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Induction Motor Performance Analysis Based On Residential Photovoltaic Water Pumping

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ABSTRACT:Performances of induction–motor-based residential photovoltaic water pump system (IMRPWPS) with low DC voltage input (24V DC) are tested in laboratory under four different operation modes, such as efficiency of DC-AC converter with high-frequency DC-DC stage machin epump and overall system. By analysis of these experiment results, it is discovered that the operation head and voltage frequency ratio of motor (U/f) have significant effect on the performances of IMRPWPS besides the configuration of system components. And the minimum unit water cost may not be reached only by the control strategy of maximum output power of the system. Hence, as for a certain site, the proper selection of characteristics of converter and motorpump and optimal ratio of U/f is significantly important to improve the economic performance of the system.

KEYWORDS: photovoltaic water pump, induction motor, optimal head, voltage- frequency ratio ，unit water volume cost

I.INTRODUCTION

Photovoltaic water pumping systems (PVWPS) are now increasingly demanded in rural districts. PVWPS in practical use now are mostly based on DC motors or DC brushless permanent motors [1]. These motors are specially designed to operate at low DC voltage (say, 24 VDC, 36V DC) from solar array. If the well is deeper, the wire cable that connects motor and controller should be longer too. In that case, great voltage and efficiency drop will be caused.
In addition to The paper is supported by the Grant Project of GEF/WB / NDRC (PRC.) (CG-2005-030) that, DC motors or DC brushless permanent motors above are complicated in manufacture and more expensive. In contrast, regular asynchronous induction motors (RAIM) are much cheaper and easier to manufacture in large quantity. So, for most developing countries, RAIMs may be more economic choice. But RAIMs cannot be used in photovoltaic system directly because they need 380 /220 AC voltage supply. To bridge the gap, a frequency-variable driving power supply (FVDPS) has been developed for the induction–motor-based residential photovoltaic water pump system (IMRPWPS) with low input DC voltage and regular induction motor by authors' group. This paper is aimed at investigating the relationship between system efficiency, unit volume water cost and power size and control strategies by simulation and test in Lab to conclude some important rules to design a higher efficiency IMRPWPS.

Solar energy is the most low cost, competition free, universal source of energy as sun shines throughout. This energy can be converted into useful electrical energy using photovoltaic throughout. This energy can be converted into useful electrical energy using photovoltaic technology. The steady state reduction of price per peak watt and simplicity with which the installed power can be increased by adding panels are attractive features of PV technology Among the many applications of PV energy, pumping is the most promising. In a PV pump storage system, solar energy is stored, when sunlight is available as potential energy in water reservoir and consumed according to demand. There are advantages in avoiding the use of large banks of lead acid batteries, which are heavy and expensive and have one fifth of the lifetime of a PV panel. A number of experimental DC motor driven PV pumps are already in use in several parts of the world, but they suffer from maintenance problems due to the presence of the commutator and brushes. Hence a pumping system based on an induction motor can be an attractive proposal where reliability and maintenance-free operations with less cost are important. The effective operation of Induction motor is based on the choice of suitable converter-inverter system that is fed to Induction Motor. Photovoltaic technology is one of the most promising for distributed low-power electrical generation. The steady reduction of price per peak watt over recent years and the simplicity with which the installed power can be increased by adding panels are some of its attractive promising. In a photovoltaic pump-storage system, solar energy is stored, when sunlight is available, as potential energy in a water reservoir and then consumed according to demand. There are advantages in avoiding the use of large banks of lead-acid batteries, which are heavy and expensive and have one-fifth of the lifetime of a photovoltaic panel .It is important, however, that the absence of batteries does not compromise the efficiency of the end-to-end power conversion chain, from panels to mechanical pump. Photovoltaic panels require specific control techniques to ensure operation at their maximum power point (MPP) .Impedance matching issues mean that photovoltaic arrays may operate more or less efficiently, depending on their series/parallel configuration.

