0165 - TECHNO-ECONOMICAL EVALUATION OF A SOLAR DRIP IRRIGATION SYSTEM BY FIELD MEASUREMENTS

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ABSTRACT
Solar irrigation is very convenient in rural areas, especially when solar radiation potential is high. Sanliurfa city of Turkey is one of the best geographical locations in that sense since it has large agriculture intensive lands as well as over 3000 sunny hours per year. A compact size of solar photovoltaic (PV) powered drip irrigation system in a selected field in Sanliurfa city was installed to investigate its feasibility in real agricultural application. The system was used in grown of local fresh red peppers. For comparison purpose, the same application was simultaneously performed with a classical irrigation pump powered by grid-electricity. Techno-economical parameters of these two systems are measured during irrigation season and the results were analyzed. It is obtained that solar irrigation is highly competitive and functional comparing with classical irrigation by electricity as long as the correct irrigation schedule is implemented.
Keywords: solar energy, photovoltaic, drip irrigation,

1.INTRODUCTION

PV driven drip irrigation systems (PVDIS) promise as one of the best solution for preventing high energy and water consumption in the GAP Region. There are however some barriers, such as high investment cost and low overall performance of the system, for wide dissemination. PV system components and configurations must be optimized for maximum utilization to overcome these disadvantages. (Yesilata et al. 2006). There are many parameters in optimum designing of PV drip irrigation systems. Main parameters are daily water needs, water quality, static and dynamic loads, length of the irrigation season and the last but not least total radiation flux. All of these factors must be carefully analyzed and optimized in detail before the system implementation. (Atay et al. 2009, Atay et al. 2012, Atay et al. 2013).

The PVDIS has been very popular and used in many different countries for agricultural production in the field. Various components and configurations have been attempted to exploit solar pumping. These initiatives were obtained using different irrigation scenarios at different levels of success. Fraidenraich and Vilela (2000) were performed extensive field experiments to determine the characteristic curve of the system after calculating the maximum volume of water corresponding to various climatic data and irrigation parameters. Al-Ali et al. (2001) developed an autonomous PVDIS to investigate required water flow rates for various specific products. Hamidat et al. (2003) also examined irrigation performances of the system for wheat, potato, tomato and sunflower crops to find an accurate relationship between PV system parameters and the specific agricultural product. Bouziane et al. (2009) have developed a comprehensive software to determine operation efficiency of the PVDIS system by performing field experiments in Algeria climatic conditions.

A compact size of PVDIS designed and installed in Sanliurfa city of Turkey is examined here. Its feasibility in real agricultural application is discussed by experimentally comparison with a conventional irrigation pump driven by grid-electricity.

2.MATERIAL and METHOD

A small-scale PVDIS system (denoted by SYS-1 in following text) for Sanliurfa/Turkey climatic condition was designed and installed to grow local fresh red pepper during irrigation season. Sanliurfa city of Turkey is one of the best geographical locations for this type of application since it has large agriculture intensive lands as well as over 3000 sunny hours per year (**see Table-1 for the long-term meteorological data of Sanliurfa**). It is remarkable in Table 1 that the average daily sunshine duration is about 12 hours in a typical summer day whereas it is as high 14 hours as on June 21, the longest day of the year. The same size of the irrigation system powered by grid electricity (denoted by SYS-2 in following text) was also installed in the same size field (280 m^2) to grow the same product (**see Fig.1 for picture of these systems taken in the field under consideration**). Techno-economical parameters of the SYS-1 and the SYS-2 were measured in real field conditions for comparison purpose.

Table-1 Long-term (between the years of 1954 and 2013) meteorological data for Sanliurfa

SANLIURFA	Long-term Mean Values											
	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
Sunshine duration (hour)	4.1	5.1	6.2	7.5	10.1	12.2	12.3	11.3	10.1	8.6	5.5	4.0
Average Temperature (° C)	5.6	6.9	10.9	16.1	22.1	28.2	31.9	31.2	26.7	20.2	12.7	7.5
Maximum Temperature (° C)	10.0	11.9	16.5	22.2	28.6	34.7	38.7	38.2	33.8	26.9	18.5	11.9
Minimum Temperature (° C)	2.2	2.9	6.1	10.5	15.5	20.8	24.3	24.0	20.0	14.7	8.4	4.1
Number of Rainy Days	12.3	11.2	10.9	9.6	6.7	1.6	0.3	0.2	0.9	5.0	8.1	11.3
Monthly Total Precipitation (kg/m2)	87.3	71.0	62.7	48.5	28.9	3.8	0.7	0.8	2.6	25.2	45.9	81.0
The highest and the lowest values between years of 1954 and 2013												
Maximum Temperature (° C)	21.6	22.7	29.5	36.4	40.0	44.0	46.8	46.2	42.0	37.0	29.4	26.0
Minimum Temperature (° C)	-8.0	-9.6	-7.3	-3.2	6.0	10.0	15.6	16.0	11.2	2.5	-2.7	-6.4

Figure 1. A photograph taken in the real field to show both systems

The schematics for components of both systems are given in Fig. 2. The equipment lists for those are described in Table 2.

