Solar Powered Irrigation System for Agriculture based on Moisture Content in the Field and Saving Energy and Water with Optimum Designing

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***Abstract*: In this research, solar power derives water pump to have water from bore well. From there, drawn water goes to reservoir. Outlet of tank (reservoir) is regulated by moisture sensor (MS) and controller, so that water consumption can be optimized. Flow of control is being controlled in this smart system, water is regulated from water tank to soil. Design of Solar Power Irrigation system saves electric energy by reducing the usage of grid energy, saves oil expenses incurred in tube wells, and most significant, it reduces wastage of water as it is an automatic system to secure water. Solar power, a cost effective source, can be a suitable solution to farmers, it has been proposed in this research that solar power irrigation system, when used with solar pump, MS and an automatic water control flow, seems to be realistic recommendation to implement throughout Pakistan so that this nation-state could overcome energy crisis and save the farmers from complications of not having sufficient resources for earning through agriculture. As solar power is abundant energy source, it is only answer to energy crisis, it is also environmentally friendly. PV (Photovoltaic) panels are made from PV cells and they are easy to use for getting solar energy from Sun rays. Efficiency comes from solar driving module, as it is crucial part of the research and moreover without using automatic irrigation component, this research would be worthless. Literature survey is given in this research with proposed solution and implementation, moreover cost analysis is done with help of results, and then conclusion is stated.**

Key Terms: Energy crisis, Grid Power, Irrigation System, Moisture Sensor, Photovoltaic, Regulator, Reservoir, Rice Crop, Solar Power, Water Pump, Tank, Water Loss.

I. INTRODUCTION

This research is conducted in Naushahro Feroze, Sindh, Pakistan for irrigating rice crop. Research is done through survey and literature review, finally software (PV Syst version 6.3.4, Arduino Programming) and hardware (Moisture Sensor (MS), Arduino, H Bridge to name a few) are used to show testing of our proposed system. Solar energy is vastly available in whole world as it is natural resource to complete our basic necessities for energy consumption. Solar energy is environment friendly as it does not have any bad effects on human health and it increases reliability of power as it is free of cost to access from Sun rays in daytime. Solar energy is a response to increasing demands and it is easy to get energy through Photovoltaic cells, they can be polycrystalline, mono-crystalline, amorphous but to name a few [1][2]. Most importantly, as solar energy is comfortable to use, so this feature makes it worthwhile. PV panels is an effective method for using solar energy. PV panels are used in solar heaters, street Lights and for domestic loads as a whole. The smart system, shown in figure 1, as crisis of energy in Pakistan is going on, it can be an appropriate option for unfortunate people and deprived farmers as a whole, of this meager country. To cope up with high tariffs of electricity and increasing demands day by day, the suggested smart system, which uses sunlight, once the initial investment made, then it would be a way for energy production. In this paper it has been proposed that this research is solely for done to save electricity, decrease wastage of water, and reduce problems for Pakistan's farmers as they are unable to irrigate their field soils due to insufficient water supply from government. Water comes from bore well through water pump to reservoir then from there to field soil by actuator and MS, this operation is illustrated in figure 1 by flow chart. Purpose of this research is to get rid of shortage of electricity from grid supply and use alternative source of energy production to run tube wells [3] and reduce wastage of water and decrease expenses of electric billing [4][5]. Government is unable to provide sufficient electricity to 1.1 million tube wells of Pakistan.

II. OBJECTIVE OF STUDY

Based on moisture sensor, to develop solar powered irrigation system to avoid over and under irrigation, wastage of water and time by farmers, to get rid of electric power shortage and ensuring proper and optimal water to rice crop.

III. PROBLEM DEFINITION

Irrigation systems of today are either manually operated or time based. They all are causing under or over irrigation. Wastage of water is done by farmers and shortage of electric power hinders productivity of rice crop. Plant should be irrigated according to its need. To address all these problems, proposed moisture sensor based solar powered system gives needed water to crop, water is utilized in proficient manner, through solar panels, and electric power problem is no more.

