CHAPTER 2

LITERATURE REVIEW

2.1 Comparative Study of Direct Coupled and Battery Connected Photovoltaic Water Pumping Systems

Mr. Roongrojana Songprakorp, KMITT (1996) This thesis adopted the PV water pumping design methodology developed by L.Rosenblum to size a direct-coupled (DC) and a battery connected (BC) pumping systems constructed under this research project for techno-economic assessment. A unit, installed at KMITT, was designed to deliver water at 13 m^3/day and 7-m head, and could be configured to operate in either a direct-coupled mode or a battery connected mode. The designed unit would consist of one 282 Wp (1.94 m^2) PV array, a 3.2 kWh battery unit, 10 m of 40-mm ∅ water pipes. Research work consisted of testing of subsystems i.e. motor-pump and battery, instantaneous and daily performances of systems.

It is found that the overall efficiency of the direct coupling system depends on the radiation intensity at a low cell temperature, less than 40 °C, whereas that of the battery-connected system the radiation intensity as well as the state of the battery is determining factors. Being in a discharged state the system efficiency exhibited more dependence on radiation intensity than in a charging state. It is concluded that the battery-connected PV water pumping system has better performance than the direct coupling system. Battery connected systems are feasible technically and economically.

2.2 PV water pumping direct coupling with AC motor

Withaya Yoonsawat and Panu Kaeoklum (1996) This research is a study of the series type solar cell pump system that is connected to an AC motor and 25 millimeter water pipe. This series type pump and the AC motor are a complete, fixed set; Specifications:

Motor: HITACHI PUMP model C – S 2511A/220V/2.59 A/520–570 W maximum head level = 30 meters.

Solar panel: ARCO solar/model 16 – 2000/49.5 W.

Testing of this system was by connecting it to 14, 15 and 16 modules in order to pump water from a ground – level source to a container that has a six meter head level.

Detail of per – hour testing results are as follows:

1. connected to 14 module

Maximum voltage	=	231	V
Maximum current	=	3	A
Approximate Solar Intensity	=	380	W/m^2

Maximum water volume	=	3060	l/hr

2. connected to 15 module

Maximum voltage	=	247.5	V
Maximum current	=	3	A
Approximate Solar Intensity	=	376	W/m^2
Maximum water volume	=	3720	l/hr

3. connected to 16 module

Maximum voltage	=	264	V
Maximum current	=	3	A
Approximate Solar Intensity	=	370	W/m^2
Maximum water volume	=	3900	l/hr

It can be concluded that the solar intensity and the current are proportionally related.

2.3 Modeling System for the Efficiency of Solar-Pumping

Weerayout Limtragool (1992) The purpose of this project is to study the efficiency of water pump by using solar cells. The solar module, which was used in this experiment, belonged to SOLARTRON CO., Ltd. model M75. This model is able produce electric power of about 47 Watts per module. In this study, seven modules and a water pump were used. Current and voltage of the array of solar modules were measured every thirty minuets from 10:00-15.30 o'clock; the data was collected from January 15-February 15, 1993.

The results of this research showed that each module of the seven solar modules which were connected parallel was able to produce a voltage of about 16 volts and circuit current was about 22.89 amperes. When the circuit was loaded by the pumping system, the current remained 5 amperes. The efficiency of the system was 0.4 % and the minimum solar radiation was 555.4 W / m^2.

2.4 PV water Pumping

Jeff Kenna and Bill Gillett (1985) Solar pumping system performance evaluation can be made for a system that has already been installed by observing the actual output. Such evaluations are important to verify the appropriateness of the design and to improve knowledge of the behavior of solar pumping systems in the field. The following data and instrumentation are needed: daily total solar irradiation on the plane of the PV array, daily electrical output of the PV array, daily volume of water pumped and daily electrical input to the motor and pump.

A comparison between the daily total solar irradiation on the plane of the PV array with the daily electrical energy output enables one to determine the efficiency of the PV array subsystem. A comparison between the electrical output and the daily hydraulic energy (from the daily volume of water pumped multiplied by total head) enables one to determine the efficiency of the motor and pump subsystem. The efficiency of the whole system is the product of these two subsystem efficiencies.

From the performance of some commercially available products it can be seen that solar pumps are available to pump from anywhere in the range of 1.5 m to 200 m head and with output of up to 250 m^3/day. Solar pumping technology continues to improve. In the early 1980s the typical solar energy to hydraulic (pumped water) energy efficiency was around two percent with the photovoltaic array being six to eight percent efficient and the motor pump set typically 25 percent efficient. Today, an efficient solar pump has an average daily solar energy to hydraulic efficiency of more than four percent. Photovoltaic modules of the single crystalline type now have efficiencies more than 15 percent and motor that is more efficient and pump sets are available. A good subsystem (that is the motor, pump and any power conditioning) should have an average daily energy through put efficiency of at least 30% or ideally more than 40%.

2.5 Irrigation system

Jeff Kenna and Bill Gillett (1985) water for irrigation purposes is characterized by a large variation from month to month for water required. This may peak at around 100 m^3/day. hectare in some months and drop to zero in others. Generally it is not economic to lift water for irrigation through very high heads because increasing the lift increases the cost, and the cost of supplying water for irrigation should not be more than the value of the additional crop that can be grown.

Most developing country farms have areas in the range 0.5 to 2 hectares, which with typical water requirements of 20 to 80 m^3/day per hectare and pumping heads of 5 to 10 metes, give daily hydraulic energy requirements in the range of 1 to 8 MJ (0.28 to 2.2 kWh) per hectare. If the water in provided over an eight-hour pumping period, the average hydraulic power requirement is in the range 35 to 280 watts per hectare.

Irrigation water requirements are normally specified in mm. 1 mm is equivalent to 10 m^3 per hectare. Also the irrigation season is generally only part of the year, so the average irrigation water requirement will be somewhat lower than the actual daily use. The average is simply a measure of the annual requirement and together with the peak water requirement gives an estimate of the variability of water demand. -The volume of water pumped will be considerably higher than the water requirement of the crop that must be estimated because of distribution losses.

2.6 Dynamic system – Head loss

Barbara A. Hauser (1991) In a dynamic water system, where water is flowing, the piezometric surface varies. The hydraulic grade line (HGL) slopes downward along the length of pipe, showing a loss of pressure energy. The difference between the level of the hydraulic grade line in the static system, and that in the dynamic system, at any one point, is the amount of pressure lost because of friction in the pipe. This is referred to as head loss, and is an important factor. A water utility must account for these pressure losses in order to provide adequate pressure service throughout the system when designing the water supply system.

To make it more convenient, we can use pressure gages instead piezometers for pressure measurement.

The head when water flows in a pipe from the tank above the ground consists of pressure head, elevation head and velocity head. Pressure head is depth of water in the tank. Elevation head is difference between bottom of the tank and ground level. Velocity head is head given by the velocity of water flow in the pipe.

2.7 Experience from the previous works

Most PV water pumping systems reports studied some part of the system or tested in the lab at different conditions by lab instruments. But, few reports on the real system of PV water pumping system which is intended for providing water for domestic use. In these systems, water is pumped from ground water sources or ponds and is stored in tanks near the center of a village. Beside this storage, the system usually consist of a PV array, an inverter and the motor / pump unit.

There were a few papers that test in normal operation of the system. But, most papers that test in normal operation were a short-term analysis. So, the objective of this study is to determine the appropriateness of the system under typical working conditions and its technical performance as a model of all systems installed. The data acquired will also be a base to determine future improvements and developments for PV pumping application in Thailand.