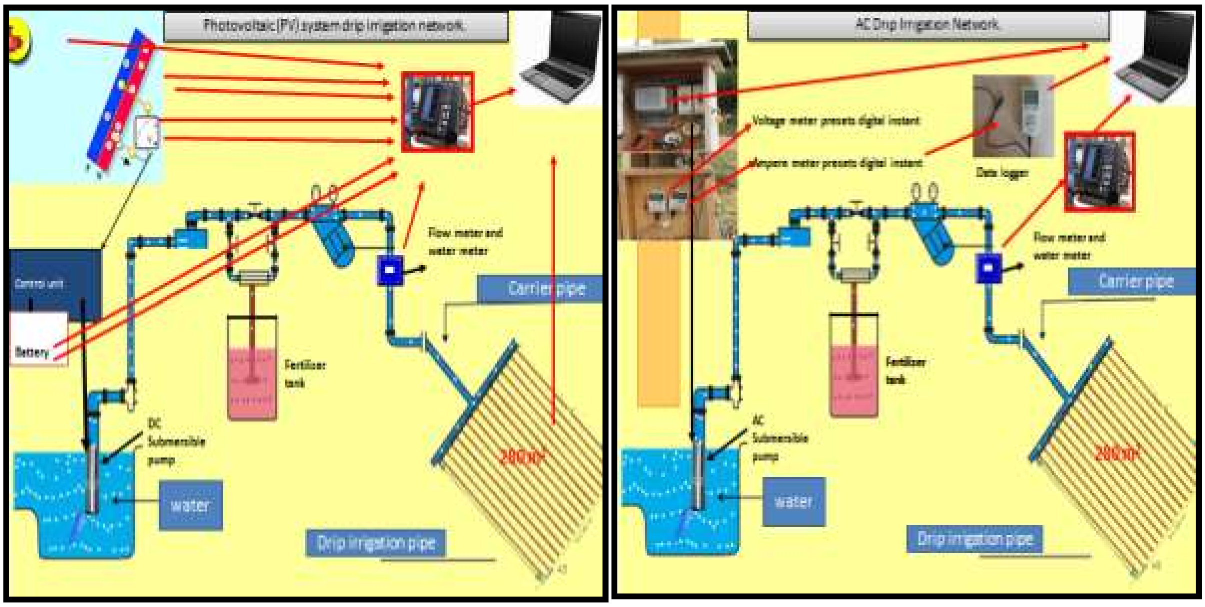

Figure 2. The schematics of the systems under comparison (SYS-1 is on the left side whereas SYS-2 is on the right side)

Table 2. Equipment list for the two irrigation systems under consideration

PV PUMPING SYSTEM (SYS-1)		**CLASSIC ELECTRICAL PUMPING (SYS-2)**	
Equipment	**Specifications**	**Equipment**	**Specifications**
PV Module	4x160 W at 24 V (monocrystal)	Electric-counter	1 piece mono-phase type
Battery	2x230 A at 12V (gel type)	Electric-box	1 piece standard
Control	1 MPPT	Electric-pole	1 piece
DC Pump	3–5 ton/h 450 W 24 V H=22m	AC Pump	3–5 ton/h 550 W 220 V H=15m
Monitoring	1 Water Counter, 1 Mass Flow Meter, 1 Manometer	Monitoring	1 Water Counter, 1 Mass Flow Meter, 1 Manometer
Plumbing	1 fertilizer tank, 1 honeycomb filter, valves, pipe fittings, main pipeline and lateral pipeline	Plumbing	1 fertilizer tank, 1 honeycomb filter, valves, pipe fittings, main pipeline and lateral pipeline

3.RESULTS

3.1. Technical behaviors of the SYS-1 and SYS-2

Field experiments were performed during two consecutive irrigation seasons, covering months between May-August. Water mass flow rates and pump input powers of both systems were instantaneously measured during experiments. The overall solar radiation intensity, ambient temperature and wind speed data were also measured. Power parameters of PV array for SYS-1 along with battery power use were accordingly recorded in a data-logger.

Measurement results for certain hours of a selected day (June 12, 2009) are shown in Fig. 3. Instantaneous power behaviors of the PV array (SYS-2), the battery (SYS-2) and the electrical pump (SYS-1) are plotted in Fig. 3(a). Total time length in the graph is about 2 hours. During this time interval; AC power consumed by the electrical pump is nearly constant. On the other hand, the PV array and battery power behaviors are highly variable and wavy. Irrigation water mass flow rates shown in Fig. 3(b) are reversibly nearly constant for SYS-1 and variable in time for SYS-2.

