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Automatic Solar-Powered Irrigation System in Greenhouse

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Abstract: It is still very common to use electric power supply (AC) or diesel to power generators in agricultural operations. However, automated control systems in irrigation have made considerable progress in recent years and also renewable sources has been applied to various applications and also these sources have been used in agricultural field.

This paper presents a prototype of an automated irrigation system used in a greenhouse (80 m^2)to produce its energy from photovoltaic solar panels. In the experiment, two solar panels (220W) has been mounted near the greenhouse and energy produced by solar panels stored in two gel type battery (200Ah). This energy was used for water pumping. The centrifugal pump sucked water from deep well with 12 m.

As a result, two main objective of this study was to determine (a) the amount of energy produced from solar panels, (b) the system performance on greenhouse irrigation.

Keywords: Solar panel, Automation, Irrigation, Renewable energy

Introductıon

Primary energy sources can be in many forms such as nuclear energy, fossil energy and renewable sources like solar, wind, geothermal and hydropower. Nowadays, the current trend has been switching from fossil energy to renewable energy because of oil crisis and precariousness in the availability of fossil energy. These cases results in rising the price of it, thus increasing costs of the electrical sector companies. Therefore, we need to use renewable energy sources, which are clean and less aggressive to nature and to humanity (Reges et al., 2016).

In agricultural sector, it is very common to use diesel or hydropower energy for agricultural operations. On the other hand, increasing costs of this kind of energy has been decreasing the profit of agricultural products and this situation moved farmers toward to find both cheap and renewable energy sources. Today, many studies have been carrying out to adapt the solar energy used in agriculture (Armaroli and Balzani,2011; Hopmann et al., 2013) since these new energy sources reduce costs of manufacturing and also one of the main advantage of this system is that it can be isolated or connected to the power grid. Solar power can be successfully used to generate power in greenhouses (Zhang et al., 2015). In order to increase irrigation efficiency in automated irrigation systems, a number of research studies have been carried out. Shull and Dylla (1980) used gypsum resistance block as a soil moisture sensor to activate the sprinkler irrigation system. Frankovitch and Sarich (1991) developed an electronic switching system to control pumping time for the irrigation system. Cuming (1990) controlled the common lines of various irrigation systems by using a soil moisture sensor. Many methods have been described and sensors developed to manage irrigation systems objectively (Weinstein & Avishai, 1995; Biernbaum & Versluys, 1998; Salas & Urrestarazu, 2001, Yildirim, 2010).Automation in agriculture has been combined with solar energy, providing a good opportunity, especially for off-grid areas. Therefore, this opportunity provides to make profit if farmers produce more than they need it and also the renewable energy sources becomes an alternative for irrigation in off-grid areas.At the same time, saving energy achieves social and economic progress of the farmers.

In Turkey, mostly common used energy sources are oil, coal, hydropower and recently coal based power plants and fossil types of energy contribute heavily to greenhouse gases emission. Even though fossil resources are scare energy sources, these are most common used energy sources not only in Turkey, still in the World. Prices of fossil energy are increasing day by day since being not renewable sources and consumed extensively in the World. Therefore, humanbeings need to think about this problem from now on and energy crisis must be addressed so that it will not a serious problem in the future. Photovoltaic solar energy is now reliable and also usage percentage increasing day by day around the World. The costs of manufacturing has been constantly decreasing, which encourages usage rate of these kind of systems in various sectors.

Photovoltaic solar energy is commonly used in the pressurized irrigation system in agriculture. Solar-powered and also automated irrigation systems save water usage and facilitate high frequency and low volume irrigation (Mulas, 1986 ; Abraham et al.2000).

Agriculture is a major user of water (surface and ground water) in Turkey, accounting for approximately 72% of all fresh water resources (Anonymous, 2007).That’s why, smart irrigation systems, both using renewable energy and decreasing greenhouse gas emission, need to be used in agriculture and farmers can produce their need power for irrigating their crops or lighting in their livestock facilities.

The objective of this study was to design a smart automated drip irrigation system running with solar-powered energy for a greenhouse system.

Materials and Methods

The experiment was conducted out in the greenhouse near Kocabaş creek from May to September,2018 at Can in Canakkale-Turkey. The geographical location of the site is $40^0$03’ N and $27^0$06’ E at elevation of 129 m. The greenhouse was covered by plastic film and characterized by vertical walls with 2 m and total height was 3.5 m (Figure 1).

Figure 1. Experimental site and greenhouse that experiment was carried out.

Plants were transplanted into soil and grown in the greenhouse of 95 m^2. During the experiment, the climate conditions inside the greenhouse were monitored by the arduino and its sensors. Soil moisture depletion and field capacity and wilting point were determined by using tomato plant (fig.2). The amount of water to be applied was determined according to the amount of water kept by the certain volume of soil in the pot and arranged to the greenhouse. It was determined that the effective root depth at the early stage was assumed as 30 cm and at the developing stage as 60cm and the covering area of each plant row was considered as 70 cm and the length of row was 19 m. The amount of water applied according to this idea. The dosage of water was determined according to the pumping time of water.

