Households Water Supply System Using Solar Power

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***Abstract* —** The solar power water pumping systems have become the interest of many people in the recent years. Acknowledging that nature has provided a bounty of energy which can be converted into electrical energy has created innovative ways of discovering materials that can be used to make a system that supports turning solar energy into electricity. This paper presented different concepts that relate to how the whole energy creation process is done and discuss useful ways of turning solar energy into useful energy, calculated the amount of water delivered depends on distance that water is lifted, distance travelled through delivery pipe, the efficiency of the pump and the amount of energy needed as the main consideration with solar water controller, the remote area residents can enjoy the benefit from the solar energy as the lowest cost and sustainable alternative option with environmental friendly that are not polluting.

***Keywords*—** Solar power, water pumping, motor, controller

People have used a variety of power sources that are human energy, animal power, hydro power, wind, solar, fuels such a diesel for small generators. The most common pumps used in remote communities are hand, direct drive diesel driven borehole, electric submersible and solar submersible. A solar module can converts sunlight into electricity. This is available when sunlight is there but the load may need electricity supply during non-sunshine hours. Therefore, in order to make the use of electricity generated by photovoltaic modules by the load as per desire, there is need to store energy from nighttime applications. For energy storage application, batteries are required. The battery stores energy in the form of DC, sometimes loads can use only AC power is required. The load may require constant power supply. A reliable power to the load using PV module, batteries and several other components are required.

II. CHARACTERISTICS OF SOLAR ENERGY

A. Solar Radiation

Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies. As sunlight passes through the atmosphere, some of it is absorbed, scattered, and reflected by air molecules water vapour clouds dust pollutants forest fires volcanoes. Atmospheric conditions can reduce direct beam radiation by 10% on clear, dry days and by 100% during thick, cloud days. Data for solar electric systems are represented as kilowatt-hours per square meter. Radiation data for solar water heating and space heating systems are represented in British thermal units per square foot.

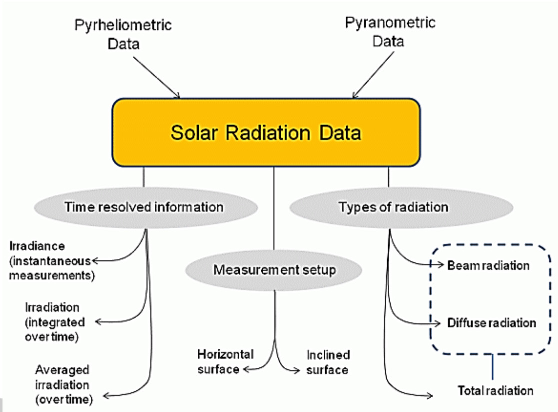

Fig. 1 Overview of solar radiation

B. Solar Irradiance

Solar irradiance is the power per unit area, received from the sun in the form of electromagnetic radiation as reported in the wavelength range of the measuring instrument.

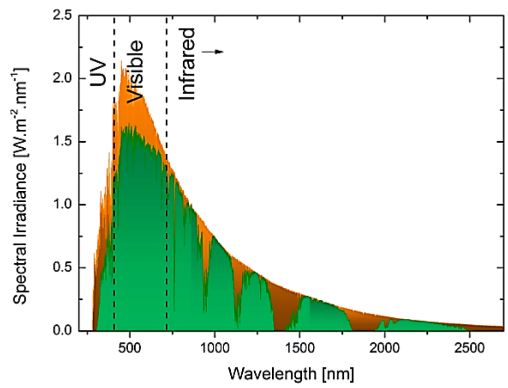

Fig. 2 Solar irradiance and wavelength

It is integrated over a given time period in order to report the radiant energy emitted into the surrounding environment, during that time period. It may be measured in space or at the earth's surface after atmospheric absorption, depends on the built of the measuring surface, the height of the sun above the horizon, and atmospheric conditions, and affects plant metabolism and animal behavior.

