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Automatic Solar Digital Wireless Irrigation Systems for Open Areas and Green Houses

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Abstract Nowadays, the water problem becomes an international issue. So, it is a critical step for scientists to use science and new technologies to solve this global problem. While many of them seeking for solutions that based on finding new water recourses, others trying to use different methods for saving water consumption. The lack of water supply in Saudi Arabia and specifically always been the major constraint on agriculture and the determining factor on where cultivation occurred. The aim of this research is to design and implement a complete, reliable wireless irrigation system that has a great advantage in saving time, labor and cost. There are several attempts to use wireless the technology in building an efficient wireless irrigation system. But, these systems suffered from the lack of permanent power supply and the inability to deal with multiple sensing and related multiplexing techniques. The solar and automatic wireless technologies add a complete hand free work for all users. The system fulfills all the farmer needs to get cheaper and better quality products. The system is based on wireless digital technology that can be used for automatic irrigation of different areas. To achieve this purpose ,digital multiplexing techniques are used to receive different control signals from different transmitters to control pumps, valves, and other end devices**.**

***Index Terms*—Irrigation System, Wireless communication, Solar energy.**

I. INTRODUCTION

Recent case studies for Kingdom of Saudi Arabia and India have confirmed the high accuracy of Solar GIS data. The Ground measurements from 12 stations that were installed as part of a project jointly run by KACST and NREL. Excellent accuracy of Solar GIS data in extreme climatic conditions was already done by using validation statistics from other similar regions such as the Sahara and Kalahari Deserts.

The existence of low power DC lamps, such as low-pressure sodium and fluorescent lamps, makes PV systems an ideal source for lighting the meeting remote or mobile. Obviously, the demands for PV lighting are greatest at night, making battery storage systems important.

Radio, television and cellular signals are electromagnetic signals that should be transmitted over long distances and need to be amplified. Repeaters can perform retransmission operation to deliver the message to its destination. The best sites for repeater stations are usually at the highest possible buildings, where power lines are not commonly discovered, and transport of conventional generator fuels would be challenging and costly. Also, PV repeater stations will be used, since the use of fiber optic cable spreads. Coaxial cable are usually used to carry power to amplify the signal, however fiber optic cable does not have this capability. PV also is used on travelers' information transmitters, laptops, mobile phones, mobile radio systems, and emergency telephones.

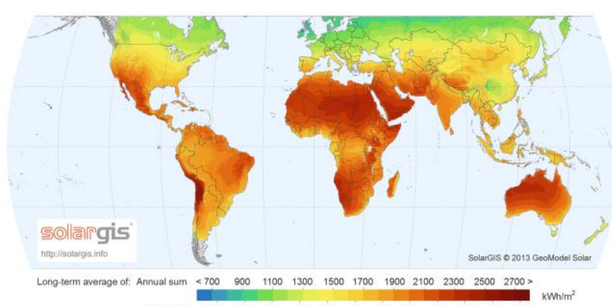

Figure 1: Distribution of solar energy

Many residential areas are simply very far from the utility distribution network to have a grid connection. Also,

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electricity is needed at construction sites before the connection has been installed. PV systems are an efficient way to provide electricity in such areas. Conventional power stations or other renewable energy systems, such as wind or micro-hydroelectric generators, may be used in parallel with the PV system to ensure intermittent power availability. Some examples of remote site electrification are for visitor centers in parks, rural homes, vacation cabins, park ranger sites, remote farm workshops hunting lodges, and villages.

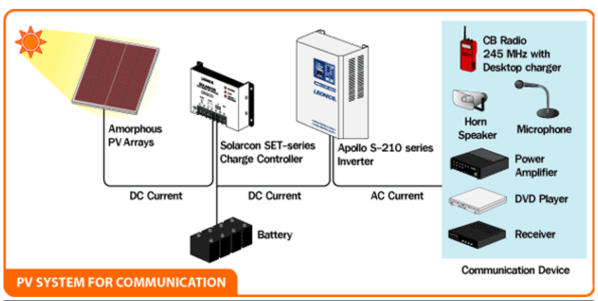

Figure 2: Using of Solar energy in streets

There is a lack of water supply in Saudi Arabia and can be considered as major problem on agriculture and the determining factor on where agronomy occurred. The kingdom has no ponds or rivers. Rain is slight and irregular over most of the country. To obtain water we use a lot of energy which results in high prices of vegetables and fruits. Because of inefficient irrigation control methods used, the waste of water, energy and needed time for irrigation is high.