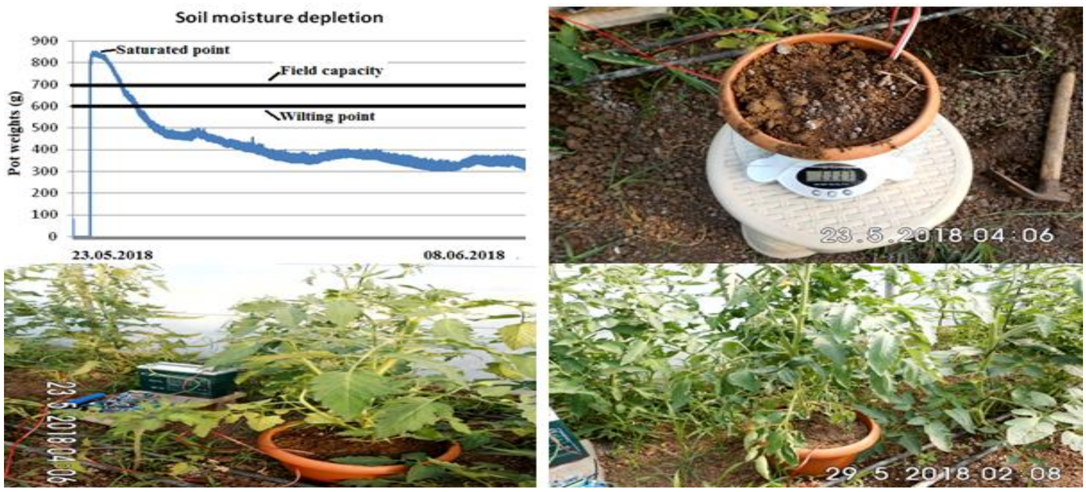

Figure 2. Changes in moisture content in the subtrate

The irrigation system is consisted of pump, main pipe and laterals (Ø16). The discharge and spacing of the in-line emitters were 4L/h and 33 cm, respectively. Also two drip lines was installed to each plant row. Connection apparatus and also valves were used to integrate all items in the irrigation system. Irrigation water was pumped from the well at the static water level of 10 m. The pump was operating at 220V and manometric height was 45 m (fig.3). Being too high, the excess water was by-passed to well again by the valves and pipes design.

Figure 3. Pump was used in irrigation

Solar panels were installed at the site near the greenhouse (fig.4) and the energy produced was saved to two gel type battery (200Ah) for electricity storage. Panels were connected to the batteries by a charge controller. Produced electricity from solar panels run the electric motor (AC) to drive the pump.An inverter was added to the system since the electric motor required AC current. The inverter converted 24 V DC into 220 V AC (fig.5 and 6). The soil moisture sensor read the volumetric content of water at the depth of 30 cm in soil, and gave the moisture level as a digital output. We converted this digital input to percent level of soil moisture by adjusting it with an equation we established between digital output and soil moisture level.

Figure 4. Solar panels; fixed and movable were mounted on a structure

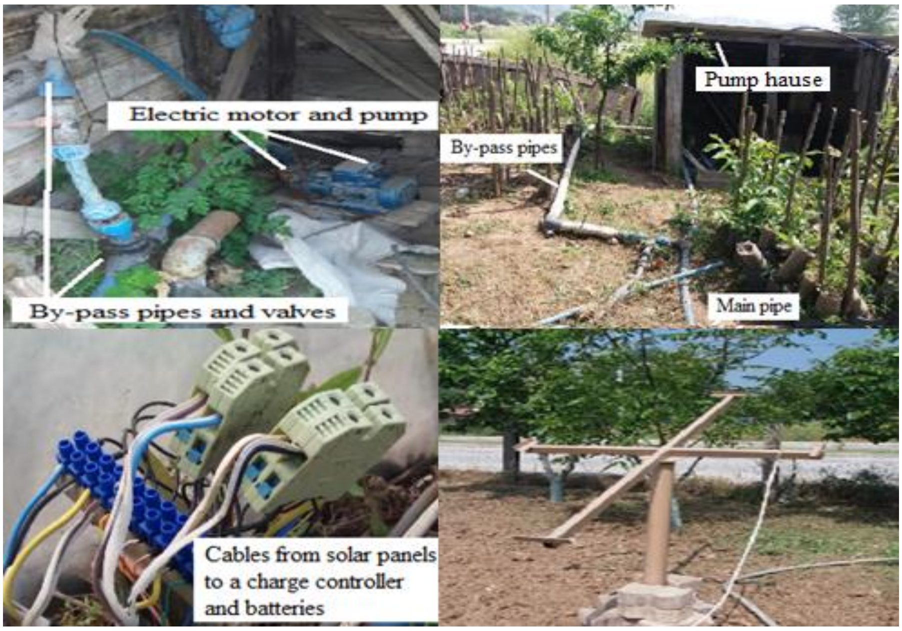

Figure 5. All connections between pump and solar panels

Figure 6. All apparatus (inverter, batteries, electric meter, data logger and etc.) used in the experiment