C. Solar Insolation

It is the amount of electromagnetic energy incident on the surface of the earth. Generally, the absorbed solar radiation is converted to thermal energy, which causes the object to heat up. Thus understanding insolation is the important in maximizing the output of solar panels which absorb and convert this energy.

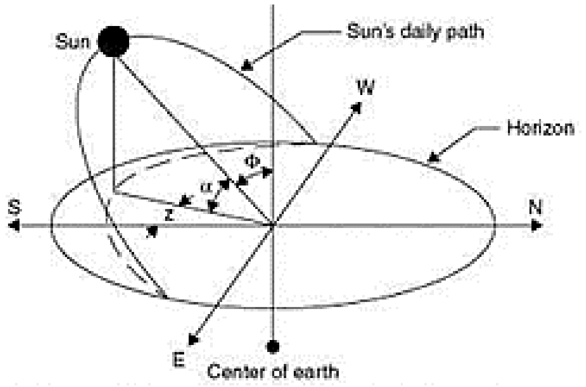

Fig. 3 Apparent daily path of the sun

D. Site Location

In most location in the Union of Myanmar, the least amount of sunlight occurs in the winter because the days are shorter and the sun is lower in the sky, as shown in Figure 3. In Yangon, specifically, there is also typically increased cloud cover in many regions during the rainy season. Therefore, sunlight intensity is least during July and greatest during mid-summer in the March – May period. And then December and January average when isolation is lowest. When selecting a site for the solar power panel to pick a spot that is clear of shade from minimum 10am to 2pm. Even a limb from a deciduous tree will substantially reduce power output.

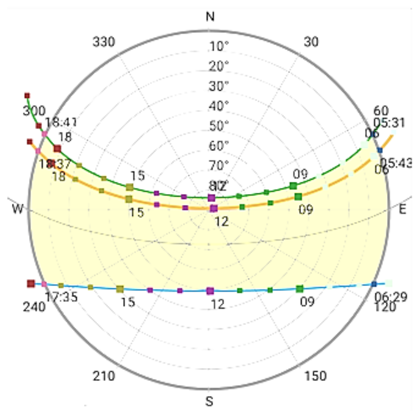

Fig. 4 Sun path diagram

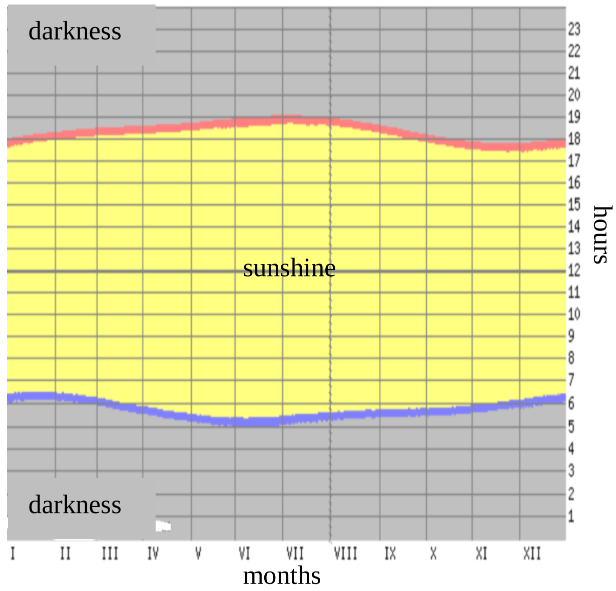

Fig. 5 Diagram of sunshine and darkness

III. DESIGNING PROCESS OF THE SYSTEM

Every pumping and watering situation is needed to consider the following facts;

- How much water need
- When the water need
- Whether the water source is a stream, pond, spring, or well
- Water available in gallons per minute
- How far the water needs to be pumped, and with what elevation gain
- Water quality problems

