MENA NWC

Middle East and North Africa
Network of Water Centers of Excellence

FURTHER ADVANCING THE BLUE REVOLUTION INITIATIVE (FABRI)

UTILIZING SOLAR ENERGY FOR WATER PUMPING AND BRACKISH WATER DESALINATION IN AGRICULTURE

FINAL REPORT

March 2016

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EXECUTIVE SUMMARY

Increasing demand for agricultural crops has put an increased strain on limited freshwater resources in Jordon and Palestine. The area currently has shortages in freshwater and an abundant supply of saline water which has not been utilized for agriculture due to the economics associated with pumping and desalinization mainly from limited availability to electricity and high running cost of the alternative diesel generators. Continued improvements in the costs associated with the implementation of large-scale renewable energy has renewed interest in understanding the potential impacts of developing distributed desalination and pumping station for agriculture. This study integrates geographically resolved data with historical meteorological data to critically evaluate the feasibility and impact of the deployment of renewable energy systems for water pumping and desalinization on agriculture production. Specifically the project includes the following activities: 1- surveying brackish water resources, assessing the potential of solar energy and analyzing previous projects for lessons learned and related national policies; 2- review RO and nanofiltration technologies and conduct comparative analysis between both, 3- Investigating the current and potential future economic and technical feasibility of PV solar water pumping and desalination and generalizing results through developing and conducting sensitivity analysis to make it beneficial for different locations and for various conditions; 4. Identifying through modeling possible high value crops and 5. development of a medium to large scale PV pumping inverter

Abundant water resources in Jordon and Palestine are not utilized mainly due to the high energy cost and corresponding economics of pumping and desalination. Solar powered water pumping and desalination technologies have been investigated until present time only for small scale sizes. To date no real medium and large scale research for these application specially for the agriculture purposes. Moreover, some system components are still not readily available in the market like solar pumping inverters and RO pumps that matches the variable power source from solar. In the past, the high capital cost of PV solar modules (above US$ 5/ Wp) was the primary barrier to their large scale implementation in water pumping and desalination . Recent advancement in PV technology and manufacturing have seen a sharp decrease in module PV prices to below US$ 1.0/W_p. The decrease in PV costs combined with increase in energy costs have the potential to make PV desalination and pumping systems economically favorable at commercial size applications.

This project seeks to improve agricultural production and productivity through: 1) increase irrigation water availability and improve its quality through water pumping and brackish water desalination using solar energy which will help in food security and 2) decrease energy cost per unit of agricultural output by recommending energy efficient, well optimized medium to large scale modular water pumping and RO desalination systems through the integration of solar systems

Objectives. The objective of the project are outlined in the following:

- Increasing agricultural productivity through increasing water availability through the development of distributed renewable energy to pump and desalinate water for irrigation.
- Demonstrate the potential impact of decreased energy cost per unit of agricultural production by developing and recommending optimized energy systems for water production

Results and key outcomes of the project:

- Detailed economic feasibility that gives water unit cost for all power supply options. The study includes sensitivity analysis for main parameters to generalize results for different situations and locations
- The consortium has developed a model for solar water pumping and desalination using HOMER and MATHLAB
- A 45 kW Inverter has been developed by ABB Group to satisfy the objectives of the project
- Previous data has been collected and analyzed to serve as inputs and lessons for this project
- A scientific paper has been accepted for publication in the Desalination Journal

3 PROJECT OPERATIONS AND OUTCOMES

Were there changes to the project operations or its objectives?

Yes ☐ No ☒

If Yes, please describe the changes and explain why they were made.