Results and Discussion

Different size of PV modules produce different amount of power. Data about the energy(Wp) produced by the PV panels and radiation(w/m^2) were recorded into a data logger. The pump we used run by 0.37 kW the discharge of it was 3.33 L/s. The fixed panel start producing an energy of 150 Wp at almost 5.00 a.m. and continued to produce same amount of energy until 21.00 p.m.(fig.7). It means we can run this pump to irrigate our plants from 5 a.m to almost 21 p.m without using a battery or batteries. By using this energy (151 Wp) it is possible to pump the discharge of 432 L/h by the pump. If we produced 377 Wp by only one panel, we would have pumped the discharge of 1080 L/h.

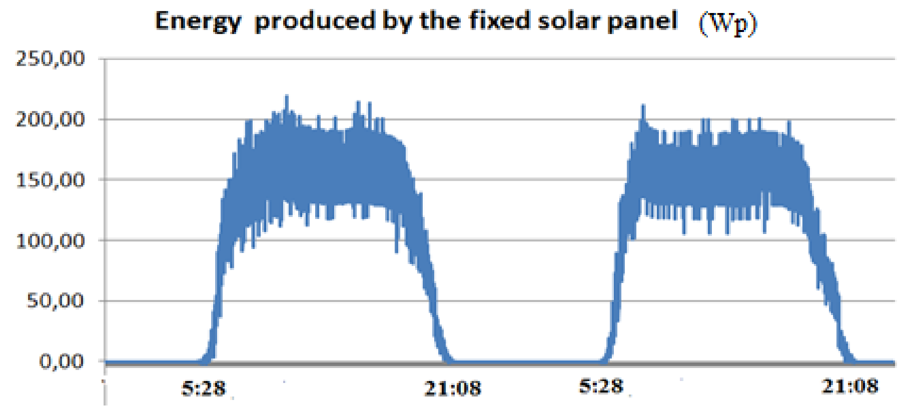

Figure 7. The energy produced by the fixed solar panel

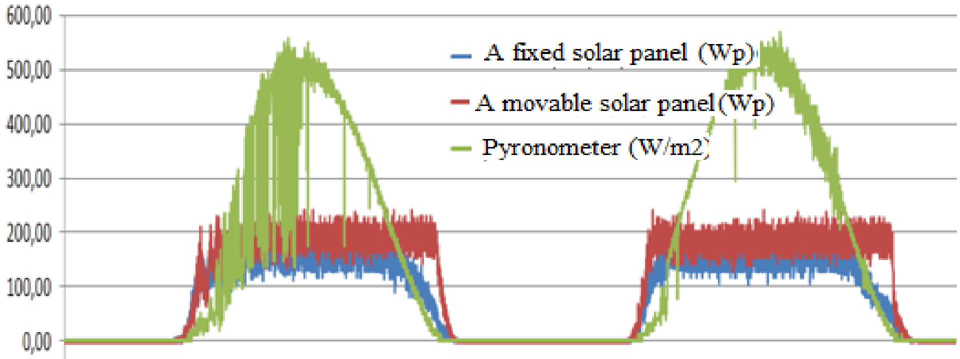

Figure 8. Energy (Wp) produced by fixed, movable solar panels and radiation(W/m^2)

The amount of energy produced by the movable solar panel is slightly higher than the fixed one (fig.8). The movable panel start producing an energy of 200 Wp at almost 5.00 a.m. and continued to produce same amount of energy until 21.00 p.m. and pumping the discharge of 575 L/h between this periods. The radiation amount as seen in fig.8 is so suitable to produce energy and also more energy can be produced by the number of solar panel if needed.

In the greenhouse, there was 7 plants row and each one included two drip lines. The spacing between plants was 70 cm.

At the early stage of plants, 20 mm (0.02 m) of irrigation water was applied

Total area to be irrigated in the greenhouse was calculated as

0.7x7x19 (Length of the row)=93.1 m^2

The amount of water to be applied=93.1x0.02= 2 m^3= 2000 L

The number of the dripper in one drip line is 58, in the double line is 116

Total row of plants in the greenhouse is 7 and 7x116=812 x 4 L/h (discharge of emitter)=3248 L/h. Therefore, the required amount of water for the plants (2000L) was applied in 40 minutes in each irrigation

At the developing stage of the plants, the amount of water was determined as 30 mm and irrigation was applied with almost 4 or 5 days intervals. Irrigation continued as like that for the whole growing season.

Conclusion

The irrigation processes have successfully been completed by the fixed solar panel system. The system took over the irrigation events successfully for the whole growing season. It is possible to save water ando fertilizer, and also to increase the amount of energy if we increased the number of solar panels. Usually small producers or having a hobby garden can use this kind of simple irrigation system running with solar panels, this system seems to be more efficient and successful forsmall farmers.

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