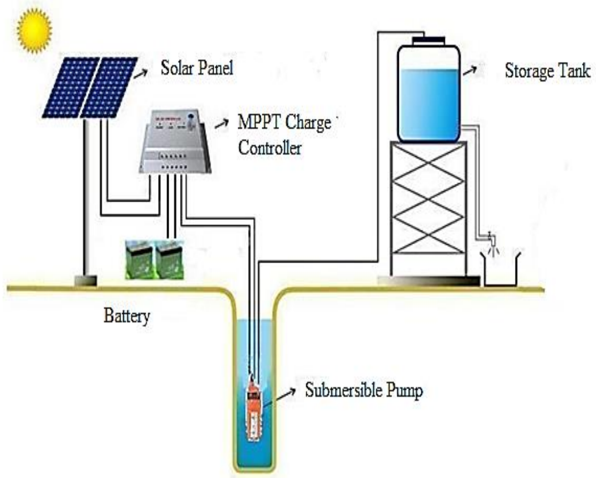

Fig. 6 Block diagram of solar water pumping

A. Daily Water Usage

Estimates vary, but, on average, each person uses about 80 gallons of water per day, for indoor home uses. In these days of water conservation, everybody starts to see toilets and showers that use less water than before. Any local governments now have laws that specify that water faucets, toilets and showers only allow a certain amount of water flow per minute.

Table I. Daily water usage

Appliance/Device	Gallons per day
Toilet	33
Shower	28
Faucet	26
Washing machine	23
Leaks	17
Bath	4
Dishwater	2
Other	5
Total	138

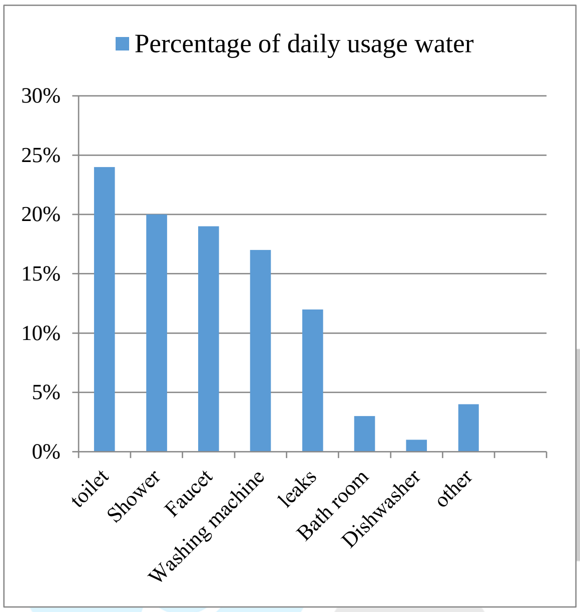

Fig. 7 Graph of percentage of daily water usage

The first thing need to consider while designing solar water pumping is to determine the requirement. Table I shows the value for the typical daily water consumption, which may take as a basis for the calculation of the energy demand. Generally, it can say that there are eight households living in eight storeyed building.

Household usage of water/day = 138 gallons/day

For eight household, = 138 × 8

= 1104 gallons/day

Required water = 1104 × 4.54609 = 5018.883 litres/day

~ 5100 litres/day

So, nominal water requirement for eight households is about 5100 liter per day.

B. Motor Selection

DC water pumps in general use one-third to one-half the energy of conventional AC pumps. DC pumps are classified as either displacement or centrifugal and can be either submersible or surface types.

