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REVİEW PAPER

The Use of Hose Reel Irrigation Machines and Energy Efficient Components in Irrigation

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Abstract

The energy consumed for irrigation is one of the most important inputs in crop production. Irrigation water is distributed within the parcel with minimum loss by using winged or gun systems together with a hose reel irrigation machine (HRIM). The increase in the amount of energy consumed for irrigation increases the cost of the unit product. To reduce the unit product cost, irrigation systems must be used with energy-efficiency units. Frequency converters (FC), pressure transmitters (PT), and programmable logic controllers (PLC) are among the components used to provide energy efficiency. A change in the amount of current drawn by the motors according to the changes in the required flow rate in the pumping facilities is possible by using FC, PT, and PLC. In addition, with more than one motor pump pair; it is necessary to use FC and PLC to be used by connecting in parallel, to operate with the principle of co-aging, and to make a soft start. Instantaneous pressure information is transmitted to PLC and FC via a PT to be installed on the collector in the discharge line in systems with parallel-connected pumps. In this way, the motor revolutions used to drive the pumps are changed via FC, in real-time according to the changes in the flow. Thus, pump-motor pairs are operated with the principle of "constant pressure variable flow" and energy savings are achieved.

Introduction

The increase in the world population day by day and the rapid decrease in agricultural areas make it necessary to use innovative technologies in the production of nutrients. For this reason, "food production and digitalization" have become two fields whose importance has increased and interaction has been studied in recent years. Accessible fresh water resources in the world are less than 1% of the total water resources and 77% of this amount is used in agriculture. If necessary, measures are not taken for the protection and efficient use of water resources in Turkey, in 2030, 49% of the total population and 78% of the irrigated agricultural areas will face the risk of water deficit. The averageirrigation efficiency in Turkish agriculture is 50%. It is aimed to increase this rate to 65% by using modern irrigation systems (Anonymous, 2023a). Measures taken due to global climate change are basically divided into two as structural and non-structural (Balta, 2023). These structural and non-structural measures are given below.

Structural Measures can be listed as,

- Completion of storage facilities to develop economically usable water potential,
- Completion of inter-basin water transfer projects,
- The irrigation systems to be built should be pressurized irrigation systems,
- Transformation of traditional irrigation systems in agricultural enterprises to pressurized irrigation systems within the scope of renewal and modernization works,
- Ensuring that renovation and modernization works are carried out quickly by finding alternative financing methods,
- Increasing the transmission efficiency by meeting the maintenance and repair needs of irrigation facilities without delay within the scope of BAK-ONAR Projects,
- Ensuring fair and reliable transmission and distribution of water,
- Equipping irrigation facilities in enterprises with measuring equipment in order to detect losses and leaks,
- Expanding the use of automation systems in irrigation systems and
- Construction of the necessary facilities within the scope of the studies carried out for the use of used water in irrigation.

Non-structural measures are can be listed as,

- Preparation of operation programs for all dams that have been put into operation,
- Within the scope of Irrigation Management Activities, general irrigation planning according to plant water needs in irrigation facilities,
- In order to prevent the use of water more than needed, with the application of a gradual water usage service fee in pressurized irrigation facilities with suitable infrastructure,
- Information and coordination work on drought and the measures to be taken.

Yükçü and Atağan (2009) define the concept of productivity as the production of an output with the least cost, and the concept of efficiency as the ability to do things right through an input-output mechanism. Inputs such as water and energy are used more efficiently with innovative technologies in agricultural production. For productivity, it is necessary to use high-tech components in modern systems instead of components found in traditional systems. Those who resist the transformation of traditional systems into modern systems will not be successful. However, those who use technologies such as artificial intelligence will be successful (Gül, 2023). Climate changes caused by global warming have made it necessary to use water resources and the energy consumed for irrigation efficiently. For this reason, traditional irrigation systems should be abandoned and should be adopted modern irrigation systems using digital techniques and objects. The effects of climate change, seen in many fields such as engineering, economy, social and cultural, are waiting for cost-effective solutions (Şen, 2009).