IV. LITERATURE REVIEW

In Pakistan, diesel cost is getting higher and higher so people have chance to convert their tube wells on solar powered pumps. In this country there are 1.1 million tube wells, and from those 30% tube wells are having supply of electricity [6], but rest of all rely on oil, which is source of greenhouse gases' emissions[7][8]. Tube wells need 2300 million liters of diesel annually and famers do not get sufficient electricity from national grid to run their tube wells for crop irrigation, so flexible techniques need to be implemented. Pakistan's farmers

cannot afford prices of oil so they are being recommended to switch from oil based to solar power irrigation system with solar-powered pumps [9] [10]. As it is clear getting water from rivers and lakes has become big problem as shortfall of water lacks farmers for their agricultural gain. Now shortfall of water affects energy source as farmers use tube wells (run on oil) to draw groundwater for their fields [11]. From researchers, investigating is being done for such power plants which use water to extract hydrocarbons and there is also research going on in energy-related activities. Generally, around the globe little consideration has been concentrated to make water available for rice crop production by diminishing consumption of energy. For agricultural purposes, seventy percent water which is fresh is being consumed solely for this purpose, and irrigation thrusts assembly of rice crop from each hectare of land, it goes for being spread [13]. Nowadays, farmers are getting shift from water that is obtained from rivers and lakes. And water is not fulfilling demands of farmers to irrigate their fields. Moreover, irrigation is not about water and agriculture but that is concerned with energy crisis [14].

V.THE STRATEGIC SOLUTION

Instead of previous irrigation systems, this proposed system gives more efficiency than any other conventional and modern irrigation system, shown in figure 1. This system saves water and makes use of free energy source. Release of water slowly, regularly and frequently is done in efficient way by determining soil's moisture content. Proposed irrigation system gets solar energy from PV panel, battery is for storage, water pump does pumping to get water for reservoir, from there according to moisture content in soil, water releases to field.

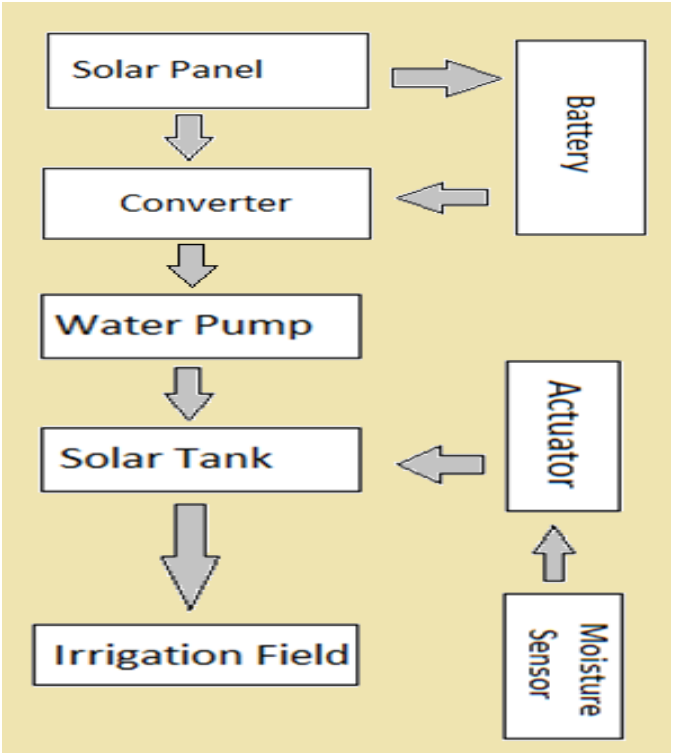

Fig. 1. Block Diagram Proposed System

Proposed model is automatic detector of soil moisture and takes intelligent action to release water in field. In conventional irrigation, surface irrigation system is very famous, shown in figure 2.

Fig. 2. Surface Irrigation System

When water is applied to series of field ditches deep into soil surface, this is called subsurface irrigation system. It is shown in figure 3.

Fig. 3. Subsurface Irrigation System

In sprinkler irrigation system, water is sprayed like rain, shown in figure 4.

Fig. 4. Sprinkler Irrigation System

In drip irrigation system where there is efficient use of water, shown in figure 5. In this type of irrigation system there is high

efficiency because of principle of applying water slowly, regularly and frequently.

