New Solar Pumping Technology with Efficient Irrigation Advisory System

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1. Introduction

Low cost irrigation pumping with efficient use of Irrigation water is a challenging direction to address the draught conditions in California, where an estimated 70%-75% of the state water, and about 8%-10% of its power are used in irrigation (1). Improving water use efficiency in irrigation (using sprinklers and micro drips) requires additional extra power use on farms (projected by about 10%) (2) which raises cost issues by farmers , and concerns of environmental regulators working to reduce GHG emission in the state by 2020 to the level of 1990.(3) Water and Energy Nexus become widely recognized by energy agencies, irrigation districts , and farmers equally. Extra low cost pumping power is needed for further irrigation efficiency improvement.

Pumps consume about 98% of the total power on farms . Any increase in pumping efficiency , or to operate them with renewable energy can offer the extra clean power needed by the state. Pumps also can be used to improve water use on farms. "Smart Pumps" with built-in intelligent functions to change source flow-rate per required irrigation volume can optimize water use on farms to avoid "overwatering" or "down-watering ". Solar smart pumps can assist to reduce both energy and water cost in irrigation.

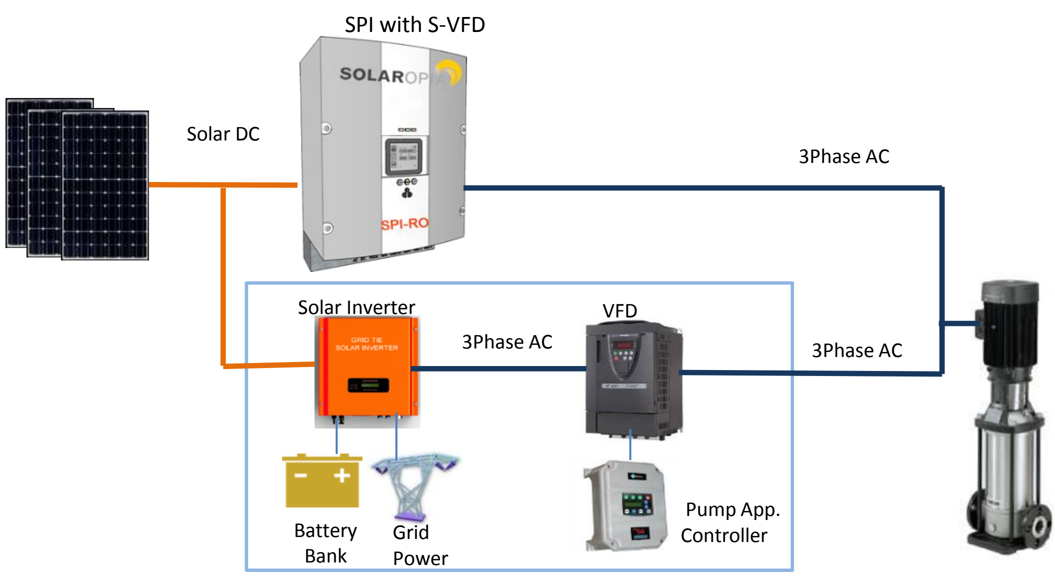
A promising technology in this direction is called SPI (Solar Pumping Inverter-VFD) recently introduced by San Diego start up company called Solaropia. SPI can operate pumps directly from PV arrays, with or without grid power at higher efficiency rate (20%-40%) than current solar technology (thus reducing with same ratio the cost of solar systems for pumping). It is projected that SPI will reduce pumping power cost by considerable 40%-60%. SPI models already exist to operate with solar power pumps up to 500 hp , that can lift, for instance 250,000 GPD from deep-1000' well. SPI also embeds Smart Pumping functions. The class SPI-I designated for irrigation embeds water efficiency advisory services. They guide farmers to avoid over-and-down watering for given corps type- land area with required flow-rate and water volume This service , if correctly used , can save farmers between 15%-to-35% of the water currently they use d in farming, reducing water cost for irrigation . On the others ide, the use of solar pumping on farms would require new " Solar irrigation Culture".Solar pumps operate everyday using the free solar fuel . It may potentially lead to pump more water at no extra cost with is free fuel. SPI addresses this problem in its smart pumping advisory tools using new metrics for water efficiency solar irrigation.

The purpose of this article is to familiarize readers with the Solar -VFD solar pumping technology implemented in the SPI systems, elaborate on the water –energy consumption metrics to use solar pumping in irrigation, discuss economic impacts of using solar pumpingin irrigation and define associated water –energy cost saving with the clean energy pumping - a promising direction to supply the state with needed clean extra energy and better use of water sources for continuous growth of the Agri-economy growth of the state even in draught conditions.

2. The Solar–VFD Technology for Solar Pumping

VFD (Variable Frequency Drives) have been widely used for decades in industrial pumping as energy optimizer and pump controllers to manage the flow rate required for pumping applications. Without VFD, pumps will operate at fixed flow-rate and always will consume maximum power. Advanced VFD systems today also provide advanced pumps protection functions from such external factors as power surge , dry run , over pressure, and they apply soft start and soft shutdown to prevent structural damages to pumps.