There were several national, regional and international attempts to design and implement wireless irrigation systems. Those systems suffered from several disadvantages:

a. The inability of such systems to deal with multiple sensing to provide full control system of moisture, humidity, temperature... etc.

b. These systems do not present a solution for the power supplying process, especially, for the sensors and transmitters.

c. Some of these systems implemented for specific irrigations applications. Such as, crop (wheat),

vegetables, green houses, trees … etc.

One of the solutions of the above mentioned problems is the use of modern technology to control the amount of needed water depending on the coverage area, humidity, temperature, soil and type of plants in agriculture. This will make the system worldwide for all irrigation purposes. The sensor and Transmitter have a flexible design. The installation and maintenance are easy.

Design and Implementation of full controlled wireless solar agricultural system gives a number of benefits such as:

1- Normal growing of different plants by controlling environmental conditions such as temperature, humidity and quantity of water.

2- Water saving: using special sensors for measuring soil humidity, air humidity, air surrounding temperature and avoiding daylight irrigation.

3- Power saving

Manufacturing a multi-purposes wireless irrigation system for farms, greenhouses and gardens will save water, energy and labor using wireless technology based solar system. Wireless irrigation solar system ensures delivery of the right amount of water needed for agriculture.

The solution of inefficient irrigation depends on the ability to combine different engineering disciplines together to work synchronously from the moment of measuring low level soil moisture up to the auto-decision of irrigation process. The research contains four main parts:

1- Sensing part: Using accurate sensors for temperature, humidity and soil moisture reflect the efficiency of the system on the all irrigation steps. In this part, sensors are responsible to feed electrical components of the system with electrical signal presenting the input of the close-loop irrigation control system.

2- Control part: Irrigation system can be considered as a feedback control system in which its output values are compared to the desired input values that defined and determined by the system depending on the environment.

3- Decision making part: Depending on the feedback of the irrigation control system, the decision part will make its decision about irrigation, ventilation or heating.

4- Wireless communication part: is a very important part due to presence of noise and interference and the need of appropriate multiplexing techniques to achieve full control of different signals received from different sensors.

Finally, the research is complicated and needs multiple phases. So, at the first phase the research we concentrated on the main functions to study the wireless communication and power supply solar system. In the second phase of research, the automatic smart controlling will be

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considered.

II. COMPARISONS AND ANALYSIS

A. Literature Review

Most of literature available concentrated on the automatic control soil moisture sensing assuming a wired connection. In this research, we tried to focus on the wireless environment of multi-controlling of different irrigation parameters. Using the suitable multiplexing technique in controlling process is critical in enhancing the efficiency, increasing the controlled area and saving power and bandwidth. So the literature used in this research merged the core and advanced concepts of digital wireless communications and its related multiplexing techniques with input/output parameters of the irrigation system. Using electronics, measurement and control theories, a complete description of electronic and electrical components combined with digital wireless multiplexing techniques will be introduced.

It is the application of control theory for regulation of procedures without direct human involvement. In

the simplest type of an automatic control loop, a controller measure a value of a process and compare with the reference set value and processes the resulting error signal to adapt some input to the process, in such a way that the process stays at its reference point despite disturbances.

Relationships between the main elements and the functions of automatic controlling are shown in Figure 3. The measuring part performs the measuring task by sensing and evaluating the measured variable. The error detection component first compares the value of the measured variable to the wanted value and then signals an error if an abnormality exists between the actual and desired values.

The final control element responds to the error signal by correcting the manipulated variable of the process.