Fig. 5. Drip Irrigation System

Water was pumped from bore well to a well and from there another pump pushes water to fields that costs huge energy consumption but in this very new flexible methods, we implement one stage algorithm, and it is core purpose of this research that pumping of water will be flexible and effective so that from tube well, water could go to reservoir which is on along ground, then again MS regulates valve in case of soil needs water to be irrigated. Efficient algorithm is proposed in order to avoid flooding of rice crop by giving unnecessary water to rice crop in Naushahro Feroze. Valve is regulated by MS which detects the level of moisture in soil, according to need of soil, water is given by that valve with regulation by MS in land. This smart system would conserve water and save electricity as it is already in shortfall. Wastage of water will be also reduced. Solar panel, battery, converter and other devices will be used to implement this smart system. Table 1 illustrates suggested tube well's components' life time and cost.

Table 1.
Components' cost and lifetime

Component	Cost	Lifetime in years
Solar Panel (250)	14000	20
Inverter	15000	4-10
Water pump	5000	2-8
Arduino	1500	5-20
Moisture Sensor	1000	3-20
Batteries (12V)	12000	

Safety is main concern of system for long-lasting of components used in planned system. Payback period (PBP) can be achieved through security and comfortable use of proposed system.

A. SYSTEM EXPLANATION

Block diagram of solar pumping module is given in Fig. 6. To recharge battery, control circuit is used. As battery stores DC and panel gives DC also, so converter is used to switch from DC to AC, then energy to water pump is given.

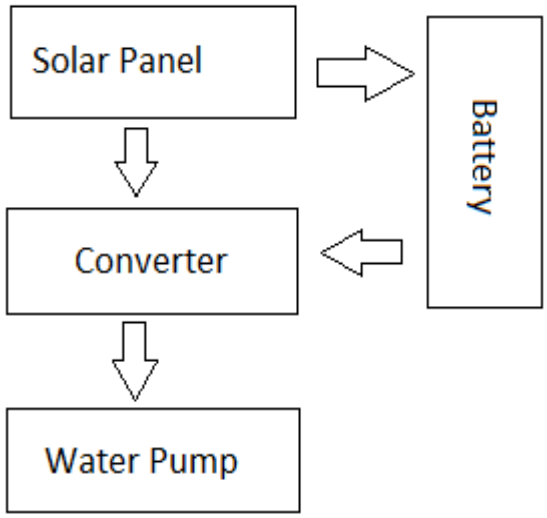

Fig. 6. Solar Pumping Mechanism

It is very much important to be plunged exclusive to the well, so that system can be fully functional and an automatic. Combination of solar panel, water pump, battery, and converter is used here for implementation of this smart moisture based solar powered system. In this work, two types of modules are being used, solar pumping module and automatic irrigation module, in former module energy from panel is given to water pump and in later module water from reservoir goes to soil. However, water is stored temporarily in reservoir before finally releasing to fields.

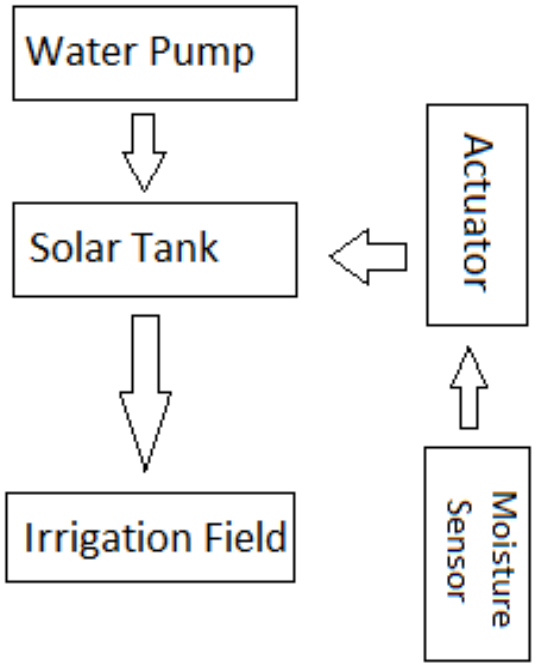

Fig. 7. Mechanism for Automatic irrigation module

For water valve, in figure 8, as it is necessary for it to be regulated by a circuit which will be electronically operated.

