Chapter 4

System description and sprinkler system design

4.1. Photovoltaic (PV) water pumping system

The photovolatic-power DC water pumping system for Photovoltaic application demonstration that are installed at SERT (June, 1999), consists of a PV array, control unit, motor and pump set, water source, delivery pipe and storage tank (figure 9). The operating design of this system is to pump water from a well to storage in the tank that is mounted above the ground. An overflow pipe is used to prevent water from overflowing out of the tank and this pipe returns the excess water to the well.

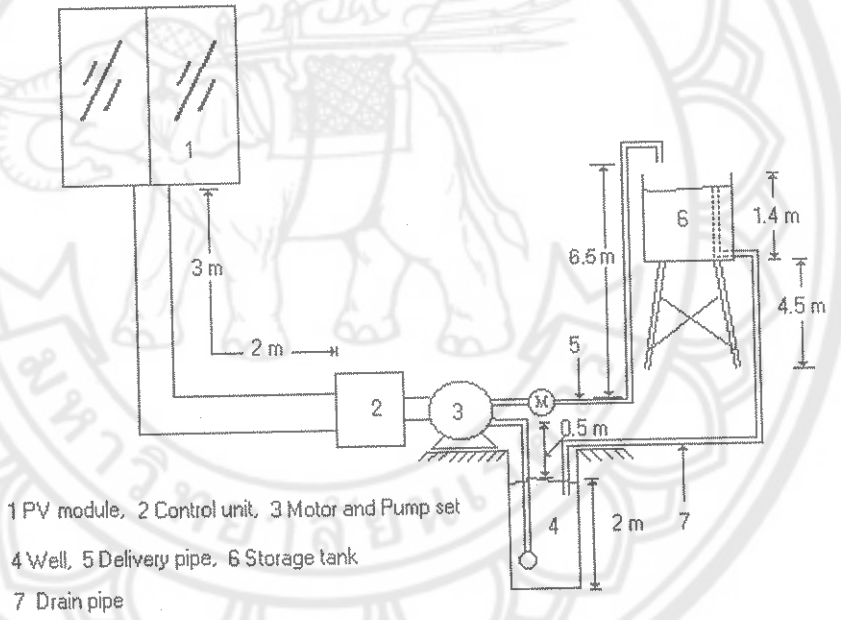


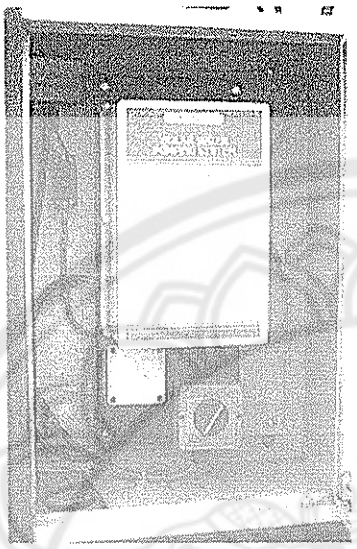
Figure 9. Diagram of PV pumping system at SERT

Photovoltaic array

The photovolatic array consists of 2 modules of the single crystalline type, model M75, power rating 75 Wp per module, connected together in series and mounted on a supporting structure with a module tilt of 15° facing to the south to optimize the solar energy reception.. The distance from the PV array to the motor is 5 m.

Control unit

The control unit box consists of 2 circuit breakers and a MPPT box with a capacity of 800w.



MPPT: the MPPT (Maximum Power Point Tracker) is a type of converter, which automatically controls the output of the solar array to maximize the watts produced which in turn does the work in powering the motor which drives the pump. The MPPT optimizes the output of the solar pumping system, increases the output from the pump over 50 % relative to the case without it. It constantly monitors the power output from the array and controls its voltage at a relatively constant current level. The MPPT then translates the available power to a relatively constant current required by the motor with the voltage varying (and hence pump speed) accordingly to sunlight levels.

Figure 10. Control box consists of circuit breaker and MPPT

Electric motors and water pumps

The electric motor in this system is a brushed permanent magnet DC motor driving a mono pump via a V-belt. This motor is rated for 180 V DC and 3.7 A DC with a motor power rating of 600 W and rotational speed of 1760 rpm. The size of the pipe diameter for water inlet and outlet of pump is 40 mm, then the size of outlet pipe is reduced to 25 mm before the entrance to the flow meter.

