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A new pump selection method for large-power PV irrigation systems at a variable frequency

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ABSTRACT

This paper presents a new method for selecting a pump for large-power PV irrigation systems working at a variable frequency. This can have a significant impact since the traditional way of selecting the pump is based on maximizing the efficiency of pump in the duty point at a certain single operating frequency, which is not useful for PV irrigation systems working at a variable frequency. The proposed method starts by considering the pumps with H-Q curves with a high slope and the duty point in the right-hand third of the curve to assure a wide range of operating frequencies. Then, the efficiency within the whole range of frequencies is evaluated. An example of a performance comparison between the pumps selected with the new and traditional methods has been carried out. Results show that by using the new method, the yearly volume of water pumped increases by 7.2–21.0% and the pump efficiency by 4.3–5.3%. Finally, it is important to mention that the proposed method has already been implemented in the SISIFO tool, able to simulate PV irrigation systems.

1. Introduction

The market for large power photovoltaic (PV) irrigation systems (from 40 kWp to 1 MWp) is growing [1–8] mainly because technical and economical barriers [9] have been removed. Technical solutions for solving the problems associated with PV-power intermittences have been developed without using batteries, taking advantage of the energy regeneration of the pumps [10]. Furthermore, the use of North-South horizontal axis solar trackers, that provide a constant daily profile of PV power, allows a better matching with the dynamic of the well [11–13]. Finally, the decrease in the cost of the PV module [14], the exclusion of batteries and the increase in the price of conventional electricity [15,16] makes this solution more competitive [17–20] with some real-scale experiences showing cost savings of 80% [7,21].

Many authors have given much attention to the design [22–26], sizing [27–31], and optimization [23,28] of PV irrigation systems. There are also some specific works regarding the modelling of the motor-pump subsystem [32–34].

These systems are basically made up of a PV generator, a frequency converter and a standard centrifugal pump [35]. Water is elevated to a water pool using the pump. The frequency of the pump and, therefore, the water flow into the pool, is variable and depends on the instantaneous PV-power available. The higher this PV power, the higher the frequency and, consequently, the water flow. This is the main difference with the traditional irrigation systems supplied by the grid or diesel generators that usually work in the same duty point, providing constant water flow [36].

So, the traditional way of selecting the appropriate pump is just to look for the pump that shows the highest efficiency just at this duty point (usually at 50 or 60 Hz) [37]. The objective of the pump selection procedure is to maximize the efficiency, i.e. that the duty point and the point of maximum efficiency are as close as possible. In fact, professional irrigator communities, in their maintenance tasks, periodically extract the pump from the well after a certain number of hours of operation and refurbish the impellers and/or diffusers or replace them with new ones, in order to increase the efficiency at the duty point even if this means reducing efficiency at other working points that are not used.

However, this usual way of selecting is not valid for PV irrigation systems because they work at different frequencies and therefore at different working points.

This paper proposes a new way of selecting a pump suitable for PV irrigation applications at a variable frequency that is based on considering not only the efficiency at the maximum operating frequency but in the whole range of operating frequencies. This new method also allows considering pumps that widen the range of operating frequencies

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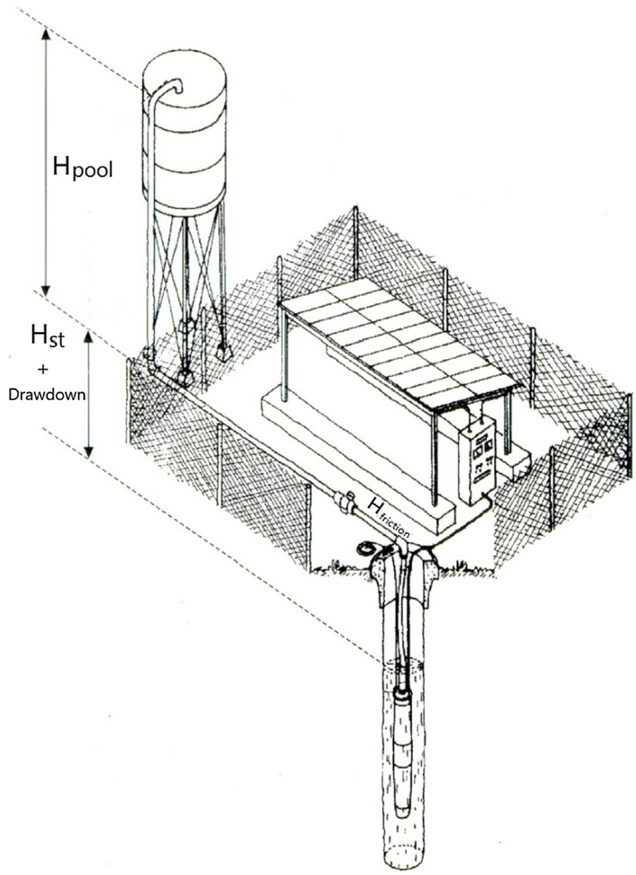

Fig. 1. PV pumping system from a well to a water tank. The figure illustrates the static head (H_{st}), the drawdown and the head of the water tank, (H_{pool}). The total manometric head is the addition of H_{st}, drawdown, H_{pool} plus the friction losses.

