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Economic Assessment of Solar Photovoltaic Micro Irrigation System for Vegetable Farming in Rural and Urban Sector

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ABSTRACT

Nowadays, renewable energy is becoming the mainstream power and the technologies used for harnessing these natural energies are reliable and durable than other forms of exhaustible sources of energy. Among all these naturally replenished energies, solar energy is the most abundant source of energy in the world and might be one of the easiest ways in India's urban and rural sector to utilize energy. An efficient approach for using abundant solar energy is through photovoltaic (PV) systems in agricultural practices. Agriculture is the key source of income in our country. Main concern for poor economics of the farmers is scarcity in the availability of water at the present era. The paper focuses on the Micro-irrigation system powered by SPV for economic benefit. Proposed system is an efficient mechanism for delivering water directly to the roots of the plants due to which a significant reduction in the wastage of water is possible. This may helps in improving the crop-water relationship by considering soil water constants and other factors associated with the analysis of water requirement. The proposed solar - powered irrigation system may also support the optimum use of fertilizers and help in minimizing the negative effects associated with its improper dosage thereby improving the quality of crop production and yield. It may lead to enhancing the economy of the farmers.

KEYWORDS: Consumptive Use of water, Evapotranspiration, Micro-irrigation, Renewable energy for Agriculture, Optimization of Fertilizers

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INTRODUCTION

Farmers always played a significant role in our society as they provide the food to country's population by agriculture. They use conventional irrigation methods. Irrigation is the application of water to ensure that sufficient soil moisture is available for good plant growth throughout the growing season.[1] Various irrigation methods are used on full-season agronomic or high-value specialty crops to provide a dependable yield every year. In many of these years, only few places in our country receive sufficient rainfall for good plant growth. But other areas experience reduced yields or reduced quality on non-irrigated crops due to water stress from insufficient soil moisture. Hence, the use of solar energy based irrigation in agriculture is becoming increasingly popular. The energy produced from renewable source can be used either in the farm or may be fed to the local power grid, providing the farmer with an additional income.[2] In the present time, PV electricity generation finds an efficient approach for harnessing sun's abundant energy because of improved efficiency and lowered per peak power (Wp) cost.

This paper mainly focuses on the new concept of solar photovoltaic subsurface irrigation system, which is having the mammoth potential for promoting water efficient irrigation to improve the economy of the farmers in the urban and rural sectors. The first section of the paper describes the introduction of SPV micro-irrigation system. The second section covers the factors related to the soil-plant relationship considered in this system and the last section relates with impact of proposed system on the economy of five different states of India.

MATERIALS AND METHODS

Proposed SPV Micro-Irrigation System

About 90 percent of water is wastefully discharged into the rivers and 65 percent of the water collected from rainfall runs off into the major water bodies. To meet the economic conditions, advancements are required to be made in the conventional methods of irrigations which are used in India. Among all the irrigation techniques, micro- irrigation involves the least wastage of water.[3, 4]

The proposed SPV micro-irrigation system, as shown in Figure No. 1, focuses on the roots of the plants rather than the top surface of the soil as in the conventional irrigation techniques. This system allows the continuous application of water and nutrients in a controlled manner to the targeted area as per requirement. One key reason for the superior performance of such a system is the fact that such a system can continuously optimize the consumption of nutrients and level of water available to the crops, in contrast to the traditional surface irrigation systems, under which, plants face stress as a result of feast and famine cycles.[5]

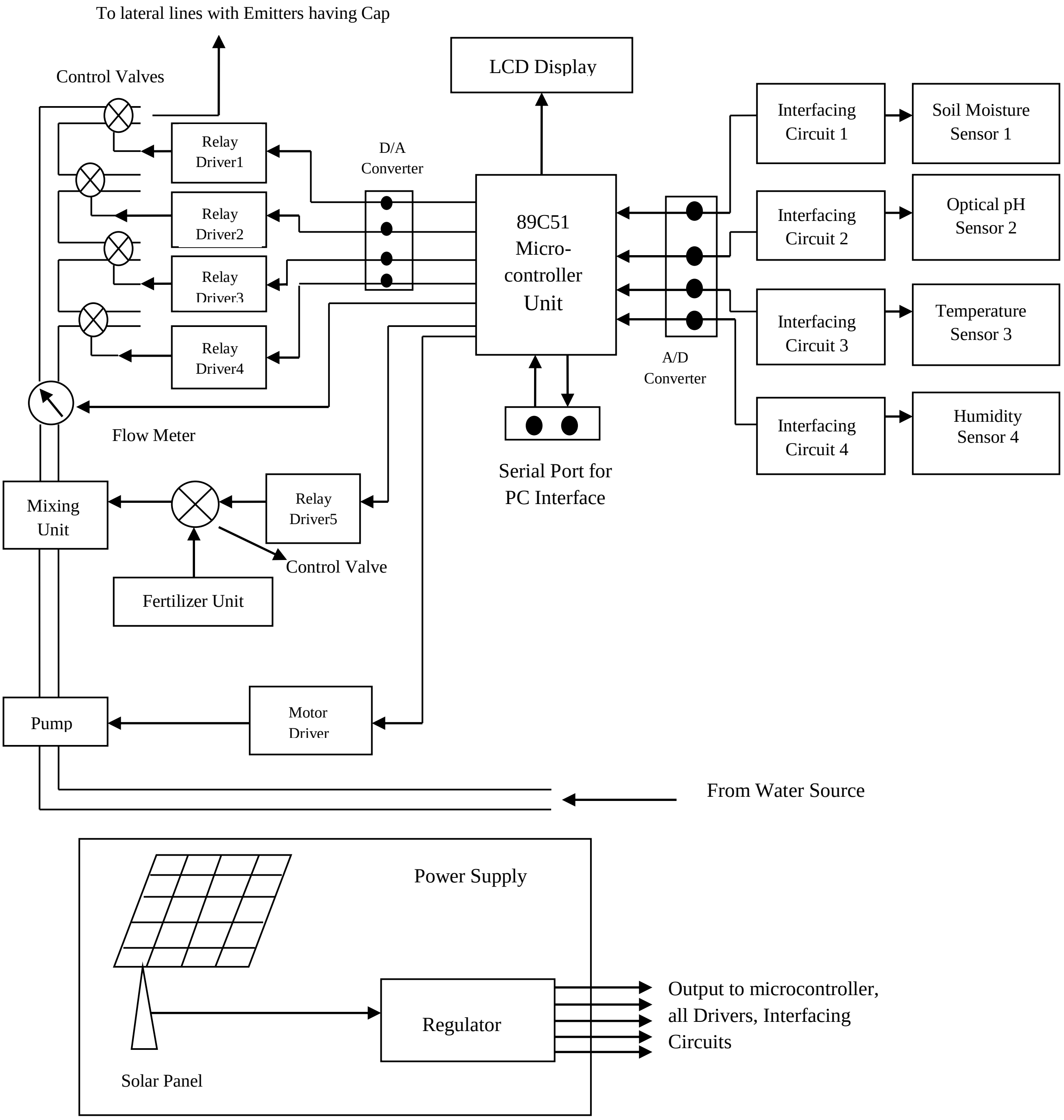

Figure No. 1: Block Diagram of Proposed SPV Micro Irrigation System

Components of the SPVM irrigation system

- Solar Panel: Converts the solar energy into electricity.
- Controller/Timer: It controls the timings for the water supply schedule during crop production. Microcontroller is used in the controlling circuit.
- Backflow Preventer: Blocks the reverse flowing of water into the system.

- Valves: It is used to turn on/off the water supply.
- Filter: This clears the unwanted particles from clogging the supply lines.
- Pressure Regulator: It optimizes the pressure to the required value.
- Pipes or lateral lines: These are used to supply water and fertilizers to the roots of the crops.
- Emitters: These are the end channels to deliver water at a controlled rate.
- Flush Valve/Cap: These are attached at the end of the system which removes the unwanted particles.
- Sensors: Measure optically the pH value of soil,[6] the moisture content of the soil and also the environmental temperature.
- Optical Indicators: These eco-friendly light emitting diodes (LEDs) indicate different control levels specified in the controller circuits.

Crop-Water Requirement and its Associated Factors

Due to urbanization and scarcity of water resources, small areas are rich for vegetable farming. Hence the water requirement is an important parameter in the arid and semi-arid areas for vegetable plants such as onion, tomato, capsicum etc. This requirement for any plant refers to the amount of water required by a healthy crop for its successful growth in a specified period.[7] This surface water depth, i.e. water requirement of a crop, is measured in centimeters and is mathematically expressed as shown in Equation 1 and Equation 2. Here the unit for quality of water expressed in centimeters is similar to the criterion used for expressing the rainfall. Actual volume of water in cubic centimeters can be calculated by multiplying it with area concerned.

$$WR = ET + W_m + W_s + W_u \quad (1)$$

$$CU = ET + W_m \quad (2)$$

where

WR = water requirement of vegetable crop

CU = Consumptive Use of water for specified period

ET = evapotranspiration from vegetable crop field

W_m = water metabolically used by vegetable crops

W_s = water applied for operations such as land preparation, puddling of soil etc.