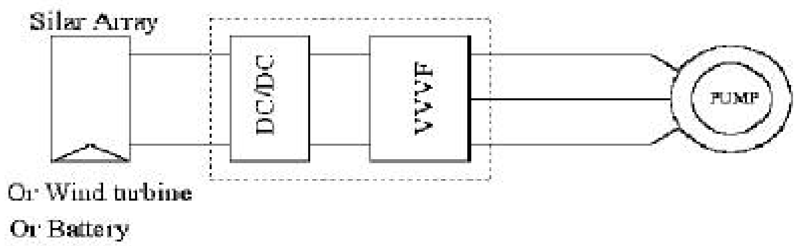

Fig. 1 schematic of the proposed water pumping system

II. SYSTEM CONFIGURATION OF IMRPWPS

The structure of the system proposed here is shown in Fig.1, in which DC-DC unit converts low DC voltage(<48V) to 350V or 520V DC, VVVF unit converts DC voltage to frequency -variable high AC voltage(say, 380/220 VAC) by using SVPWM DC-AC converting technology. In DCAC converter, ASIPM and MR16 chip are used. Both DC-DC converter and DC-AC converter forms the FVDPS.According to the design above, a prototype is made, inwhich the rated parameters are as follows: 1) Voltage: 220VAC. 2) Current 4.1A. 3) Frequency: 50Hz. 4) Power 750W. 5) Motor speed 2800 r/min. 6) Input DC Voltage:
To validate and analyze performances of the IMRPWPS, an experiment system is designed shown as in Fig.2. where 52V DC voltage in series with an adjustable resistor is used to simulate the power output of solar array varying with insolation and environment temperature. The system configuration parameters as follows:
Input DC voltage : 48 V DC
Output AC voltage : 0-220V AC,50HZ, three phases

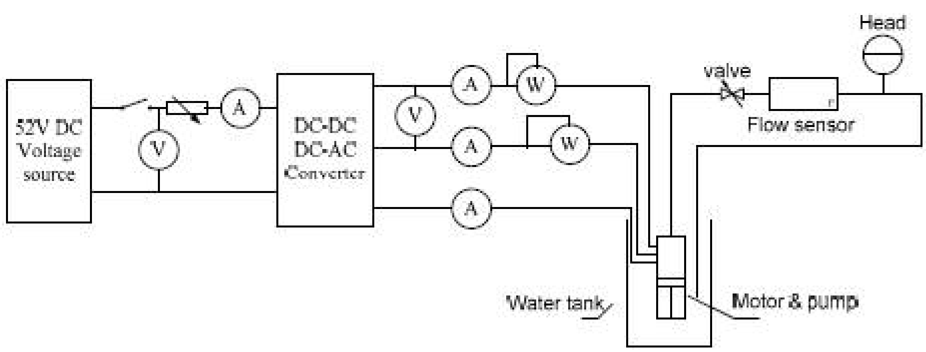

Fig.2 Experiment system for IMRPWPS

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III. PERFORMANCE TEST AND ANALYSIS

The relationship of head vs flow rate at different frequency is shown in Fig.3. It can be observed that at a certain frequency, flow rate will be doomed to decline if head is increased. And when the frequency increases, that is, input power increases, the whole characteristics will shift up. This means that the operation points of motor-pump cover very wide ranges. The following test will be carried out under four different operation modes.

This test conditions are to keep the input DC power constant and change the head and flow by adjusting the valve of the pipeline. The tested results of ηc, ηm and ηs vs head are shown from Fig.4 to Fig.7, corresponding to the DC input power 1220W, 815W, 600W and 400W respectively. From the data above, some results can be concluded as follows:

1) If the input DC power is kept constant, the efficiency ηc , ηm , ηs will reach a maximum value respectively when the characteristic of the pipeline is changed. This shows that only the system is designed such that the maximum points of ηc and , ηm are coincided can the whole system efficiency reach maximum power point.

2) At a certain DC input power, that is, a certain insolation and capacity of solar array, there is an optimal head that leads ηm to reach an optimal value. For the proposed IMRPWPS, when the motor operate about rated power, the maximum system efficiency happens at head 36m, far from its maximum head 48m and minimum head 26m. When the operation point of motor shifts from its rated power point, the maximum system efficiency happens around maximum head point, but around head 15m when the input DC power drops to 400W.