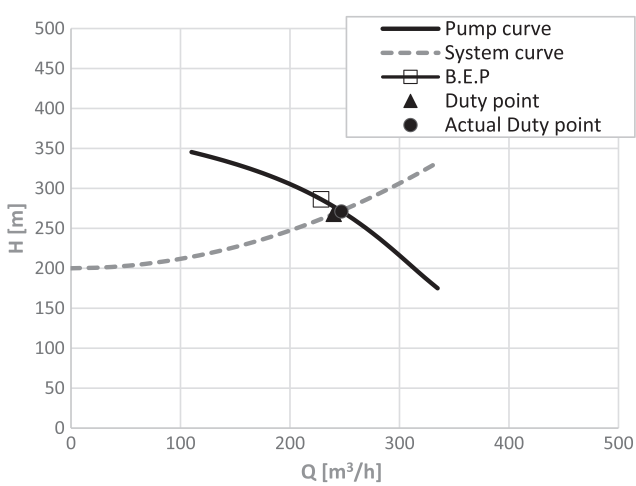

Fig.2. System curve, H-Q pump curve and characteristic points to select a pump.

and, therefore, enlarge the daily number of hours of irrigation and increase the volume of water pumped during low irradiation periods.

As it influences the performance of the system, this paper not only describes the new method but also shows how it affects the final performance. For this, the yearly water pumped by two pumps selected with the traditional method and with the new method proposed here has been simulated for three locations with different climatic conditions, showing the improvement in the performance associated to this

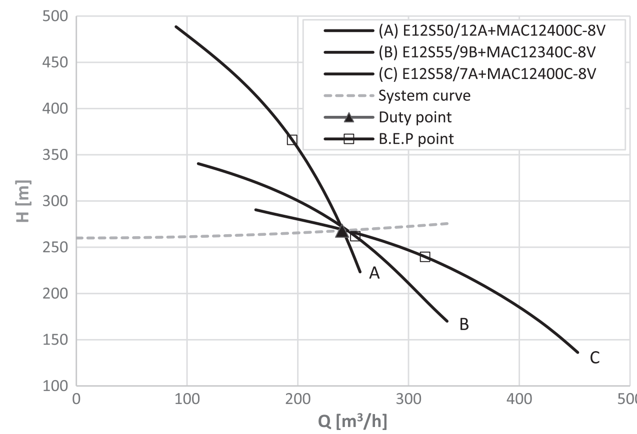

Fig.3. Three possible pumps for a certain duty point. Pump A has its BEP too far to the left in respect to the duty point; Pump C has its BEP too far to the right in respect to the duty point. Pump B has the BEP close to the duty point and the pump would be the selected according to the traditional pump selection method.

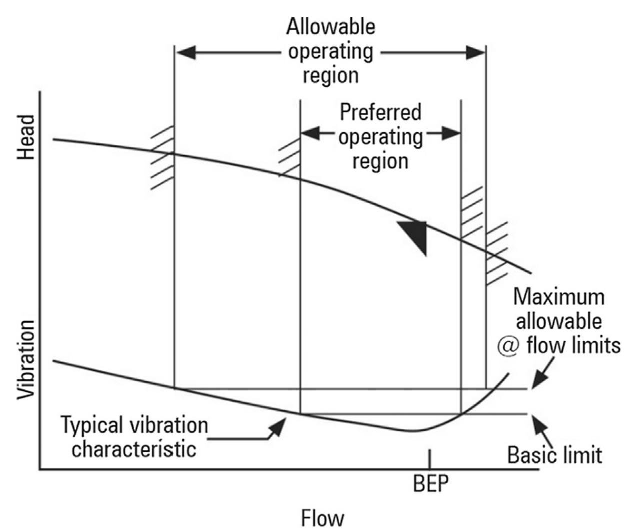

Fig.4. Preferred operating region to bring about the lowest energy and maintenance cost and to reduce the risk of system problems since hydraulic excitation forces and cavitation risk attain a minimum close to the BEP [38].

new pump selection method.

The impact of the way of selecting a pump on the performance of the system is shown for PV irrigation systems pumping into a water pool but it can also be applied to direct pumping to the irrigation network, which usually is carried out with sprinklers, pivots or drip systems. Direct pumping requires constant pressure and water flow which also means constant power. But the reality is that one single irrigation network includes several sectors with different values of constant pressure and water flow. So, different powers are needed but, in this case, it does not depend on the instantaneous PV-power available but on the sector being irrigated. In any case, the pump must also work at different frequencies and working-points.

This new method has been implemented in SISIFO (www.sisifo.info), a simulation tool developed within the framework of a real-scale demonstration project of large-power irrigation systems [21]. The implementation of this method in this tool is also shown.

2. The traditional pump selection method

The following items need to be taken into account to select the appropriate pump for an irrigation system: