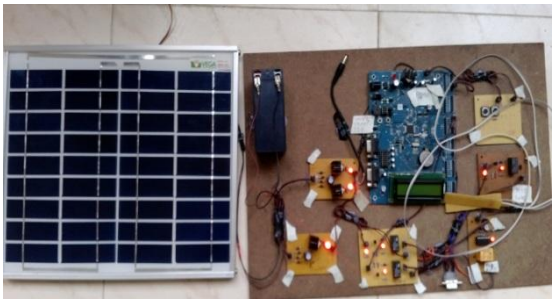

Figure 8: prototype lab model

The use of pesticide dosing system in this project makes an added advantage to the irrigation system by mixing the pesticide in required proportions, was designed in Embedded coding, the mixing ratios are such as one percent of pesticide two percent of water or one percent of pesticide to four percent of water will get mixed in the

dosed pesticide tank. The four DC sprinkler motors which are connected to their respective tanks are shown below. The bottom tank is a water sprinkler, which is connected to sensor parts to sense the soil whether it is wet or dry by using comparator according to that the motor will water the plants. The second tank from the bottom is pesticide material and the third tank from the bottom is solvent which is nothing but water, from both the tanks according to proportion ratios it will mix in the fourth tank from the bottom i.e. dosed pesticide tank and it sprinkles the dosed pesticide to the farm.

Figure 9: water and pesticide dosing, sprinkling tanks with dc sprinkler motors

## VI. SIMULATION MODEL

The below simulation model shows the dc sprinkler motors with solar power operated system. In remote areas solar power is also used in the fields of agriculture applications. Solar panel generates the dc voltage; each cell in the panel generates 0.6 volts. Like these 36 cells are connected in series to sum up voltage. Initially this voltage is stored in the battery. From this battery the voltage is applied to dc motor controller. In this a PWM voltage controller and an H- bridge are used to control the speed of dc sprinkler motor. The ON / OFF and the direction of rotation is controlled by H- bridge. The PWM controls the rate of speed of sprinkler by supplying the amount of voltage to the dc motor. The main aim of developing this project by using simulation is to calculate the open circuit voltage to the given input as mentioned above.

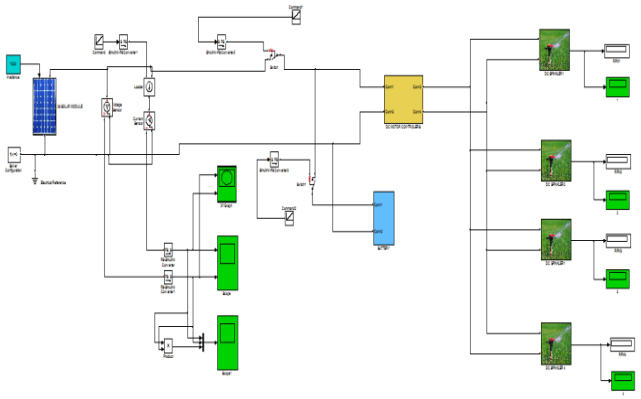

Figure 10: simulation design

### *A. Analysis of simulation model*

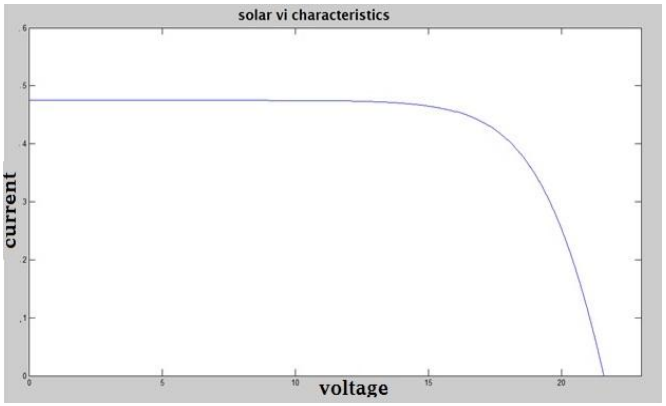


Figure 11: I-V characteristics of solar

$I=I_S\{\exp(q*V_{oc}/K_bT)-1\}-I_{ph}$ (1) Diode equation of solar cell

$V_{oc}=(K_bT/q)\ln\{(I_{ph}/Is)+1\}$ (2) Opencircuit voltage

The above two equations is to find out the open circuit voltage of solar cell when load is not connected i.e. when current is zero. The above figure illustrates the V- I curve of a solar panel. Photovoltaic are electronic devices that use P-N junctions to directly convert sunlight into electrical power, the P-N junctions in the solar cell has a complex relationship between voltage and current. As both the current and voltage is a function of sunlight falling on the solar cell, the relationship between insolation (sunlight) and output power is complex. If load is not connected to solar panel which is in the sun, an open circuit voltage $V_{oc}$ will be produced but no current follows. When a load is connected, the I-V curve of the solar panel is considered to figure out how much power can be delivered to the load. For a particular load, the maximum point is changed according to the I-V which is varied with the insolation, temperature and shading. Because solar power is relatively expensive, it is important to operate solar panels at their maximum power conditions. In figure11 which shows the voltage and current ratings of about 20volts and 0.45amps respectively.