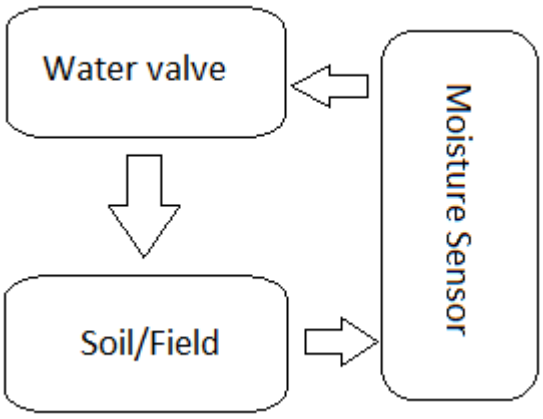

Fig. 8. Electronic controlling of water valve

In an involuntary irrigation segment, sensor is placed in the soil for detection in condition of dryness. Sensor gives different signals' strength according to moisture level of soil, as different moisture level for different crops are already set, a reference voltage (V) level is set to trigger the circuit in need of water for rice crop irrigation. Here are two voltages, one reference V set by farmer for certain crop and another V of MS which is giving after sensing moisture level of soil. Voltage difference would determine that a certain soil needs water or not, and more vital piece of work would be to decide the quantity of water needed for dried field soil.

Moisture Sensor, H Bridge, Arduino Board and Stepper motor are used in hardware prototype. Stepper Motor rotates in both directions, it can be used in digital circuitry. It is used for precise control of shaft's position. When the pulse of electricity is provided, then shaft turns a precise distance from magnet operation. Stepper motor via control signal rotates according to difference of these two voltages. Though turns stepper motor control will be as efficient as according to need of field soil, tank valve would be regulated either to finally release water to soil or not after careful detection from sensor of moisture. To have an example, if 30 cm water is required for rice crops to be irrigated for 130 days and water flow is 18 liters per second for 14 hours a day.

Therefore, to calculate hectare land to be irrigated as follows;

Available Water = $(18 * 60 * 60 * 14 * 130)/1000$ **m³**
= **117,936 m³**
Area irrigated = **117,936/30**
= **3931**
Hectare land to be irrigated = **3921/100**
= **39.31** hectare land to be irrigated

VI. SYSTEM DESIGN AND METHODOLOGY

Here we used 2HP water pump with proposed 60w polycrystalline solar panel with specifications given below in table 2. Water valve operated by MS released water to soil and for that mechanism to work, energy comes from panel, it can be done with amorphous and polycrystalline technology also. Engineers and researchers design required systems according to requirement of the farmers and their need for energy from sun rays according to crops' irrigation in Naushahro Feroze district of Sindh. Flow chart which shows how moisture sensor's value is of important is given below and when water valve releases water to field is also shown.

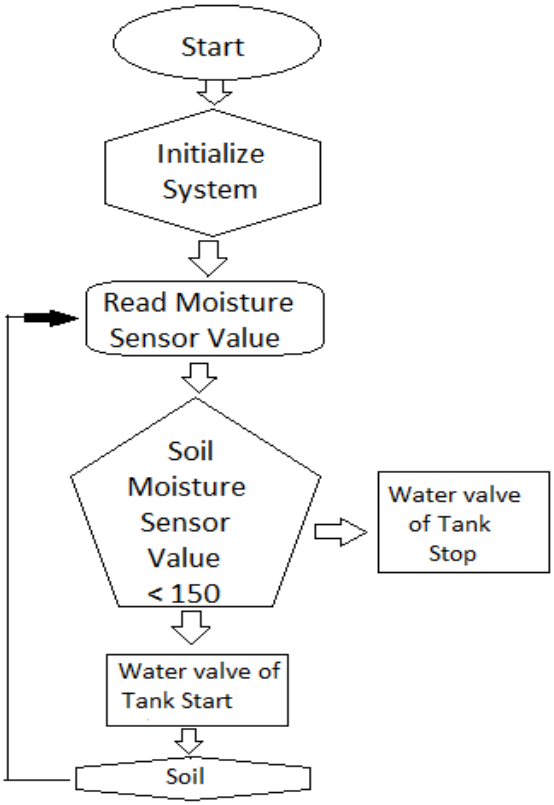

Fig. 9. Flow Chart of regulating water

It is clear that more solar panels would be needed if there are more number of agricultural land is to be cultivated and irrigated, however system can be optimized to reduce cost of increasing number of solar panels. In absence of rainfall, water needed for soil is equal to moisture deficit in soil.