W_u = economically unavoidable water losses during application

Soil water content varies continuously and has a direct bearing on plants. To maintain the soil-water relationship, some important soil water factors are considered in this automated irrigation system as compared to the checkbook method of conventional irrigation practices.[8] The first factor is evapotranspiration or ET. It is given as a daily estimate of the combination of the amount of water transpired by plants (T) and the amount of water evaporated from the soil surface around the plants (E). This parameter changes with a predictable pattern from germination to maturity. The second factor is the Consumptive Use (CU) which includes water utilized by vegetable plants for their metabolic activities (W_m) along with the evapotranspiration process as in Equation 2. The CU is estimated for specified period i.e. daily consumptive use, seasonal consumptive use and peak period consumptive use. Another important aspect that is considered in this optimized irrigation system is the water required for pre agricultural arrangements (W_s) such as soil preparation, mulching process etc. The last factor considered is unavoidable wastage of water occurring during its application (W_u). By monitoring this factor, the economic loss to the farmer can be improved.

Advantages of Proposed SPV System

- Slow application of water and fertilizers over a longer period gives better root zone environment and results in higher growth rate and yield.
- Hardly any manpower is required to operate the system.
- The system is designed to save water and provide better application efficiency.
- No dependence on conventional energy sources.
- Saving of fuel cost required to operate a pump and irrigation system.
- Reliable systems as solar panels come with 25 years of performance warranty.

RESULTS AND DISCUSSION

Economical impact on fertilizer and energy consumption

The soil is rich in minerals as well as organic nutrients but due to regular cultivation practices of a similar variety of vegetable crops, the field soil gets depleted of its primary nutrients i.e. NPK. This also changes the pH value of the soil.[9] The prerequisites of soil for vegetable growth vary for different varieties of vegetable crops. Hence before proceeding with the agricultural practices, the testing of soil parameters and its pH value should be conducted either by any outside agency or by an additional circuitry consisting of optical pH sensors connected to the proposed automated system.[5, 6] IAI, FICCI & Grant Thornton India surveyed 13 states under government micro-irrigation supported project i.e. National Mission on Micro Irrigation (NMMI). Out of the various government projects, NMMI has been the most centrally sponsored and strong program. In this paper only five surveyed states are considered and their economic impact of micro irrigation on fertilizers and energy consumption is shown in Table No. 1. [9] Automation regulates the fertilizer consumption by avoiding it's over dosage and hence encourages farmers to economize their expenses. The fertilizer consumption percentage savings is calculated as 32.28 percent on an average for five targeted and surveyed states of our country i.e. Bihar, Chhattisgarh, Uttar Pradesh, Uttarakhand and Haryana.

With more judicious use of this technology, the consumption efficiency of fertilizers can get improved in the states where the saving percent for fertilizer consumption is much below the average percent.

This irrigation technique, when powered by solar energy may save more energy as compared to energy saving percent obtained by conventional micro-irrigation method which is 35.04 percent on an average. However, this value varies across the country i.e. different for various states. In saving energy consumption, the highest percentage of 49.30 for Haryana and the lowest percentage of 18.2 for Uttar Pradesh are possible. Application of water and nutrients directly to the roots of the crops results into lowering number of hours of irrigation and also avoids fertilizer over dosage, which further translates into significant cost savings and high yield for farmers.

Table No. 1: Impact of Micro Irrigation

Surveyed States	Fertilizers consumption savings in percent (%)	Energy consumption savings in percent (%)
Bihar	7.6	40.0
Chhattisgarh	40.4	37.8
Uttar Pradesh (UP)	22.8	18.2
Uttarakhand	18.0	29.9
Haryana	37.5	49.3

CONCLUSIONS

Proposed system is specially designed to optimize irrigation in areas where there is no mains electricity supply. This proposed solar-powered micro irrigation system, has various benefits for the farmers even in adverse climatic conditions as the energy of the sun is harnessed for powering system.[10] It optimizes the utilization of fertilizers by reducing it's over dosage and human involvement in Fertigation, thus improving their economic conditions. Its design is simple and user-friendly and is also useful for attracting the youth in agriculture in rural as well as in the urban sector. Hence this new concept can be a suitable solution for energy crisis in the states where maximum saving can be done by micro irrigation in India.

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