Results and Key Outcomes of the Project

- Detailed economic feasibility study that gives water unit cost for all power supply options has been prepared. The study includes sensitivity analysis for main parameters to generalize results for different situations and locations
- It is clearly concluded that PV solar systems are more economical than diesel systems under all operational conditions and scenarios. In Jordan, where water is heavily subsidized for agriculture, PV has reached the breakeven with the electricity grid. Any decrease in subsidy will bring PV to the front as a better option than the grid
- The consortium has developed a model for solar water pumping and desalination using HOMER and MATHLAB
- A 45 kW Inverter has been developed and it is ready to be tested in the field. Further modifications and control algorithms will be developed in the next stage of the project to reach the most optimum operational algorithm for the different operational scenarios.
- Previous data has been collected and analyzed to serve as inputs for this study and utilize the lessons learned from that
- A scientific paper has been accepted for publication in the Desalination Journal

Actual Results Compared to Expected Results

Actual resulta match expected results

Project Impact

As it is clearly found that PV powered systems provides the best economic alternative, this will reduce the water pumping unit cost and the desalinated water unit cost. Moreover, the development of the medium size modular inverter has paved the way for PV applications in agriculture which was limited in the past for small scale applications. As a result, the following impacts are expected:

- Improving the economic situations of the farmers
- Reducing agriculture products cost will inturn mitigate the economic burden on the consumer and thus improve their economic situation
- Reduce government energy bill and reliance on imported oil
- Reducing co2 emissions and thus improving health conditions

Table 11: Maximum subsystem efficiency for eight systems

System	**Maximum subsystem efficiency (%)**
Jafr 7	30.7
Fidan	33.9
Jafr 1	31.3
Breekeh	37.9
Hazeem	31.5
Umruk	37.2
Ritem	38.3
Hasa	31.9

4.1 System Efficiency

System efficiency is defined as the ratio between the useful output hydraulic power (P_{hyd}) and the solar input power and is given by;

$$\eta_{sys} = \frac{P_{hyd}}{G_T A} \tag{4}$$

Figure 7 shows a sample graph for system efficiency as a function of insolation. Trend lines have been obtained for the eight systems and presented in figure 8.