Table 2.
Specification of Solar Panel

1	**Max power at STC (Standard Test Conditions)**	**60W**
2	**Optimum Operating Voltage**	**18.5 V**
3	**Optimum Operating Current**	**2.70 A**
4	**Open Circuit Voltage**	**22.7 V**
5	**Short Circuit Current**	**2.84 A**
6	**Module Efficiency (Ref. PVsyst Software)**	**10.67 %**
7	**Maximum System Voltage**	**600 VDC UL**
8	**Cost of 60W Panel**	**3500**
9	**Life of Panel**	**20 years**

Selection of water pump is crucial in order to get reliable supply of water according to need of soil sensed by MS. Polycrystalline

panel sounds better in Naushahro Feroze because it is hot arid area of Sindh. If we use monocrystalline than cost of panels would be increased which is main concern of our research. And amorphous silicon technology is giving very low efficiency so it cannot be used in proposed model.

A. CCONVERTER's DESIGN AND BATTERY DESCRIPTION

Circuit is designed where DC 220Volts supply is achieved from DC 12Volts supply through boost converter because it enhances strength in great quantity to 220 Volts, and for inverter 220Volts that were being given to it as an input. Battery with 12 Volts and 100 Ah volume is used for 2HP, this 2HP is rating of water pump, which is an essential component.

B. MOISTURE SENSOR MODULE

How much quantity of moisture is present in the soil, it would be detected effectively and according to this detection further action will be taken automatically. It will be sensed by MS component with help of level detection module it can easily determine how much water is needed for crops. Effective circuit is being used to give proportional V according to data given by sensor that would be absorbed from soil of field. Analog probes will be nice to use for this functionality. Sample of such probe VG400 is shown in Figure 9. Conductivity between two probes would determine V proportional to moisture present in crops field.

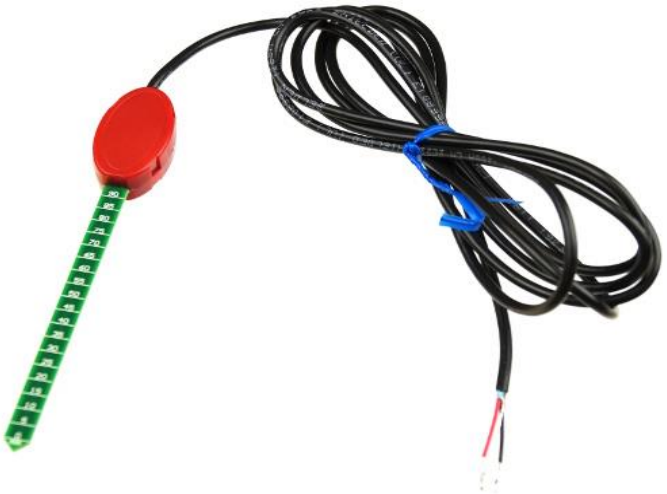

Fig. 10. Soil Moisture Sensor Probe

C. ARDUINO UNO

To integrate software and hardware, this open source arduino board is used. Arduino senses object and controls it. Programming in C language is done in arduino UNO.

Fig. 11. Aarduino UNO

D. SOLAR PANEL

By PV effect, solar panel converts sunlight into electrical energy. Solar panel is made up of photovoltaic cells. The characteristics like current, voltage and resistance varies when panel exposed to sun rays.

Fig. 12. Solar Panels

E. WATER PUMP

Water pump is used here to get water from tube well to reservoir for storage till the need of crop comes to irrigate it. Selection of water pump is essential, how much diameter of pump should be for flow of water, which type of water pump should be like displacement, submersible pump, turbine and centrifugal pumps, these are main factors to consider in account before selecting type of water pump. Here we use displacement pump to move water from tube well to reservoir.

F. AUTOMATIC VALVE REGULATION

A required value is given to derive the circuit with respect to quantity of moisture in the soil, if there is no need of water then driver circuit do not get power, so stepper motor is closed then controller would be in sleep mode to lower consumption. Stepper motor, is used as actuator for controlling valve, which is connected to outlet of reservoir's valve.

Through MS and controller driver circuits get control pulses for exciting stepper motor to rotate proportional to moisture content which is sensed by moisture sensor. By detection of moisture content in the soil of fields the valve is opened and closed. But in case of drying moisture content in soil, controller leaves sleep mode is wakes up for regulating flow of control when soil moisture reaches minimum cut-off value. It is how this whole system works automatically, and there is no any flaw coming in regulating flow of water either to increase or decrease by deteriorating the whole settled mechanism of algorithm, and this complete phenomenon works efficiently.

VII. PVSyst SOFTWARE AND COMPONENTS SELECTION

From PVsyst software, Polycrystalline panel of 60W(50W panel is not present in PVsyst version 6.3.4) is used here. monocrytalline is bit more costly than polycrystalline and amorphous is not being used because its efficiency is very low as compare to crystalline family.

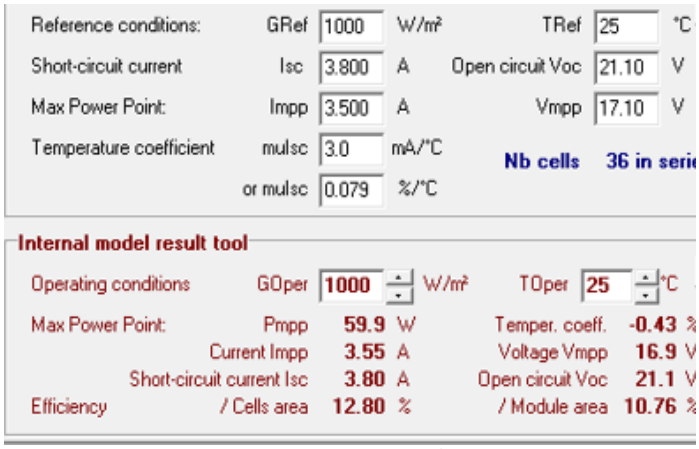

Fig. 13. Poly 60W panel specifications

At temperature of 45 ^{0}C, irradiance from sunlight is given with different outputs. Normally in summer temperature of 45 ^{0}C prevails in Naushahro Feroze. Moreover solar trackers can also be implemented to increase conversion of sun rays to electrical energy but cost would be increased.

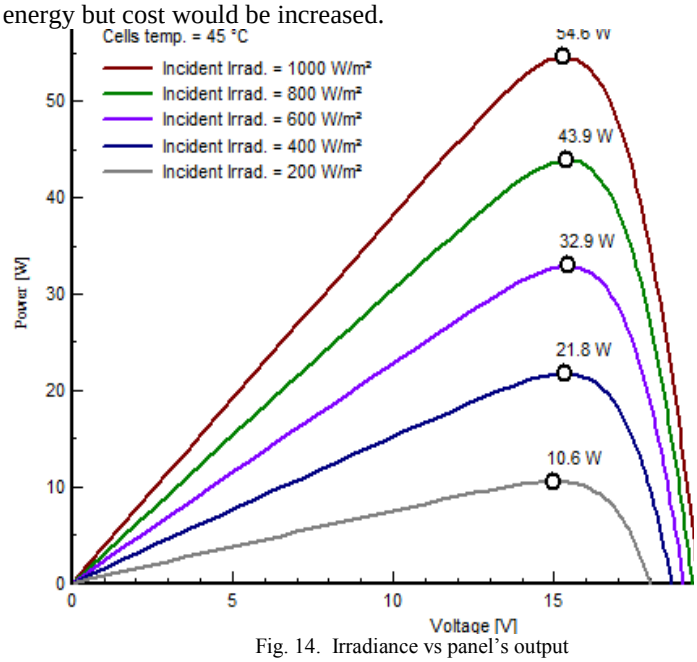

Fig. 14. Irradiance vs panel's output

Relative efficiency loss by respect to standard test conditions is with 10.76% of efficiency.

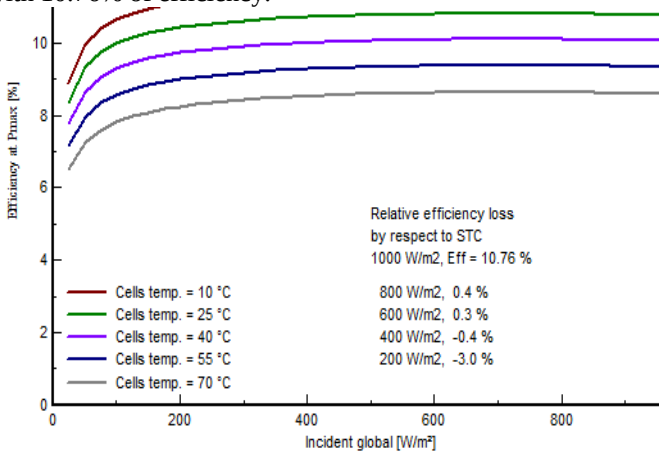

Fig. 15. Relative efficiency loss

VIII. RESEARCH ANALYSIS AND INVESTIGATION

Now comparison between solar and electricity based tube wells would be illustrated. There are 11 lac tube wells operating in whole Pakistan while consuming huge amount of oil and electricity and suppose, if these 100% tube wells will be converted to solar power irrigation system, then we can easily reduce expenses and Pakistan's government can easily overcome energy crisis [14]. By studying several resources like magazines and daily newspapers, it has been analyzed that eleven million kWh (kilo watt hour) energy daily is to be used for tube wells to have water for agriculture. Just assume if cost of 1 kWh is 13.5 rupees then 1.157 trillion rupees is cost which is likely to be paid by farmers in 20 years if governments ensures required supply from national grid. However by implementation of this proposed system, this amount could be saved in 20 years by installing 11 lac solar powered tube wells in just 0.176 trillion. Hence reliance on government's supply will be decreased as already there is huge shortfall of electric energy is going on.

Table 3.
Proposed irrigation cost for 20 years

Year	Cost of Proposed Solar Powered Tube well	Cost of 11 lac tube wells	Cumulative cost till next years (trillion)
1	160,000	0.176 trillion	0.176
2			0.176
3			0.176
4			0.176
5			0.176
6			0.176
7			0.176
8			0.176
9			0.176
10			0.176
11			0.176
12			0.176
13			0.176
14			0.176
15			0.176
16			0.176
17			0.176
18			0.176
19			0.176
20			0.176

Now, cost for 20 years from electricity based 11 tube wells would be analyzed. Maintenance cost is same in both solar powered and electricity based tube wells that is why it is not being considered in analysis.

Table 4.
Electricity based irrigation cost for 20 years

Year	Cost of Electricity based tube well (PKR)	Cost of 11 lac tube wells (billion)	Billing in respective year (billion)	Total incurred cost from first year (billion)
1	80,000	88	53.46	141.46
2			53.46	194.92
3			53.46	248.38
4			53.46	301.48
5			53.46	355.3
6			53.46	408.76
7			53.46	462.22
8			53.46	515.68
9			53.46	569.14
10			53.46	622.6
11			53.46	676.06
12			53.46	729.52
13			53.46	782.98
14			53.46	836.44
15			53.46	889.9
16			53.46	943.36
17			53.46	996.82
18			53.46	1050.28
19			53.46	1103.74
20			53.46	1157.2

Approximately 1.16 trillion would be saved if we switch from electricity to smart sensor based solar powered irrigation system. Suppose 11 lac tube wells of Pakistan based on electricity and fossil fuels are switching to moisture sensor based solar powered system, then 2300 million liters oil would not be needed and expense of 184 billion can be saved annually, and government's burden will be decreased to provide this high amount of oil to farmers besides households and commercial demands. Tube well costs 160,000 which is solar based having moisture sense phenomenon, then eleven lac tube wells would cost 1.76 billion rupees only one time, while in case of oil there is expense of 184 billion annually.

By using moisture sensor based solar powered tube wells, 3.75 trillion would be saved. Moreover, due to less utilization of oil, there will be no emissions of greenhouse gases. Generator of high rating is being used to get ground water for soil of field and these generator consume massive amount of oil, while big motors are also being used by consuming large amount of national grid supply.