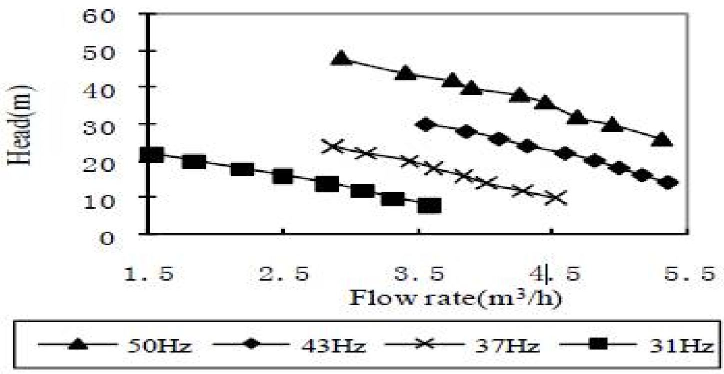

Fig 3. Head vs flow rate at different frequency

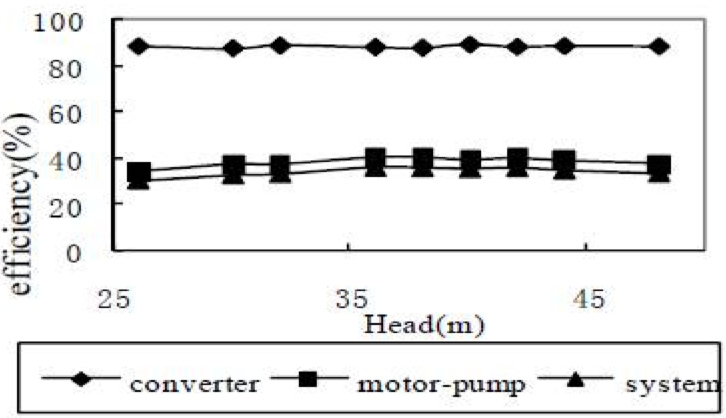

Fig.4 converter, motor-pump and system efficiency vs head with 1220W DC input power

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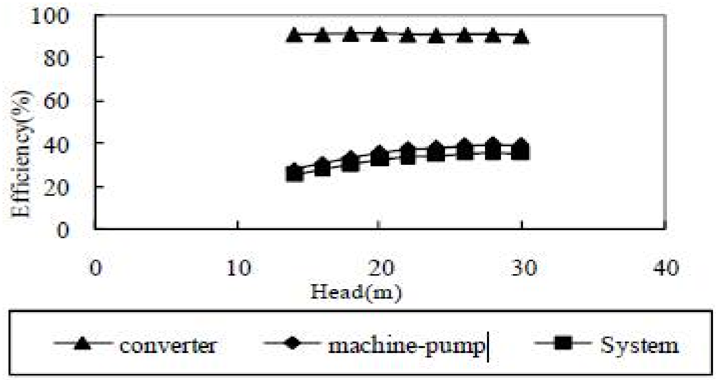

Fig.5 converter, motor-pump and system efficiency vs head at 815W DC input power

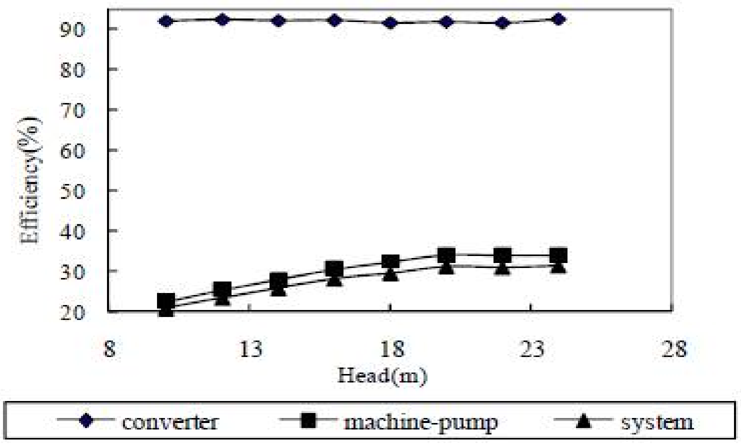

Fig.6 converter, machine-pump and system efficiency vs head at 600 W DC input power