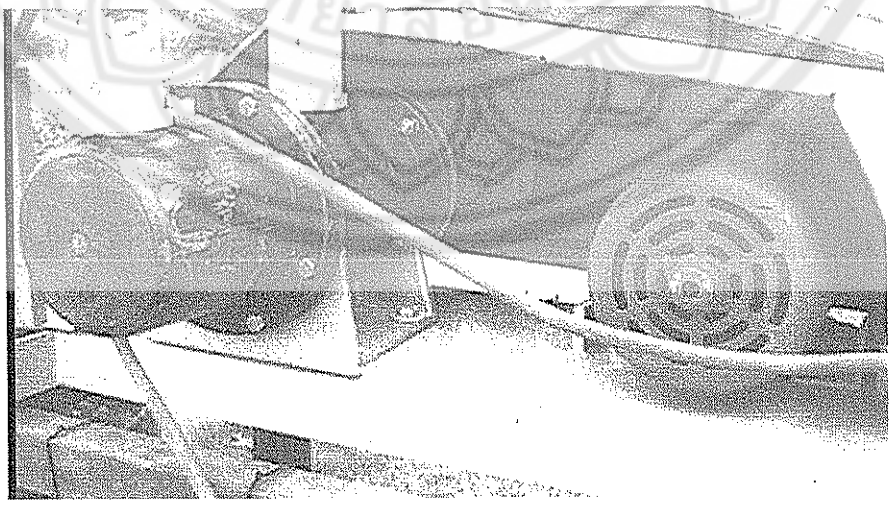


Figure 11. Motor and pump set

Water source

The water source is concrete cistern, which has a diameter of 0.8m and water is kept at a 2 m depth through a float valve connected to the water supply having a 25 liter/min flow rate. This cistern is 2m from the tank.

Storage tank

The capacity of storage tank is 1.4 m^3. The plastic, spherical tank is mounted on a steel structure with a height of 4.5 m.

Figure 12. Storage tank set

4.2. Sprinkler system design

4.2.1. Design constrains

The sprinkler irrigation system design is for supplying water in the general case of a crop with a 5 liter/m^2.day water demand. The area irrigated is 1200 m^2 (30 m x 40 m), and the field is in a flat area.

The total head of this system is 5.9 m considering dynamic head plus static head (figure 4, and figure 9). In real operation, the pressure head is typically less

because the tank is not generally full. In this design, the total head that is used to operate the distribution system is 5 m.

The design uses a single nozzle, rotating sprinkler type, with 1.16 m^3/hr of rated discharge and 18 m of wetted diameter at 10 m of head. But for this system, the head available to operate the sprinkler is less than 5 m caused by losses in the delivery and main pipes. The discharge rate and wetted diameter are therefore reduced.

4.2.2. Size of system

Arrangement of sprinkler grid

The system is constrained to 30m x 40m of area to irrigate with the wetted radius of each sprinkler about 4m and ignoring effects from wind. The sprinkler pattern is a rectangular grid, with 6m of sprinkler spacing along the lateral and 5m of sprinkler spacing along the main pipe. There are seven sprinklers in a lateral and the grid consists of six laterals making the total sprinkler use in this grid 42 sprinklers (figure 13).

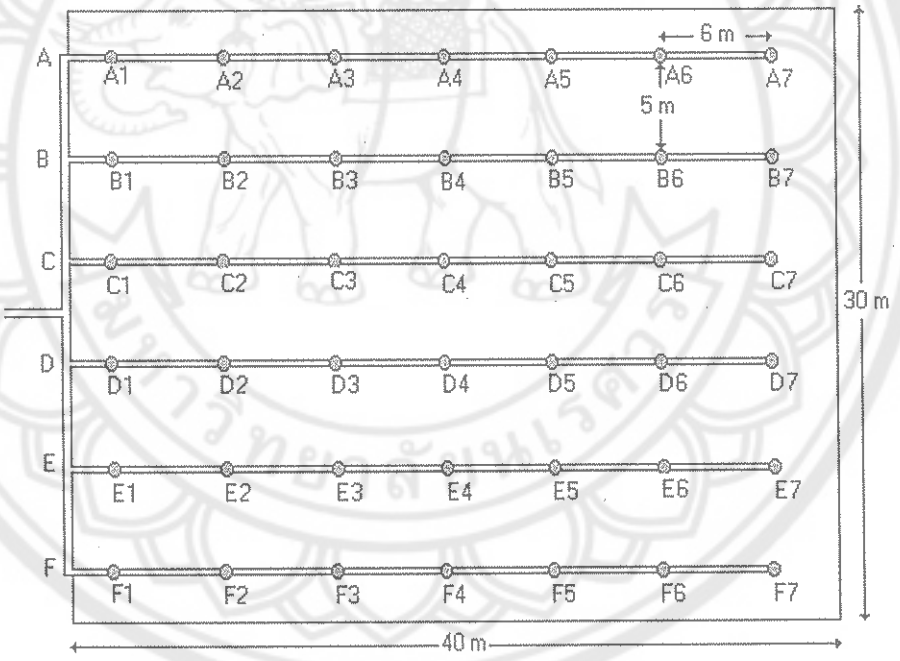


Figure 13. Arrangement sprinkler grid

Size of laterals and main

Laterals and mains should provide the required rate of flow with a reasonable head loss. For laterals the sections at the distant end of the line have less water to carry and may therefore be smaller.