Table 5.
Oil based irrigation cost for 20 years

Year	Cost of Oil based tube well (PKR)	Cost of 11 lac tube wells (billion)	Expense(2300 m liters) of oil in 1 year for 11 lac tube wells Per litter (80) 2300 m liters	Total incurred cost from first year (billion)
1	70,000	77	184	261
2			184	445
3			184	629
4			184	813
5			184	997
6			184	1181
7			184	1365
8			184	1549
9			184	1733
10			184	1917
11			184	2101
12			184	2285
13			184	2469
14			184	2653
15			184	2837
16			184	3021
17			184	3205
18			184	3389
19			184	3573
20			184	3757

IX. EXPLORATION AND ADVANTAGES OF THIS PROPOSED SYSTEM

Through implementing recommended moisture sensor based solar powered system instead of surface, subsurface, sprinkler and drip irrigation systems, following advantages seem to be realistic.

1. This system Provides water to crop according to its need avoiding under and over irrigation, by this water is being utilized effectively while manually operated irrigation systems are causing flooding and dryness in field.

2. Where electricity is not available, this system is designed to use sunlight by PV panels to operate water pump for releasing water to reservoir and finally to field while previous manually operated systems only rely on oil and electric power.

3. This system saves water tariff but manually operated system makes use of extra water.

4. Recommended system saves electric billing cost as it used sunlight for generating energy.

5. This proposed sensor based solar powered irrigation system does not require manpower and it operates automatically according to crop's need. While conventional methods of irrigation need huge labor to work.
6. This planned model improves crop production by adequate supply of water avoiding flooding and dryness of soil. While in previous techniques of irrigation systems there is minimum chance of high net profit.
7. Saving of time is done in this anticipated moisture sensor based prototypical model while in Basin and Furrow irrigation system there is time taking process by labor's involvement.
8. Human error is decreased in this suggested sensor based system comparatively to drip and sprinkler irrigation system.
9. Oil expenses are also saved in this offered solar powered irrigation system based on sensor as compared to surface and subsurface irrigation system.
It is being analyzed that if switching from orthodox to newly inventive irrigation system is done then obviously there would be sufficient benefit for this underprivileged country of south Asia on the whole.

X.CONCLUSION

In this paper, planned sensor based solar powered irrigation system gives reliability, it can be implemented through low cost, and it uses alternative source for electric power. Farmers can properly irrigate their fields as this recommended irrigation model is automatically controlled. Research in Naushahro Feroze for rice crop irrigation based on moisture content in field, this design for land irrigation is done with help of software and hardware. This research is solely done is order to reduce reliance on grid supply and using sunlight to furnish rice crop. PV syst software of version 6.3.4 gave authentic knowledge that what type of panel should be used in the region of Naushahro Feroze. By doing comparative analysis, it is clear that from conventional and modern irrigation systems, like surface, subsurface, sprinkler and drip irrigation system, this proposed system sounds better because it makes efficient use of water and reduces burden of electric billing on farmers. Most importantly, it makes sure that field gets enough water for rice crop irrigation. There are several drawbacks in previous irrigation systems but this recommended model gives reliability to farmers for their earning.
By implementing proposed design of smart solar power irrigation system, wastage of water will be decreased, oil consumption would be reduced, and electricity problem will not disturb Pakistan's farmers in order to irrigate their fields. Shortfall of energy can be reduced by switching electricity and oil based running tube wells to solar power irrigation system based tube wells. Condition of Pakistan is very deteriorating nowadays. Still government is unable to meet energy demands of public so how it can fulfill further requirements in agricultural sector. Pakistan has been importing oil in enormous quantity, if these 1.1 million tube wells would not use either oil or electricity, then this very country could reduce its burden and it can work on other projects to strengthen the economic profile. If farmers are generating more energy through solar panels they can sale to national grid or it can be utilized by their own house consumption. This system requires minimum maintenance and is easy to implement and is very simple. This research can be enhanced by using daily pumping rates via tracking arrays, and this research will be economical, as it is cost effective, if Government of Pakistan would think in long run development this solar powered system system will be beneficial. It will save lot of electric energy supply given by government to farmers for tube wells, and less oil will be imported due to not use in irrigation purpose. And also, water preservation will be done and lot of wastage of water will be stopped.

XI. ACKNOWLEDGEMENT

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