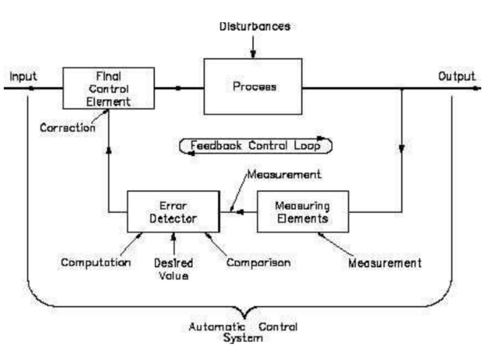

Figure3: Relationships of Functions and Elements

In work [1], a methodology to optimize the design of the tank irrigation system is presented. Such systems taking into account the limitations, aims, options of the position, transportation and application approaches; crops and their irrigation levels, productivity, request of the population dependent upon that area in terms of amount of food grains, pulses, oilseeds, nutrients, and the accessibility of different inputs to achieve an optimal design of all components of the system is presented. The system suffered from no using new Communications, Control Computer technologies. In 1997, the work [2] concentrated on the water depth measured using the pulsed irrigation. This work can be considered as a part of all system and can be utilized as a feedback of the control system. May we can find out that all techniques in this research are already studied, analyzed, manufactured and implemented. But on the other hand, in work [3], a control system is comprised of readily available commercial components and provides an efficient way of implementing variable rate water and chemical application in production studies for evaluating potential benefits. The soil and chemical applications in KSA need more studies and analysis. In [4-10], individual problems related to land, control system, chemical applications are considered. In our work, a complete full-controlled system with full applications and independent power supply unit will be explored and implemented for KSA environment. In 2009, the work [11] presented a wireless solution for intelligent field irrigation system dedicated to Jew's-ear planting in Lishui, Zhejiang, China, based on ZigBee technology.

B. Solar Systems

Every day the sun radiates an enormous quantity of energy. It emits more power in one second than the world has used since time started. This energy comes from the sun itself. Like all stars, the sun is a big gas ball made up mostly of hydrogen and helium atoms. The sun produces energy in its inner core in a process called nuclear fusion.

During nuclear fusion, the high pressure, and temperature in the sun's core causes hydrogen (H) atoms to come apart. Four hydrogen nuclei (the centers of the atoms) combine, or fuse, to form one helium atom. During the fusion process, radiant energy is produced. It takes millions of years for the radiant energy in the sun's core to make its way to the solar surface, and then just a little over eight minutes to travel the 93 million miles to Earth. The radiant energy travels to the Earth at a speed of 186,000 miles per second, the speed of light.

Only a small portion of the energy radiated by the sun into space strikes the Earth, one part in two billion. This amount of energy is enormous. Every day enough energy

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hits the United States to supply the nation's energy needs for one and a half years. About 15 percent of the radiant energy that reaches the Earth is reflected back into space. Another 30 percent is used to evaporate water, which is lifted into the atmosphere and produces rainfall. Radiant energy is also absorbed by plants, the land, and the oceans.

Photovoltaic comes from the words photo, which means light, and volt, a unit of measuring electricity. Photovoltaic cells are abbreviated to PV cells or solar cells for short. There are several home applications which use the solar cells such as calculators, Solar-powered toys, and roadside telephone call boxes by converting sunlight into electricity.

Solar cells are composed of a thin piece (called a wafer) of silicon, the substance which constitutes sand and the second most common substance on Earth. A minuscule amount of phosphorous is added to the top of the wafer which gives the top of the wafer and more free electrons. This type is called n-type silicon and it has a tendency to give up electrons, a negative trend. A small amount of boron added to the bottom of the wafer, which gives it a tendency to attract electrons. This type is called p-type silicon and it has a tendency to attract electrons, a positive trend. After adding these elements to the silicon wafer, some of the electrons flow from the n-type silicon to the p-type silicon forming an electric field between the layers. The p-type now has a negative charge, and the n-type has a positive charge.

When the PV cell is installed and directed to the sun, the photons energize the free electrons. If the top and bottom of the silicon wafer are connected with wire, electrons flow from the n-type through the wire to the p-type. The PV cell is producing electricity—the flow of electrons. If a load, such as a light bulb, is placed along the wire, the electricity will do work as it flows. The conversion of sunlight into electricity occurs without rotating parts, silently and instantly. So, there are no any mechanical parts to wear out. By comparing to some other ways of producing electricity, PV systems are expensive. Recently, it costs 10-15 cents a kilowatt-hour to produce electricity from PV. In USA, people pay about 11 cents a kilowatt-hour for electricity from a power company using conventional fuels like hydropower, coal or uranium. Nowadays, PV systems are used mainly to generate electricity in rural areas.

In the past few years, Photovoltaic (PV) generation has emerged as a one of the most promising sources of large-scale renewable energy systems. The importance of the PV generation comes from its advantages such as the absence of fuel cost, little maintenance, no pollution, no noise and wears due to lack of moving parts [12].

The advantages of photovoltaic:

1. Solar energy makes use of a renewable natural resource that is readily available.
2. No carbon dioxide or other toxic emissions is created by solar power.
3. The production of electricity by the PV process is silent and produces no toxic emissions.
4. The generated electricity from PV cells is direct-current electricity which can be stored in batteries and then used in a large scale of voltages depending on the configuration of the battery bank.
5. Although most of home electric appliances operate on AC current, an increasing number of appliances using DC current are now available. Practically, PV-generated DC current can be converted into AC current by use of power electronics devices called inverters.
6. All radioactive and chemical polluting by products of the thermonuclear reactions remain behind on the sun, while only pure radiant energy reaches the Earth.
7. Energy reaching the earth is enormous.

III. THE RESEARCH METHODOLOGY

The research methodology is concentrated on the following main steps:

1- Studying and analyzing the main parts of the system based on the functionality, complexity, and cost.

2- Choosing the essential devices and considering their parameters and their parameters to be fit with the research requirements

3- Analyzing and testing the integrated schematic diagram of systems units

4- Measuring the data from the sensors to the control unit through the whole process

5- Modification and updating the system requirements based on the data analyzed from measuring.

6- Building the hardware of the systems and measuring (This stage is completed partially for the solar system, but analyses are performed for all parts of the systems).

7- Writing concussions and recommendations.

The full control irrigation system is shown in figure 4.

The solar system used is a part of engineering senior design submitted by us to the department for general

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purpose applications, and we used the same system because it is applicable and tested and ready to use for measurements and to supply the transmitting part of our research

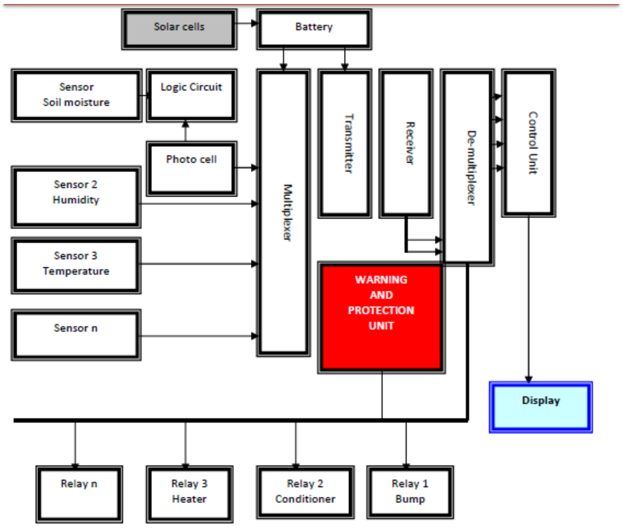

Figure 4: The block diagram of one full- control Automatic Solar Irrigation system.

So the study concentrated on the controlling and wireless communications parts.

The system is depending on the knowledge of three primary disciplines:

1- Digital Communication Systems: Digital modulation, multiplexing, and Demodulation.

2- Digital Control and Digital Signal Processing: DSP, PIC, and Relays. (Programmer is needed)

3- Sensors.

5- Supported devices and materials: Such as pumps, fan and heaters.

The figure 5 below shows the main units and devices of the system.

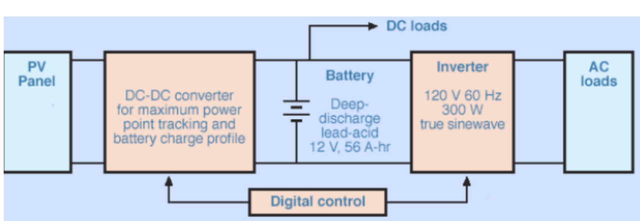

Figure 5: PV power circuit system

The power circuit consists of Photovoltaic module, battery charger and DC-AC inverter as shown in Figure 3.

In the following sections, a brief description of each part is introduced:

The photovoltaic cell is an unusual power source whereas most sources of electrical power are constant voltage sources, such as a battery, a PV cell is a constant current source. The PV cell only displays this constant current characteristic up to a limiting voltage where the current collapses. The I-V and P-I characteristics for a PV cell do not look like Figure 4 but exhibit the following characteristics.

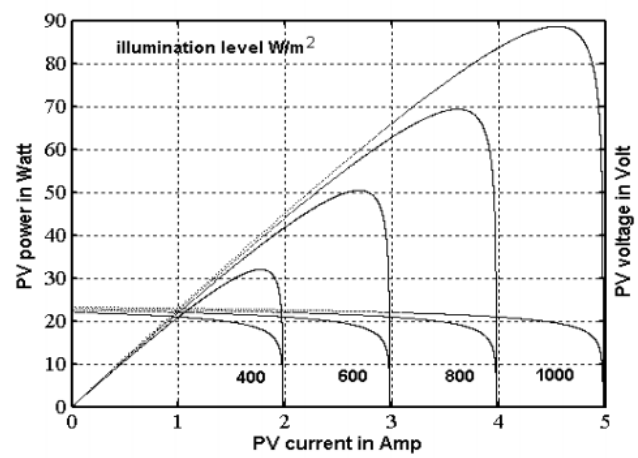

Figure 6: V-I and P-I characteristics at a constant temperature

These features are obtained by measuring the array volt-ampere for different illumination values. From these features, the optimum voltage or current, corresponding to the maximum power point, can be determined. It is clearly seen in Fig. One that the current increases as the irradiance levels increase. The maximum power point increases with a steep positive slope proportional to the illumination.

In this research we use a photovoltaic module with these specifications:

20-Watt and 12 Volt Solar Panel made of Monocrystalline.

Operating Voltage (Vmp): 175V

Operating Current (Imp): 114A

Open Circuit Voltage (Voc): 220V

Solar Cell: 36Pcs

Batteries are one of the most common electrochemical energy storage devices. They are used in a kind of applications, and most people are accustomed to using in industrial, commercial, renewable energy systems, uninterruptible power supply, power management systems, marine, and automotive Applications, where the value of its ability to provide currents of the power supply. Lead-acid

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batteries have a moderate energy density and excellent response time. Depending on the energy conversion technology registered, the cells can go from accepting the energy of the power supply immediately.

Lead-acid batteries by temperature affected and must be properly maintained to maximize the life expectancy. They are used in a variety of applications. In this study, a battery charge circuit which is the studying block diagram, circuit, bridge-diode circuit battery charging, circuit simulation and circuit design. Finally, we sued a battery level indicator which is the studying of circuit components, circuit design, measuring the voltage and current of the battery using D'Arsonval meter movement.

The circuit lead acid battery charger circuit aims to charge the 24V lead-acid battery. The circuit is given here currently limited lead acid battery charger the created the critical variable voltage regulator IC LM 317 as shown in figure 3. The charge current depends on the value of a resistor R4, and here it is configured to be 700mA. The resistor R1 and R2 determines the charging voltage. Transformer U1 is a step down the supply voltage and bridge diodes to the rectification work. C1 is a filtering capacitor.

Diode D5 prevents the reverse flow of current when the battery charger is off or if power is not available U1 can be a primary 230V, secondary 40V step-down transformer. X1 can be a 2A fuse. To configure the charging voltage, set the output voltage 35Vdc. So we can get R2 by using the formula R2 = R1 (Vo / 1.25 -1) = 5.94Kohm. Now the charger is available, and you can connect the batteries. This charger is designed for 24V lead-acid battery. After full charging, the Q1 will be short circuit then the voltage of R2 = 0. So, no current flows from the battery.