The diameter of the main should be adequate to supply the laterals in each of their positions. The rate of flow required for each lateral may be determined by the

total capacity of the sprinklers on the lateral. The position of the laterals that gives the highest friction loss in the main should be used for design purposes. Allowable friction loss in the main varies with the cost of power and the price differential between deferent diameters of pipe. The design capacity for sprinklers on a lateral with uniform spacing should be based on the average operating pressure.

The flow rate from the water pumping system varied from 16 liter/min to 19 liter/min during the period from 10.00 to 14.00 (appendix B). That means the maximum flow rate of the water supply can not be more than 18 liter/min. if the discharge rate of a sprinkler is 6 liter/min, the number of sprinklers operate at the same time can not be more than 3 sprinklers. The pressure also is limited for number of sprinklers in operation. In order to reduce head loss, large diameter of main and lateral pipe should be chosen.

The table below presents the head loss in different sizes of pipe when the water flows though a straight pipe at a flow rate of 18 liter/min and through 43.5 m of pipe length. This comes from the equation:

$$Q = 0.278.C.d^{2.63}.S^{0.54} \tag{4.3}$$

Where Q is water flow rate (m^3/s), C is the flow coefficient that depends on the pipe type, d is pipe diameter (m) and S is slope or hydraulic gradient, given by head loss divided by pipe length. See the detailed calculation in appendix A.

Table 1. Head loss in difference pipe diameter

Flow rate Q (m^3/s)	Pipe diameter d (m)	Slope S	Pipe length L (m)	Head loss H_L (m)
0.0003	0.018	0.094	43.5	4.091
	0.020	0.0563		2.449
	0.025	0.0189		**0.826**

For this design, 0.025 m of pipe diameter was chosen for delivery and the main pipe because head losses were less than 1m (20% of 5 m).

Since the sprinkler must operate with low pressure in order to get good distribution, the 0.025 m pipe diameter was also chosen for lateral pipes.

Sprinkler operating time

The time to supply water to crop can determine by equation as below:

$$T_{sop} = \frac{W_{C.D} A_S}{Q_S} \tag{4.4}$$

Where $W_{C.D}$ is water demand of crop (liter/m^2/day), A_S is wetted area of sprinkler (m^2), Q_S is discharge rate of sprinkler (liter/min).

With crop water demand 5 liter/m^2.day, wetted radius of a sprinkler about 4 m, discharges rate 6 liter/min. The operating time of a sprinkler is about 25 min. See calculation in appendix A.

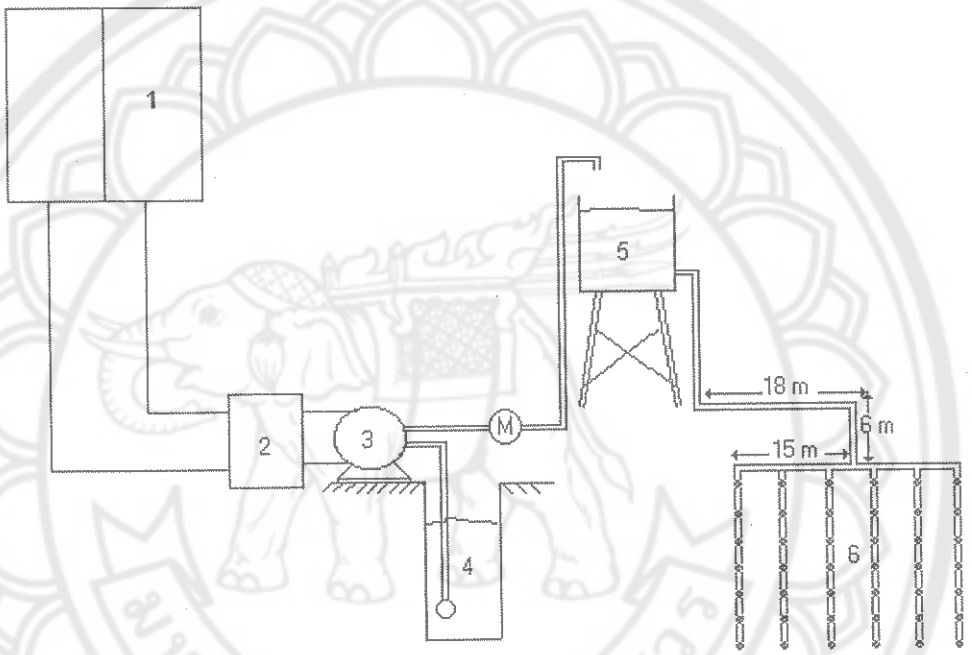


Figure 14. PV water pumping and sprinkler irrigation system diagram