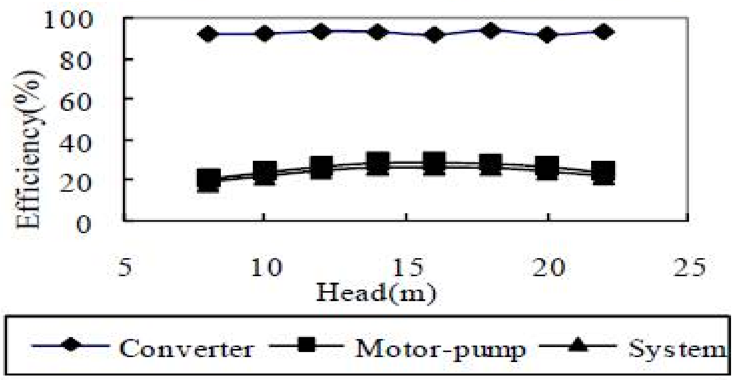

Fig.7 converter, machine-pump and system efficiency vs head at400 W DC input power

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IV. SIMULATION OF UNIT VOLNUME WATER COST

To further observe the effect of configuration and head on economic performance of IMRPWPS, by the simulation software and test results of system efficiency, the unit volume water cost *Cu* is calculated at different size of solar array and different heads shown in Fig.8. It shows that *Cu* may be reduced when the power of solar array is increased under a certain range. However the *Cu* at low heads may be increased. This shows the optimal configuration is closely related to the characteristic of motor-pump and operation points of the whole system.

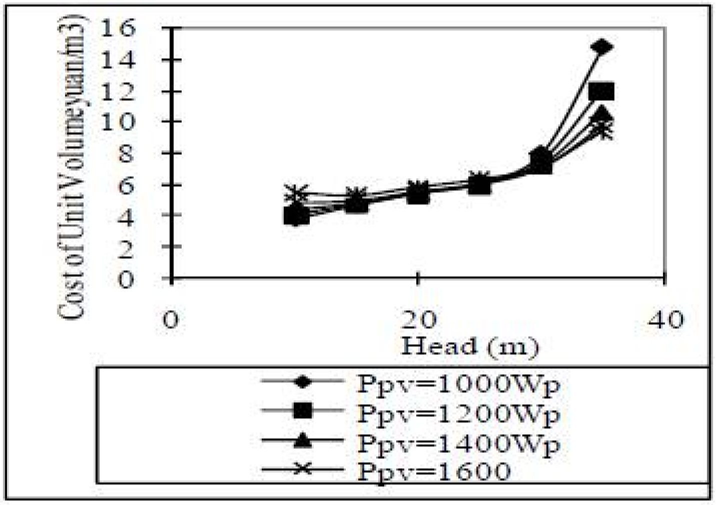

Fig.8 the unit volume water cost vs head at different PV array size

V. PV CELL

When photons of light strike the material, however, some normally non-mobile electrons in the material absorb the photons, and become mobile by virtue of their increased energy mobile electrons. Because of the "built in" electric field, the new mobile electrons in the n-materia cannot cross over into the p-material. In fact, if they are created near or in the junction where the electric field exists, they are pushed by the field towards the upper surface of the n-material. If a wire is connected from the n-material to the p-material, however, they can n-material. flow through the wire, and deliver their energy to a load On the other hand, the holes created in the n-material, which are positively charged, are pushed over into the p-material. In fact, what is really happening here is that an electron from the p-material, which was also made mobile by the adsorption of a photon, is pushed by the electric field across the junction and into the n-material to fill the newly created hole.

VI.RELATED WORK

1. N.K.Jain I.P.Singh proposed that PV (photovoltaic) water pumping system had been becoming increasingly important in remote, isolated, and non-electrified population, where either accessibility to the grid was difficult to establish or implementation cost is indeed very high. In such location, PV water pumping application is significant area of interest for sustainable development.
2. S.S. Chandel, M. Nagaraju Naik, Rahul Chandel proposed that The deficit in electricity and high diesel costs affected the pumping requirements of community water supplied and irrigation; so using solar energy for water pumping was a promising alternative to conventional electricity and diesel based pumping systems. Solar water pumping is based on photovoltaic (PV) technology that converts solar energy into electrical energy to run a DC or AC motor based water pump. The main objective of the study is to present a comprehensive literature review of solar pumping technology, evaluate the economic viability, identify

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research gaps and impediments in the widespread propagation of solar water pumping systems and technology.

VI.CONCLUSION

From experiment results and analysis above, the conclusions can be reached as follows:

- Higher efficiency range will become narrow. Hence, the size of solar array and motor-pump should be optimized according to the insolation distribution and the system characteristic of one year so that unit volume water cost can be minimized.
- The optimization of ratio U/f will also improve the performance of the system.

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