Apart from the question of what the pump characteristics should be, the most important question to be asked while designing the pumping facilities of agricultural irrigation systems is whether different amounts of flow will be needed. The answer to this question by many farmers who produce plant varieties in different families, genera and species is “Yes”. Because the total amount of water needed by plants is different of different genera and different species in the same family during the growth and development period. For example, the water consumption of cool climate cereals and warm climate cereals, all of which are in the cereal family (Gramineae), differ from each other. In order to show the relationship between the water consumption of some cereal species and the dry matter production rate, the amount of dry matter they provide with 1 liter of water and the amount of water they consume to produce 1 g of dry matter are given in Table 1. According to the findings obtained from different researchers, it is stated that cool climate cereals consume 500-700 grams of water for the production of 1 gram of dry matter, while hot climate cereals consume 300-400 grams of water (Kün, 1994). However, a significant part of the total amount of water needed in cool climate cereals is met by natural precipitation. In hot climate cereals, a significant part of the total water need is met by irrigation.

Table 1. Ratio of water consumption and dry matter production of some cereal species (Kün, 1994)

Species		Dry matter supplied with 1 liter of water (g)	Water consumed for 1 gram of dry matter (g)
Winter Cereals	Rye	1,46	690
	Oat	1,70	590
	Wheat	1,94	515
	Barley	2,30	495
Summer Cereals	Corn	2,72	370
	Sorghum	3,11	320
	Millet	3,20	315
	Canarygrass	2,86	350

The water needs, irrigation times and methods of different species in different families such as starch and sugar plants, cereals, legumes, meadow-pasture and forage plants, medicinal and aromatic plants, oil plants, vegetables and ornamental plants are quite different from each other. However, plant type is not the only effective factor in determining the required flow rate and head when designing a pumping plant for irrigation of different species. For this reason, when designing a pressurized irrigation system, physical parameters such as hydraulic radius, irrigation line length, and number of branches separated from the main line, number of fixtures installed on the main line and laterals, and suction and discharge heights are used to calculate the pump characteristics. In addition to these, it is necessary to know which plant species will be grown in how much area and the maximum amount of water to be consumed.

One of the ways to save energy in pumping facilities is to use more than one pump in parallel for the flow rate to be provided by the facility. The flow rate of a pump can be changed instantly by changing the number of revolutions. The flow rate to be provided by a pumping facility with more than one pump is also provided by instantaneously changing the number of pumps operated simultaneously to feed the same collector in that pumping facility. The need for automation components both to use more than one pump and to manage these pumps as desired increases the investment cost. However, the supplied automation components will amortize for themselves after a certain period. Atay et al. (2009) stated that as a result of the studies they carried out within the scope of the Photovoltaic (PV) Power Supported Micro Irrigation System Project, the use of solar energy, which is a renewable resource, instead of energy obtained from fossil fuels, should be included in energy policies in order to both reduce imports and obtain cleaner energy.

Hose Reel Irrigation Machine and Energy Efficient Components

Hose Reel Irrigation Machine

Hose reel irrigation machine (HRIM) is a trailed type machine. The machine consists of two parts, the body and the water distributor. The body part is connected to the water source and does not move during irrigation. The water distributor is drawn to the head of the parcel to be irrigated and is linearly moving. The water distributor can be easily used on sloping plots. The machine is extremely easy to use, maintain and transport from one place to another. Hose reel irrigation machines are preferred by businesses or farmers with medium-sized land with a mwater source. Hose reel irrigation machines can be used with both boom and gun water distributor. The boom has a small diameter and many, while the water distributor with a gun has a large diameter and one nozzle. Boom is preferred for irrigation in low water pressure and windy conditions. In addition, the water distribution uniformity of the boom is higher than the uniformity of the gun.

There is a water turbine-gearbox pair that produces the necessary moment for the polyethylene (PE) irrigation pipe on the hose reel irrigation machines to be wound on the drum. Hoses with a length of 500 m can be used in these machines. The water turbine drives the ring gear on the drum with the help of the gearbox with four different speed stages and enables the drum to move. Generally, the water turbine and the gearbox are integrated. The boom or gun water distributor used with the machine can be easily mounted on the carrier arms by using the hydraulic system on the machine and the road condition can be reached. The drum, which is mounted on the tower on the trailer, can rotate to the right and left in the horizontal plane to scan 270° angles. The water usage efficiency of these machines is quite high (~ 99%). For this reason, they ensure efficient use of the energy in the transmission of irrigation water to the plant root zone. An image of a hose reel irrigation machine with a boom is given in Figure 1.