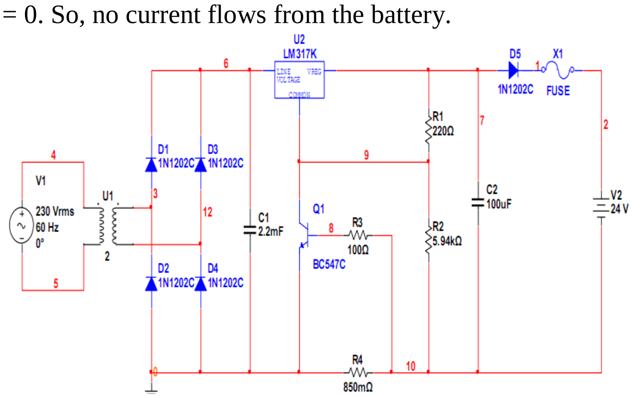

Figure 7: Circuit for battery charging.

A power inverter is an electronic device that changes direct current (12V DC) to alternating current (220V AC) with maximum power 1000 watt.

The automatic control methods are studied and analyzed; there are three main types of controlling:

1- Manual controlling (Out of research scope) and it needs a personal monitor and observing 2- Automatic controlling: in this case an electronics switching gates and relays are used to switch on and off of several devices (bump, Ventilation, heater...). In the first phase of this research, we used automatic controlling to control the level of water in the soil for different levels to accommodate different plants water requirements.

3- Smart Automatic Controlling: Software program with database and full control and self-update System. (This will be used in the second phase of the research).

IV. SYSTEM IMPLEMENTATION

Studied and analyzed the suitable modulation and multiplexing techniques should be used. The ASK modulation method is employed in this research.

The sensing method used is simple and base on the permittivity of water and soil.

An initial testing model of the research designed and takes in account the different parameters of irrigation systems and central control units associated with the system.

Following are the main units of the study:

1- Sensing and transmitting system: to sense, soil moisture, humidity, and temperature and sending data to the receiver. Usually, the distance between transmitters and receiver depends on the application. Some wires will be used depending on the controlled area. In this research, we used only one transmitter and one receiver. The distance was below 20m

2- Receiver:

This part of system receives and re-multiplexed the different signal (Different parameters) transmitted by the first part and sends them to the control unit [14].

In this section, the RF wireless system is used to transmit the encoded information i.e. level of water in the tank, at receiver, the data is decoded to perform controlling and indication functions.

The transmitter module consists of an encoder and ASK RF transmitter. The sensor senses four different level of the

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water tank and is interfaced to the HT12E encoder pins from D0-D3. The HT12E encoder data bit D0 represents a low degree of water in the reservoir; D1 represents the medium level of water in tank; D2 represents the High level of water in tank, and D3 represents the full level of water in the tank. The HT12E has eight address bits used for encryption/ security which in our case is connected to the ground i.e. logic ZERO. The ROSC =1.1Mohm is combined to generate the 3KHz frequency. The data is transmitted only when the Transmit Enable (TE) pin is low.

The serial output pin DOUT of HT12E encoder is connected to the ASK RF Module. The RF module uses ASK modulating scheme at a carrier frequency of 433MHz. The modulated signal covers approximately 100m distance in open space using a wire antenna. The range can be increased by using proper antennas.

For the transmission of data, the status of the address pins A0 A7 at transmitter must be matched to the state of the address pins A0-A7 at receiver. The received signal is decoded using HT12D; it converts the series data to 4bit parallel data D0-D3. The glowing LED indicates the valid data transmission between transmitter and receiver. The ROSC =51K to generate 150 KHz frequency..