SPI uses Solar-VFD technology (S-VFD) and it executes exactly the same functions as conventional industrial VFD with a unique difference –it can operate pumps with Solar instead of AC power. It embeds many new solar technologies dedicated for solar pumping that makes them more energy efficient (20%-40%) than conventional solar inverters when used in pumping applications. They eliminate the double DC-to-AC power conversion, and they use special solar MPPT technology to operate pumps with VFD more efficiently with solar. SPI in fact replaces three systems that are otherwise required if conventional solar inverters used to operate pumps (see the diagram below where SPI replaces three conventional systems : conventional solar inverter , VFD and Pump application controller). . By replacing these three systems, SPI simplifies the operation of solar pumps and provides additional (about 30%) cost efficiency of solar systems in pumping.



SPI eliminates all these systems to operate pumps with solar

One of the distinguishing features of SPI is that it can operate pumps in three power modes , with and without grid power. This feature is specifically important for farms located far away from the grid power. SPI can operate with only solar PV (battery less) , only AC, and a hybrid of Solar and AC. The hybrid mode prolongs solar pumping time by 15%-20% - it uses any solar energy available early morning , and late evening for pumping. Being an industrial pumping system , SPI does not inject power back to the grid, on the contrary, it uses grid power at night time irrigation. SPI uses only optimal solar PV power for required pumping application to operate on daily basis to supply required water volume- no extra power is required, nor it generates extra power that is not used .

SPI can operate all types of Irrigation pumps (deep-wells pumps, positive displacement, Axial, Boosters , Centrifugal , submersible , and large surface water pumping). It is pump type and brand independent and can operate existing pumps without changes to the existing pumping infrastructure. SPI- also provides advanced pump protection functions (about 15 functions) and it embeds pumping application controller that provides smart pumping functions , can be remotely accessed (built-in industrial protocols- such as Modbus and Profinet) to set up pumping parameters, and to transmit pumping data such flow arte , pressure, consumed solar and AC power, water volume, and other valuable parameters to optimize pumping performance for efficient irrigation making it user-friendly "smart pumping" system. It embeds tools-set that advice farmers on required water volume for successful efficient irrigation (described below).

3. Water Efficiency Use in Solar Powered Pumping

Most irrigation designers and pumping engineers use 40-80% more hp margin above the actual operating hp required to pump water on farms. There is a good reason for that : this margin helps farmers to easily control the water volume needed per season schedule (usually pumps are operated about 400h in winter to 1200 h in summer season). The less hours they operate , the less water they pump, the lower energy bill they receive, and vise versa. Switching to operate pumps with solar , farmers can now operate pumps everyday since there is no solar counter to pay as with utility power. Accordingly, solar pumping needs new metric, other than the hour counter that farmers currently follow in practice. For instance, farmers who operate 50 hp pump for 500 hours in winter can use the same pump operated with solar for 1000hat no extra cost . This will lead to overwatering .

The Alternative metric that solar can use is to set the required flow rate and volume per day that is established based on farm corps-type and irrigated area. to guide farmers to avoid both over and down-watering . Solar power (KW PV)for pumps must be designed following the required operating pumping hp to provide the required flow-rate and volume. The operating horse power (hp) and the required solar power (in KW PV)- are selected based on the required flow rate (Q) in (GPM- Gallon Per Minute) , and the required pressure (psi) for sprinkler boosters, or well head (H in feet) for ground water pumping. The flow-rate is determined based on the land area and crops type. For instance, Avocado trees usually require about 2-3 AF per 1Acre per year (average 20 GPD per tree)[(4)]. This translates into solar pumping at flow rate about Q= 4-6 GPM to supply the required 2-3 AF/A (solar pumps average 5 hours in winter, 10 hours in summer, and on daily -basis 8 hour yearly average). This metric can be used by solar pumps to provide easy to implement and easy to follow metric. For example, by using 2AF/A (4GPM flow rate metric), a 50 Acres Avocado farm would require 200 GPM flow rate, and if the source, for instance, is ground water at 350' pumping head, then the required pumping operating hp can be easily determined and its about 24 hp. The required solar power will be only 24 KW PV (this gives margin of 35% to increase /decrease flow rate for winter / summer seasons).

An observations made in San Diego North County have shown that farmers use 50 HP for the above 50 Acre farm area with an average 1500 operating hours per year that supplies about 4AF/A , or 33% more water than the required norm for Avocado. If the same 50hp pump is operated with 24 KW solar system (at 200GPM) it will supply 2AF/A the optimal mode with 50% efficient water use , and at 300GPM to supply 3AF/A would require 36 KW (33% more efficient use of water in irrigation).

Solar pumps are easy to operate and to use on farms with the defined above flow-rate / volume metrics for solar pumping. Little needed to be changed during the season with offered flexibility to increase or decrease the flow-rate as per weather conditions. Solar pumps will naturally supply about 3 time more water in summer than in winter season, which meet the usual irrigation norm of water volume difference per season.