Figure 1. Hose reel irrigation machine with a boom

Energy Efficient Components

Correctly Selected Pump-Motor Couple for HRIM

Hose reel irrigation machines can distribute water at high capacity (30-90 m^3/h). Therefore, they should be supplied with pumps that can press water at high capacity. If the right pump and the right motor are not selected to be able to pump water at high capacity, more energy is consumed than is needed. Vertical pumps are preferred because they lubricate with water and take up less space. In addition, since there is no transmission mechanism between the motor-pump pairs in vertical pumps, the efficiency is higher. Images of vertical shaft pumps used for hose reel irrigation machines are given in Figure 2 (Polat and Bowler, 2010). The characteristics of the pumps are 150 m and 100 m^3/h. The power of the electric motors used to drive the pumps is 90 kW.

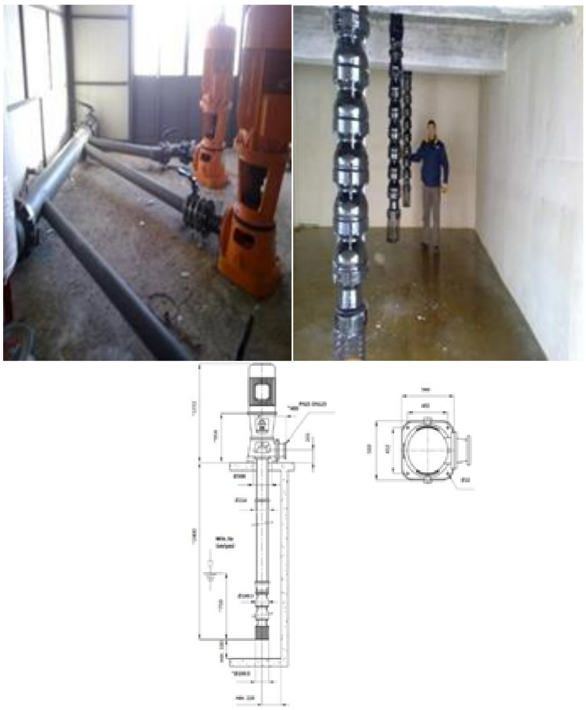

Figure 2. Parallel connected vertical pumps (Polat and Bowler, 2010)

Frequency Converter

Different types of plants can be produced in different sizes parcels. Therefore, different amounts of irrigation water are needed at different times for different plant species produced in these different sized parcels. Pumping plants with large capacities may need to be operated at a value below their capacity. Pumps that provide small flow can be connected in parallel to increase the flow. Similarly, it is possible to reduce the flow rate by sequentially deactivating the pumps connected in parallel or by reducing the number of revolutions. Changing the revolutions of the pumps driven by electric motors is provided by changing the revolutions of the electric motors. Changing the number of revolutions of electric motors is also provided by changing the frequency of the alternating current. Frequency converters (FC) are used to change the frequency of alternating current.

Frequency converters are generally used with high-tech components. By using frequency converters together with automation systems, it is ensured that the electric motors used to drive the pumps connected in parallel are operated at different speeds, they are put into operation in a sequential manner and they start to work by making a soft start. Thus, the electric motors are not suddenly loaded into the grid and mechanical stresses are prevented.

Energy saving is achieved by adjusting the motor speed according to the need. About 20% of the total energy produced in the world is consumed in pumping systems, especially centrifugal pumps (Shankar et al., 2016). Therefore, efforts to save energy in enterprises using centrifugal pumps are very important in terms of both unit product cost and environment. Using a frequency converter with water pumps reduces energy consumption by about 15-20% (Yimchoy and Supatti, 2021). The image of the frequency converter used to feed a submersible pump and an inline pump by operating at different speeds is given in Figure 3.

Figure 3. Frequency converter used in series connected pumps

Pressure Transmitter

One way to save energy in farms where variable amounts of irrigation water are needed is to use more than one pump in parallel. With the activation and deactivation of each pump connected in parallel, the amount of water pumped into the line used in water transmission increases and decreases as the flow rate of each pump. Similarly, an increase or decrease in the number of laterals connected to the irrigation line causes the line pressure to decrease or increase, respectively. For this reason, operating the pumps according to the required flow rate ensures efficient use of energy.

Different types of each water distributors (nozzles, sprinkler heads, etc.) used in irrigation systems have their own operating pressure ranges. These different types of distributors irrigate at the most suitable operating pressures with the most appropriate wetting radius. Thus, the areas wetted by the successive water dispensers are prevented from overlapping excessively or not at all. The important issue for proper water distribution in pressurized irrigation systems is to transmit water to the distributors at a constant pressure throughout the irrigation period. Deactivation or activation of one of the laterals during irrigation in an irrigation line causes the line pressure to change. Therefore, the water distribution uniformity is disturbed. For this reason, the line pressure should be measured instantly and digitally reported to the automation system used to manage the pumps.