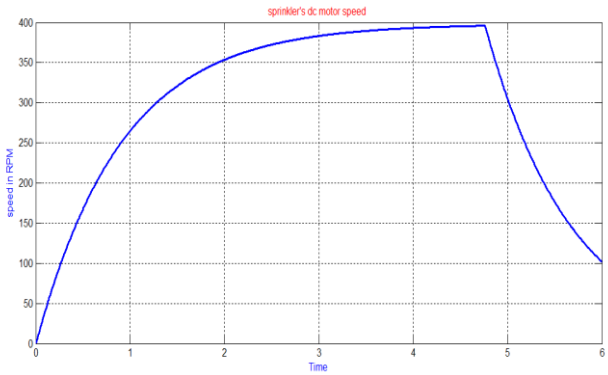


Figure 12: Speed wave characteristics of dc sprinkler motor

The figure 12 shows acceptable characteristics, however the speed doesn't go instantaneously at 380 rpm but follows

the acceleration ramp. The motor reaches steady state at t = 3 s. At t = 4 s, the torque applied to the motor's shaft by sprinkler on condition. Observes the drop in motor speed. After the transient nature of speed, the dc motor maintains constant speed.

*B. Analysis of Experimental Setup*

Experimental setup was designed and developed accordingly. The experiment was conducted on 5th October to 9th October 2013 at Centre for Energy Studies at JNTU Hyderabad. The approximate values of three day averages of voltage, current and power are shown in below table1.

$I=I_s \{\exp (qV/K_b T)-1\}-I_{ph}$ (3)

According to Kirchhoff's law V+VL=0 or VL= -V

Then current I=VL/RL (4)

Output power of solar when load is connected

$P=IV=I_s V (\exp (qV/K_b T)-1)-I_{ph}*V$ (5)

$K_b$=Boltzmann constant

Table 1: Measured values of Power, Voltage and Current

| Time | 09 am | 10 am | 11 am | 12 pm | 01 Pm | 02 Pm | 03 pm | 04 Pm |
|---|---|---|---|---|---|---|---|---|
| Voltage | 11.33 | 13.56 | 15.01 | 15.33 | 16.56 | 17.01 | 15.87 | 14.33 |
| Current | 0.2 | 0.34 | 0.45 | 0.48 | 0.49 | 0.50 | 0.49 | 0.27 |
| Power | 2.26 | 4.61 | 6.75 | 7.35 | 8.11 | 8.50 | 7.77 | 3.86 |

The figure 13 shows the curve between power and time, as we can see at the mid noon from 12pm to 3pm the power is maximum for solar.

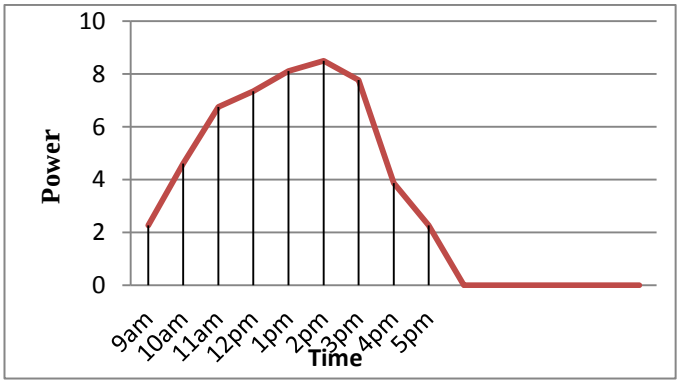


Figure 13: power vs. time wave form

## VII.RESULT

The low cost gypsum block sensors measures soil moisture tension of 100% for 150kpa (kilopascals).The use of automatic pesticide dosing and sprinkling with no human control makes an added advantage for this technology. From the above analysis of both simulation and experimental we can say that the use of solar power for agricultural purposes is more effective than any other power sources due their renewable energy technology, hence the processor ARM7TDMI used here consumes very less power i.e. 3.3V when compare to the other microcontrollers.

## VIII. CONCLUSION

Measuring soil moisture is important in agriculture to help farmers manage their irrigation systems more efficiently. Not only they are able to use less amount of water to grow a crop, they are able to increase their yields, the quality and quantity of the crop by the better management of soil moisture during critical plant growth stages and sprinkling the dosed pesticide in an effective way is an added advantage in this project. Hence this project is designed and implemented successfully by using advanced processor ARM7TDMI.

## ACKNOWLEDGEMENT

I take this opportunity to express gratitude to my guide Dr.M.T.Naik, Centre for Energy studies JNTU Hyderabad for his exemplary technical guidance which helped me in completing this project.

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