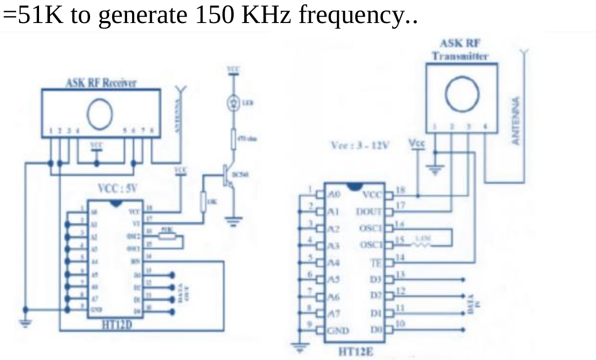

Figure 8: Sensing and wireless digital parts of the Irrigation system [14]

Because of different difficulties faced the research project mainly buying the transmitter and receiver components, we implemented the system using Arduino, which is described in the next paragraph.

1- Arduino watering system

Arduino used a voltage divider and based on this, turns the water pump on or off. It measures the value of soil moisture sensor, which serves as the first resistor and compares its value with a potentiometer. You can set humidity level with potentiometer - different plants want different humidity.

The electronics are to switch to a rubber hose part. As mentioned, 6 mm rubber hose is used for this. Attach one end to the pump, measure how long it has to be to cover your watering area and cut it off. Close tight this end of the hose. Then, the optimum way to make sure that you have holes for dripping water in the places you want them is to lay down your water hose and mark the starting and the end of the watering area.

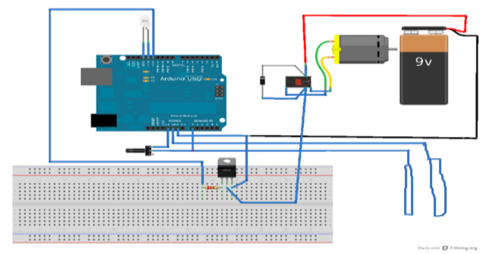

Figure 9: Implementation or the system

Material used:

- Arduino board
- Transistor TIP122
- Potentiometer 100k
- Resistor 1k
- Diode 1N4004
- LED
- Relay (12V DC coil voltage /230V AC) - depends on your water pump
- Water pump 220V AC
- Rubber hose 6mm (1/4")
- Adapter 220VAC/12VDC (for relay)
- Able soil moisture sensor

The schematic and breadboard view, are shown in figure 10

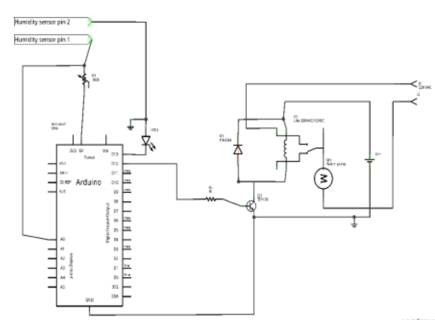

Figure 10: Schematic Diagram

Water pumping is one of the most appropriate and simplest applications for photovoltaic. PV-powered water pumping systems meet a broad range of water needs such as crop irrigation to stock watering to domestic purposes.

Storing water for use when the sun is not shining and eliminating the need for batteries are another advantages which are added to the PV pumping systems. In addition, enhancing simplicity and reducing overall system costs. Many people considering installing a solar water pumping system are put off by the expense.

V. RESULTS AND CONCLUSION

The concrete results of the research are:

1- The ASK communications system is suffering from noise, so the received signal will be noisy and difficult to extract the information and to control the system due to the low level of information power from the source.

2- The Solar system used is capable but the dimensions are huge, and it needs to be minimized to be simple for assembly with the transmitter.

3- An addition converter should be added to the solar system to meet the power supply voltage requirements for the transmitter, and control ICs.

4- The control method analyzed is simple and can be replaced by a smart multi-functional control system in phase 2 of the research.

5- The research is a part of senior design course in the electrical engineering department.

1- Automatic control solar Irrigation systems are critical in saving water and power. For efficient use, the irrigation can be utilized in the night using photo sensing control system, and it is considering different levels of washing for various plant roots.

2- The system is simple and can be utilized for commercial purposes for individual and farms applications in open areas and greenhouses.

3- Improvement the controlling system and modulation technique will enhance the efficiency the system and saving labor and minimizing the human interaction. .

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