Pressure transmitters reliably convert small pressure changes into electrical signals as well as large pressure changes. They usually produce a 4-20 mA output signal. They react to pressure changes in pressurized lines within a few milliseconds (Anonymous, 2023b). An image of a pressure transmitter used in irrigation systems is given in Figure 4.

Figure 4. A pressure transmitter used in irrigation systems (Anonymous, 2023b)

Programmable Logic Controller

Automation systems are used in every field of industry, and their use in agricultural production is increasing day by day. Production is carried out successfully with automation systems used in different disciplines of agricultural production such as seed selection units, milking facilities and irrigation system. Reasons such as the increase in the human population in our country and in the world, the decrease in agricultural production areas, and the low number of qualified producers cause the product costs to increase. Therefore, it is a necessity to use automation systems in order to reduce product costs and obtain quality products.

Today, when automation is mentioned, almost everyone thinks of Programmable Logic Controller (PLC). However, automation does not mean a system consisting only of PLC. PLCs are devices that control the actuators by evaluating the data received from the sensors and other devices in the system within the scope of the preloaded logic program (Karaçor and Keleş, 2007). For example, PLCs provide variable-speed management of pumps by using the data from the sensor that measures the irrigation line pressure. Thus, energy is used efficiently. The images of PLC used in an irrigation pumping plant operating with constant pressure variable flow principle are given in Figure 5.

Figure 5. PLC used in an irrigation pumping plant

Polyethylene Pipes

Polyethylene (PE 100) pipes; It is used in many areas such as agricultural irrigation and drainage systems, sea discharge systems, sewage discharge systems, geothermal systems and underground drinking and utility water lines. The advantages of polyethylene pipes are given below as items (Anonymous, 2009c).

- They are long-lasting and do not rust,
- Due to their flexibility, they are not affected by the topography during their establishment and then by soil movements,
- They are robust due to their high crack and impact resistance,
- Due to their high resistance to corrosion, they do not rot and corrode,
- They do not require cathodic protection measures,
- Due to the smooth inner surfaces, less friction will occur during operation, so less electrical energy is consumed,
- They are not affected by sunlight (Ultraviolet) because they contain catalysts,
- They can be perfectly welded with each other or with armatures by butt welding or electrofusion methods,
- Due to their lightness, they can be laid easily and quickly,
- It can be produced for any pressure class,
- They are frost resistant.

"Internal surface smoothness", which is one of the features listed above, is extremely important in terms of reducing the "system friction losses" seen in pressure pipelines used in water transmission and distribution in irrigation systems. The fact that the system friction losses are low means that the irrigation is done with less energy consumption. In other words, it means increasing energy efficiency.

The images of the PE 100 pipes used to feed the hose reel irrigation machines and the jointing works by the butt-welding method are given in Figure 6.

Figure 6. PE 100 pipes and jointing works by butt welding method

Flowmeter and Water Meter

Flow rate in irrigation systems is defined as the amount of water passing through a line per unit time and is measured with a flow meter. The amount of water pumped by the pumps per unit time is also a flow rate. The flow rate, symbolized by the letter "Q" in the continuity equation, is equal to the product of the area of the cross section (A) through which the fluid passes, and the fluid velocity (V). Therefore, units such as L/s, L/h and m^3/h are used to indicate the amount of flow.

Counters are used to measure the total amount of fluid passing through a line. A water meter is a measuring instrument designed to measure, store and display the volume of water coming from the measuring transducer under measuring conditions (Çiftçi, 2008). Many types of meters have been developed for water measurement. By adding a GSM module to the recently developed meters, remote reading and high accuracy measurement can be made. Energy saving is achieved due to the low shape losses caused by these meters, which have a flat measuring tube that is resistant to wear and has no moving parts. In addition, the meters, which have a dustproof and submersible protection class (IP 68), can be used by mounting underground (Anonymous, 2023d). The image of a high-tech water meter that can be used to measure the amount of instant and total water consumed is given in Figure 7.

Figure 7. A water meter with a high technological level (Anonymous, 2023d)

Turkish farmers use 74% of the water potential in Turkey for agricultural irrigation. Due to such a high water consumption, meter systems should be used in order to save water in agricultural irrigation (Özbek, 2023). Farmers who do not have sufficient awareness may consume more water than necessary despite using pressurized irrigation systems such as drip or sprinkler. Excessive use of water will not increase the yield, but it also causes the emergence or increase of many problems such as salinity, washing of plant nutrients, soil erosion, and the proliferation of diseases and pests. Measuring the amount of irrigation water consumed with a meter is important in terms of efficient use of both the water and the energy consumption in water transmission and distribution.

Photovoltaic Panel

Wind energy is converted into electrical energy by using wind turbine and solar energy using photovoltaic panel (PV). Therefore, the electric motors used in irrigation systems can be fed independently from the electricity grid by systems using wind turbines or PV panels. For this reason, in areas with frequent power cuts, irrigation can be done without any problems by using a wind turbine or PV panel. However, the use of solar panels in electricity generation is more common than wind turbines. This is because there is not always enough wind to produce enough electricity in every area. Therefore, electricity generation from solar panels is also more common in irrigation. Irrigation can be done independently of the electricity grid with systems using thermal motor-pump couple. However, these systems require periodic maintenance and refuelling. On the other hand, the maintenance and operating costs of renewable energy systems, which have relatively high installation costs, are quite low (Atay et al., 2011).

With a general definition, fertilization is the delivery of plant nutrients to the plant and/or plant root zone. Fertilization and irrigation are essential cultural practices in crop production. The images of the works made by using a fertilizer spreader and solid granular fertilizer in wheat production are given in Figure 8. Burt, (1995) stated that systems with high water distribution uniformity, which are more environmentally friendly and can make sensitive applications with low energy consumption, have been developed in the last 20 years in the irrigation industry. Burt explained that in some state's irrigation water is priced according to the efficiency principle. Burt even stated that there are systems that start and stop irrigation according to the weather and soil moisture with the help of computers and sensors. Burt explained that these systems could be used with systems such as drip irrigation, subsurface drip irrigation and micro sprinkler. In addition, referring to the report published by the California Polytechnic University ITRC (Irrigation Training and Research Center) Board and stated that as much as the energy used in the production of chemical fertilizers, energy is consumed in their distribution within the production area. He stated that the systems to be designed in the future would be advanced equipment called "fertigation technique", which mixes plant nutrients into irrigation water according to the need in order to increase crop yield.

Figure 8. Fertilizer application studies in wheat production

In a recently developed fertigation system, a 25 W solenoid-based dosing pump was used to pump liquid fertilizer into the water inlet pipe of hose reel irrigation machines. There is a monocrystalline photovoltaic panel with a maximum output power of 195 WP in the system in order to meet the electricity need of the dosing pump used independently from the grid. Liquid chemical fertilizers could be mixed with the components used in the system with a high homogeneity of 99% into the irrigation water (Polat et al., 2022). Thus, it has been revealed that fertilization can be done by irrigation in enterprises using hose reel irrigation machine, without using solid granular fertilizer with tractor and fertilizer spreader. It has been explained that the fertigation application using a photovoltaic panel with a hose reel irrigation machine is a suitable technique for energy efficiency by eliminating the necessity of energy expenditure for fertilizer distribution (Polat and Çolak, 2022). The images of the fertigation system components developed for hose reel irrigation machines are given in Figure 9.

Figure 9. Images of the fertigation system developed for HRIM

The performance of a "fixed solar cell irrigation system" established in Şanlıurfa to take advantage of the high solar energy potential has been analyzed. In the first year of the study, which was carried out with the drip irrigation method, an accumulator was used with photovoltaic panels. In the second year, irrigation was done without using accumulators. At the end of the operation, irrigation can be done at any time of the day or for 24 hours when the accumulator is used; however, it has been determined that irrigation cannot be done in the early morning and cloudy weather when the accumulator is not used (Atay et al., 2012).

Float valve

Float valves are used to ensure that the water level in the pools used as reservoirs is not higher than the desired maximum level. The valve, which has an object that acts as a floater is installed at the water inlet of the buildings used as reservoirs. The floater ensures that the valve closes when the water level rises. Images of float valves used in a pool built for more than one hose reel irrigation machine are given in Figure 10.

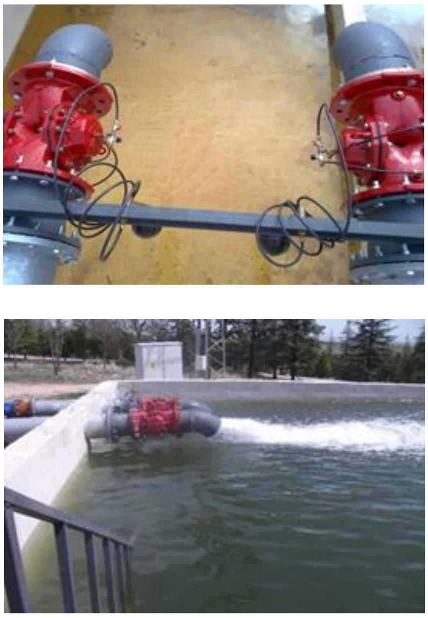

Figure 10. Float valves

Conclusion

The aim of this study is to explain how energy efficiency and water savings are made in irrigation with hose reel irrigation machines. Written to achieve the stated purpose, this article has been prepared by compiling the professional experience and the information obtained from the referenced sources. In this context, it is mentioned that more than one hose reel irrigation machine is operated with the principle of "constant pressure variable flow". In addition, information is given about the components used in the operation of hose reel irrigation machines with the said principle. The block diagram showing the operation of hose reel irrigation machines with the principle of constant pressure variable flow is given in Figure 11.

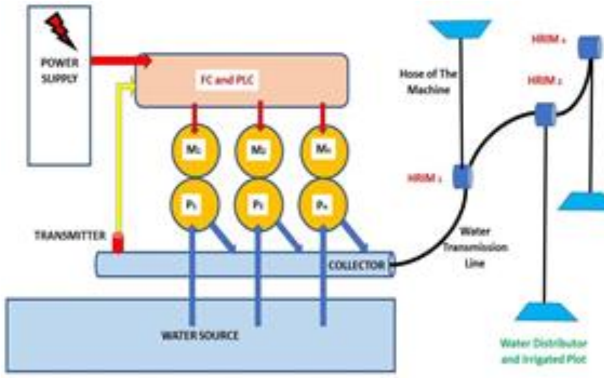

Figure 11. Block diagram of constant pressure variable flow principle

Hydrants are usually installed on the pressure line extending from the collector outlet to the farthest parcel, at intervals equal to the maximum working width of the hose reel irrigation machines. Irrigation can be done by connecting more than one hose reel irrigation machine to these hydrants at the same time. The principle of constant pressure variable flow rate is to keep the collector pressure constant no matter how many hose reel irrigation machines areconnected to the hydrants in the pressurized line. In other words, changes in flow rate do not cause a change in line pressure.

The benefits of feeding hose reel irrigation machines using pumping facilities operating with the principle of constant pressure and variable flow are given below.

- Operating the hose reel irrigation machine under constant pressure ensures that the water distribution uniformity is realized at a high rate and with a constant working width.
- More than one hose reel irrigation machine can be fed from a center.
- Components such as turbine, gearbox, PE pipe that make up the hose reel irrigation machine are not damaged because there are no sudden changes in pressure.
- The required amount of irrigation water is supplied to the pressurized pipeline regardless of the number of hose reel irrigation machines used laterally, thus saving water and energy.
- Energy saving is achieved by keeping the collector pressure at the “operating point” value of the pumps.

In order to provide both energy efficiency and water saving, the purpose of the components used in pumping facilities that feed with the principle of constant pressure and variable flow is given below.

- The purpose of using vertical pumps with high efficiency is to reduce maintenance and repair costs, increase profit and provide energy savings.

- The purpose of using FC is to operate the pumps at variable speeds and to provide a soft start of the electric motors.
- The purpose of using PT is to convert the collector pressure into an electrical signal and transmit it to the PLC unit.
- The purpose of using PLC is to operate the pumping system with constant pressure variable flow principle. In addition, the operation of the motors with the principle of co-aging and soft starting is also carried out using PLC.
- The purpose of using PE 100 pipe is to transmit water without being affected by the topography, to reduce friction losses, to save energy and to prevent water losses.
- The purpose of using flow meters and water meters is to measure instant and total water consumption and to ensure fair use of water.
- The purpose of using PV panels is to feed the electrically powered components independently from the grid.
- The purpose of using float valve is to prevent possible water losses in structures used as reservoirs.

An irrigation system with a high technological level and the components in the system should be introduced to all stakeholders, especially farmers. Policies should be developed by governments to establish and support these systems. In this way, on our planet, which is under the threat of global warming, energy consumption will be reduced by protecting the extremely important water resources.

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