SPI implements exactly the above metrics in its smart pumping operation. It assist farmers to:

1. Setting flow-rate norm based on Irrigated-land– Corps type .
2. Allows to change flow rate between summer-and winter seasons if required.
3. Setting required volume per day .
4. Advice on Down-Watering in cloudy day to use Hybrid mode (in fact it allows to switch automatically to hybrid mode to reach the required volume).
5. Assist to avoid over-watering (when it exceeds the set volume- and can be also set to halt pumping when the required volume is reached).
6. Generate reports on total water volume per day, per week, per season , per year (It has built-in flow and volume meters).
7. Assist in avoiding continuous well water level drop in by detecting partial dry-run conditions and advising farmers to reduce current flow rate ,
   And many other options that makes pumping control easier and irrigation more rationalized.

SPI can be very useful to rationalize the water use in irrigation by 15-to-40%, and there is a room to achieve this goal on California farms with this smart pumping system. The data compiled by US interior department and USGS in 2010 [(5)] on irrigation water volume use per Acre (in AF/A) in CA is 2.5 AF/A (see the table below) , is about 30%-48% higher than other southern states (1.29 in TX and 1.64 in FL).

State	Irrigated in thousands Acres			Water Withdrawal (mgpd)			Av. Rate AF/Acre
	Sprinkler	Micro-Irr.	Surface Irr.	Ground	Surface	Total	
California	1790	2,890	5,670	8,690	14,400	23,100	2.50
Florida	584	712	731	1,580	1.34	2,920	1.64
Texas	3770	244	1910	5,100	1730	6,830	1.29
USA							2.07

With the wide use of SPI on CA, farmers can now benefit from reduction both pumping power and water cost. The lower pumping power cost will also stimulated wider use of micro-irrigation. SPI can assist in achieving about 20%-30% higher rationalization of water use in irrigation (for instance reducing the current 2.5 to 2 AF/A which is translated into saving about 7 million AF per year of the current 36 million AF used in irrigation in CA)[(5)].

4. THE Economic Impact of Solar Pumping Irrigation

Energy cost constitutes about 25% - to-35% of farming cost , and about 50% of total farming operating cost [3]. Accordingly, a decrease of energy cost by 40%, for example, will reduce farming operation cost by 25%. To evaluate the immediate economic impact of using SPI solar pumping in CA, one can evaluate the cost of irrigation pumping from various resources (ground -water pumping, sprinkler pumping, district irrigation water pumping, and water transportation pumping). The table below compares the energy cost of supplying 1 acre-foot (A/F) (about 325,000 gallons -1233 m3) for irrigation from these various sources with the use conventional energy (utility power) , and the use of SPI Solar Pumping cost established per 15 years solar operation.

Water Source	**A/F Approx. Power Consumption (KWh)**	**A/F Cost with Convent. Grid power (₵17 KWh)***	**A/F Cost with SPI solar Energy (₵8 KWh)**
On-Farm Ground water pumping at 500' well-head (including dripping pressure)	450	$76.50	$36
On-Farm booster Pumping at 45psi for sprinklers	180	$30.50	$14
District surface water Pumping at 5 bar	210	$35.70	$16
Surface Water transportation for 100 miles	250	$42.50	$20

* The utility cost is not fixed as with SPI for 15 years . Utility cost is an average for next 15 years . With draught hardening the lower cost hydraulic power generation can be increased dramatically [Z pacific report]

In order to draw a wider picture for the economic impact of switching to widely use SPI solar pumping on farms to operate 33% of its pumps by 2020 with solar (the state is set to meet the 33% renewable power by 2020[6]) , the sate will offer about 3,417 ,000 MW extra power , and farmers can save about $13 billion USD (see the table below). If the smart pumping can contribute to reach 2AF/A norm (20% irrigation water rationalization) , both famers and the state can

Water-Power Metrics	Irrigation District Pumping		On- Farm Irrigation Pumping		Total /Year	% total State
	Surface Water	Ground Water	Surface Boosters	Ground Water		
AF/ Year	23,410,700	734,200	11,700	12,085,400	36,230,300	70%
KWh/year	821,800	246,000	4, 079,000	5,209,000	10,355,800	8%
KWh @ 33 % Solar pumping	271,194	81,180	1,346,070	1,718,970	3,417,414	33%
Power cost Saving over 15 years (billion $USD)	$1,069	$0.32	$5,306	$6,776	$13,471	52%
Water saving Per year at 2AF/A (20% rationalization)	4,682,140	146,840	2,340	2,417,080	7,246,060	20%

5. Future Vision on Solar Pumping for Irrigation

The emerging S-VFD technology and on its base the SPI solar pumping systems for irrigation can pave the road for wide deployment of low cost clean-energy operated pumps at farms that can meet the rigid high standard environmental regulation in the State , and increase the renewable portion of energy in irrigation. The S-VFD pumping technology will assist farmers operators, and the state in achieving these two ambitious goals by supplying durable and very valuable low cost energy and water resources for continuous growth of the state Agri-economy even in draught conditions with clean power. This goal can be achieved by using both renewable energy and smart pumping systems . New practices and norms as pumping metrics would required extra effort on farms. its achievement is feasible since farmers will tremendously benefit from the solar pumping technology.

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