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On the Performance and Tuning of Large-Power Pv Irrigation Systems that Stand Alone

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Introduction

A recent development is the installation of large-power PV irrigation systems that do not require batteries. This indicates that their design is still in its infancy and that there is no experimental evidence to support their performance. This paper makes a contribution to both the knowledge of experimental performance data for these kinds of systems and the systematic tuning of their control. Based on the application of the Approximate M-constrained Integral Gain Optimisation (AMIGO) design rules to the frequency response tuning method, a systematic Proportional, Integral, and Derivative (PID) control tuning method for frequency converters is proposed and applied to two PV irrigation systems in Villena and Aldeanueva de Ebro, Spain, that had a "conservative" tuning through an experimental trial and error method. The experimental performance of both systems has been evaluated from 2017 to 2021 to assess the goodness of this systematic tuning. Both the system's robustness to PV power fluctuations (the "Number of abrupt stops" and the "Passing-cloud resistance ratio") and performance (by factoring the conventional Performance Ratio (PR) to determine the influence of various factors external to the system) have been evaluated using new indices. According to the findings, the proportion of PV irrigation systems with abrupt stops decreases from 40% and 39.8% prior to systematic tuning to 7.3% and 1.3% after tuning; The PR goes from 61.4% and 60% to 65.7% and 64.7%, and the passing cloud ratio goes from 65% and 79.9% to 97.9% and 99.8%.

Description

Due to rising energy costs in modernized agriculture, stand-alone large-power photovoltaic (PV) irrigation systems that do not require batteries are relatively new technology. This kind of system was only available until recently in plug-and-play kits that included an alternating current centrifugal motor pump, a frequency converter (FC), and a PV generator with a maximum power of 40 kWp. Due to the variability of the PV power, it was impossible to guarantee the stability of the FC's control, which led to sudden stops of the FC, which caused water hammer in the hydraulic system and overvoltage's between the FC output and pump motor. Even though new accumulation technologies like those based on phase change materials were able to solve this issue by incorporating batteries, this did not result in an increase in system power [1].

New control algorithms that take advantage of centrifugal motor pumps' ability to regenerate have been developed over the past ten years to address control instabilities and the issues they cause. In addition, trackers with a horizontal north–south axis were incorporated to better adapt PV power profiles to the dynamics of the water sources and to adjust PV production throughout the year to meet irrigation requirements. In order to make it simpler for farmers to adopt the innovation, communication protocols were developed to integrate control of PV irrigation systems and irrigation controllers. Fixed help structures for the PV generator called "delta" were likewise proposed which, because of their east-west direction, additionally produce steady power profiles. In order to demonstrate their technical dependability as well as their economic and environmental viability, these solutions were incorporated into five full-scale demonstrators in real irrigation infrastructures of farmers, irrigation communities, and agro-industries in Spain, Portugal, Italy, and Morocco as part of a European project. However, due to the nature of contemporary technology, its design has not yet reached maturity, and there is no experimental data available to estimate the system's performance.

Regarding the design, the current state of the art for tuning the FC's PID control is based on trial-and-error procedures that must be performed in situ due to the influence of the PV irrigation system's connection to the hydraulic system. PV irrigation systems cannot achieve their best performance through these trial-and-error methods. In PV irrigation systems, the relationship between the control variable (PV generator voltage) and the output variable (pump rotation frequency) is non-linear and dependent on irradiance and temperature, i.e., variable over time. There are no automatic procedures for this tuning because the existing ones are for linear and invariant systems. This issue has been addressed by a few studies that have been published. They were carried out in small laboratory facilities where some of the variables that have a significant impact on the control of large-power PV irrigation systems in their three relevant operating zones could be controlled: operation at constant and high irradiance levels (during the day); the speed with which it responds to sudden changes in irradiance (when clouds pass over the PV generator); and start-up, in which the pump moves from a standstill to the highest frequency possible in a very short amount of time, typically less than two seconds [2-5].

Conclusion

Regarding performance, a number of publications examine PV pumping systems' overall system efficiency. For instance, reports of 5% and 7%, respectively, for diaphragm and helical pump systems; has an optimal water flow rate of 2.7 m^3/h and an overall efficiency of 2.5 percent; reports a best system efficiency of 7% for a 50-meter pumping head at low solar irradiation and 6.6% for an 80-meter pumping head at high solar irradiation, with and without shading, respectively. However, it is important to note that, in contrast to grid-connected PV systems, whose performance is largely determined by the system's quality, PV irrigation systems are affected by external factors, despite the system's high quality: the crop's irrigation period, which is typically shorter than a full year, the characteristics of the irrigation infrastructure to which it is connected (which prevents it from utilizing all of the available radiation, such as by preventing the pump from operating at its nominal frequency) or the irrigator's behaviour The traditional Performance Ratio (PR) has been incorporated into a variety of utilization ratios to calculate performance indices that quantify the impact of these external factors on system performance. However, the experimental performance data that are currently available in the literature do not provide any insight into the anticipated performance of these systems.

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