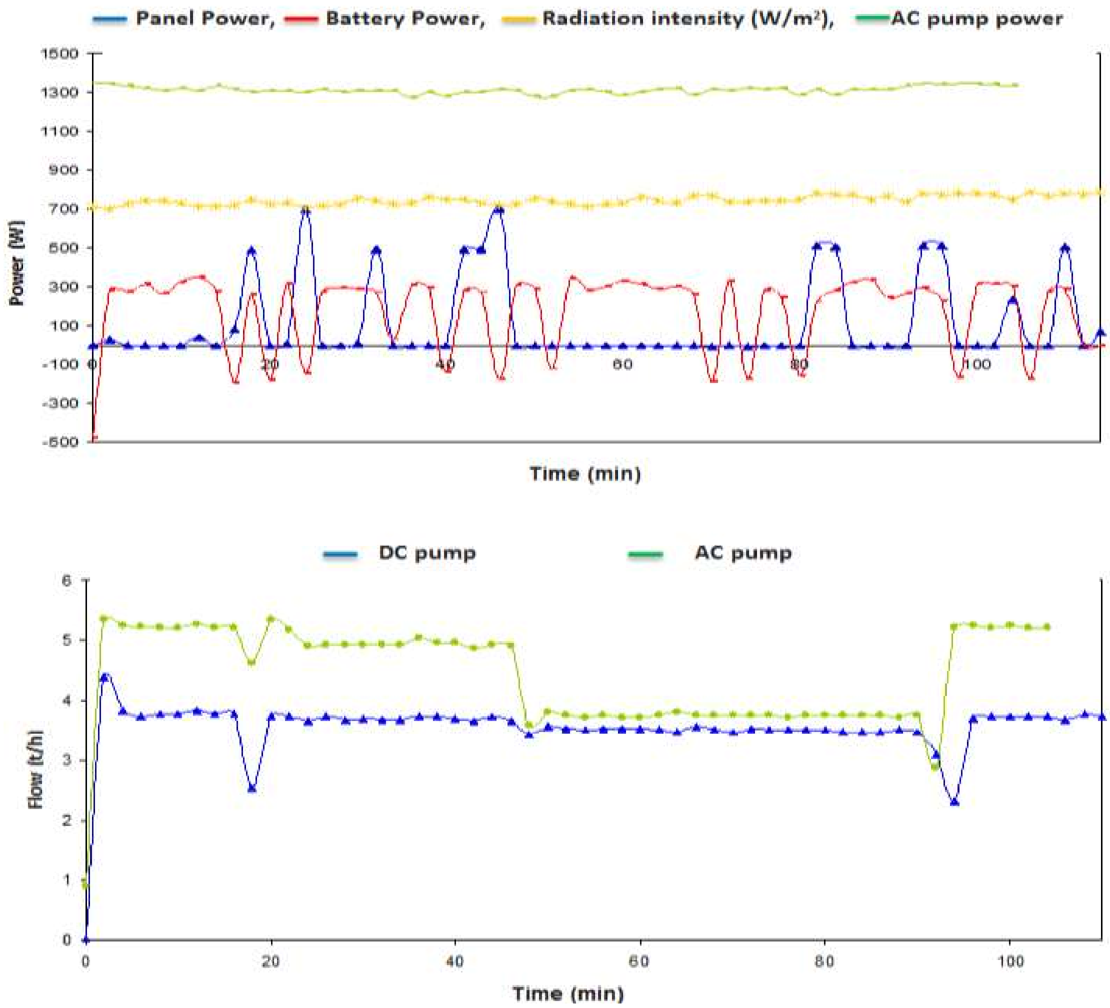

Figure 3. Field measurement data for certain hours of a selected day (June 12, 2009) during irrigation season; (a) power behaviors, (b) irrigation behaviors.

3.2. Economical feasibility of the SYS-1 and SYS-2

During long-term experiments of two-years, major observations obtained summarized below:

The SYS-1 has experienced wavy power input to the DC pump but supplementary battery system has recovered it up to provide nearly constant water mass flow rate to the field. The battery system also provided extended hours of system usage into night shift. The SYS-2 has frequently experienced power-cut problems; thus failure in providing necessary water to the field. As a result of this unexpected and sudden electricity-cut, the first AC pump was broken down. Another new AC pump was re-purchased and re-installed.

İnitial investments for SYS-1 and SYS-2 for experimental purpose were approximately $10,000 and $1,000 in 2009, respectively. No grid-installment cost for the SYS-2 was included since the site was in the urban area with grid-ready condition. A hypothetical case study for a site in rural area, 1 km away from the grid, is also considered. Grid-line installment in this case is very expensive, causing the investment for the SYS-2 to raise $13,500. In this case, the SYS-1 can be highly preferable and feasible, even though failure and cut-off problems of SYS-2 are not capitalized.

4.CONCLUSIONS

The PVDIS studied here are suitable and feasible for agricultural irrigation, when the site is in rural area, far from the grid. Its initial investment is high; however, return of investment has been sharply decreasing due to sharp decrease in PV manufacturing costs. The other strong argument here is that the PVDIS are favorable when a site/location has high solar potential. The system is excellently preferable in the areas where electricity-cut problems are frequent.

The GAP Region in overall, with its nine provinces, is very suitable for the PVDIS since high solar potential and agricultural intensive fields exist. The grid has frequent cut-off problem due to intensive energy use in irrigation and air-conditioning. The PVDIS will be reliable and economically feasible if the system design and optimization are very precisely realized.

Acknowledgement
The authors acknowledge partial supports provided by TAGEM (under the project number of TAGEM-TOPRAKSU-2012/138) and TÜBİTAK (under the project number of TOVAG-110O541)

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