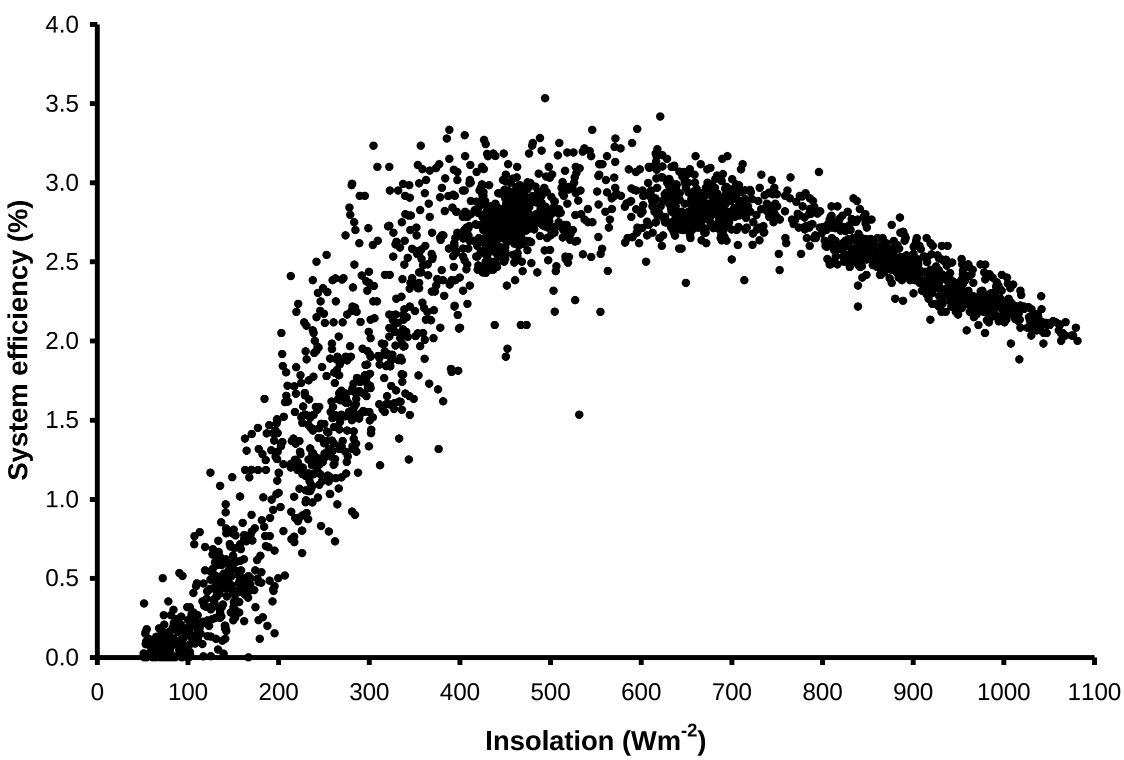

Figure 7: System efficiency as a function of insolation for Jafr 7

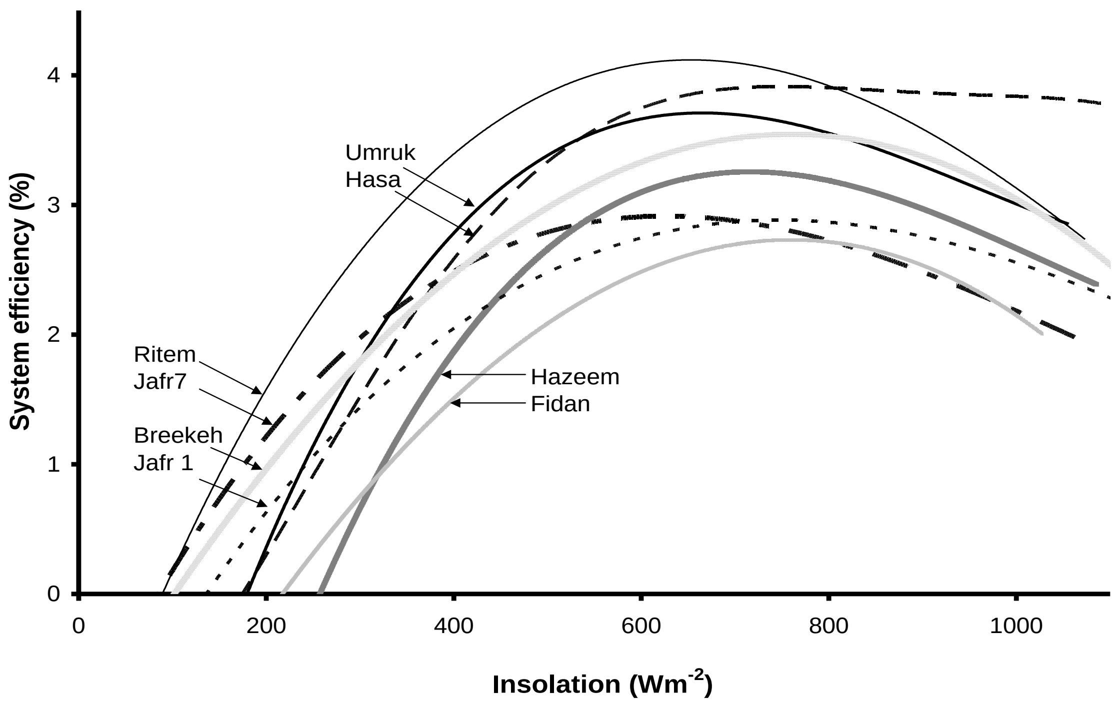

Figure 8: System efficiency as a function of insolation for eight systems

System efficiency curves as a function of insolation gives general information about design accuracy. It also shows how the load affects system performance. Based on figure 8 it can be concluded that there is a unique trend in the relationships between the system efficiency performance and insolation. System efficiency increases from zero up to a maximum value that corresponds to particular insolation. The insolation level at which the maximum system efficiency is reached may differ from system to system. The system operates at its maximum system efficiency over a particular insolation range which may also vary from one system to another. Then system efficiency decreases again at high insolation level, when the maximum capacity limit of the pump is reached and the system becomes unable to utilize more insolation. However, for systems that have two pumps such as Hasa, they may retain constant efficiency at high insolations due to the utilization of increasing PV power by the second pump.