Required water = 5100 litres/day = 5.1 m^3

Pipe size = 1 in

Flow rate = 8 GPM

Vertical lift = 85 ft

Horizontal lift = 10 ft

Total lift = 95 ft

Table II. Friction loss in plastic pipe

		Pipe Diameter(inches)								
Flow Rate		1⁄ 2	3⁄ 4	1	11⁄ 4	11⁄ 2	2	21⁄ 2	3	4
GPM	LPM	0.662	0.82	1.05	1.38	1.61	2.07	2.4	3.07	4.03
1	3.8	1.13	0.14	0.05	0.02					
1	7.6	4.16	0.35	0.14	0.05	0.02				
3	11.4	8.55	2.2	0.32	0.09	0.05				
4	15	14.8	3.7	0.53	0.16	0.09	0.02			
5	19	22.2	5.8	0.81	0.25	0.12	0.05			
6	23	31	7.9	1	0.35	0.18	0.07	0.02		
7	27		10.6	1.5	0.46	0.23	0.08	0.03		
8	30		13.4	1.9	0.58	0.3	0.09	0.05		
9	34		16.9	2.4	0.72	0.37	0.12	0.06		
10	38		20.3	2.9	0.88	0.46	0.16	0.07	0.02	
11	42		24.3	3.5	1.04	0.53	0.18	0.08	0.03	
12	45		28.6	4.1	1.2	0.65	0.21	0.09	0.04	
14	53			5.5	1.6	0.85	0.28	0.12	0.05	
16	61			7	2.1	1.1	0.37	0.14	0.06	
18	68			8.7	2.6	1.3	0.46	0.16	0.074	

$$\text{Friction loss from pipe} = 95 \times \frac{1.9}{100} = 1.8 \text{ ft}$$

For 1 inch plastic pipe, one 90° elbow connector and three thread fitting contribute total loss of 12 ft.

Friction loss from head = 1.8 + 12 = 13.8 ~ 14 ft

Total dynamic head (TDH) = vertical distance + friction loss

= 85 + 14 = 99 ft

$$\text{Needed horse power} = \frac{TDH \times Q \times SG}{3960}$$

$$= \frac{99 \times 8 \times 1}{3960} = 0.2 \text{ hp}$$

Most modern pumps are between 50% and 85% efficient when used as intended.

$$\text{Pump rating} = \frac{0.2}{0.5} = 0.4 \text{ hp} = 298.4 \text{ W}$$

Therefore, 300W DC submersible pump is selected.

C. Battery Sizing

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices.

$$\text{Required running hour/day} = \frac{\text{Amount of running hour/day}}{\text{DC pump max flow}}$$

$$= \frac{5.1}{0.5} = 10.2 \text{ hrs/day}$$

Required electrical energy/day = 300 × 10.2

= 3.06 kWh/day

To determine ampere hour requirement of DC load

System voltage = 24 V

Load current =12.5 A

Required ampere hour/day = Load current × Running hr/day

=12.5 × 10.2

= 127.5 Ah/day

$$\text{Required capacity of battery} = \frac{\text{Required total Ah/day}}{\text{DoD}}$$

$$= \frac{127.5}{30\%} = 425 \text{ Ah}$$

$$\text{Nos of parallel batteries} = \frac{\text{Required capacity fo battery bank}}{\text{Selectedbattery capacity}}$$

$$= \frac{425 \text{ Ah}}{120 \text{ Ah}} = 3.54 \approx 4\text{nos}$$

So, 4nos; of batteries are connected with parallel.

Fig. 9 Lead-acid battery

C. PV Sizing

Polycrystalline solar cells are blended together from multiple pieces of silicon. Poly solar panels are slightly less efficient than mono panels due to imperfections in the surface of the solar cells. They are cheaper to manufacture which means they cost less for the end user and consist of several crystals of silicon in a single PV cell. They absorb energy from the sun and convert it into electricity. Increase by a factor of 20 to 30 % in order to compensate for the system losses.

So, compensate for the system losses = 127.5 ×1.2
=153Ah/day

$$\text{Solar array current} = \frac{\text{Required Ampere hour/day}}{\text{Sunshine hour}}$$

$$= \frac{153 \text{ Ah / day}}{4 \text{ hour}} = 38.25 \text{ A}$$

Solar module current I_{sc} = 8.72A

$$\text{Numbers of module in parallel} = \frac{38.25 \text{ A}}{8.72 \text{ A}}$$

$$= 4.38 \approx 5 \text{ modules}$$

$$\text{Numbers of module in series} = \frac{24\text{V}}{24\text{V}} = 1 \text{ module}$$

So, Total number of module in the array = 5 × 1
= 5 modules
(parallel)

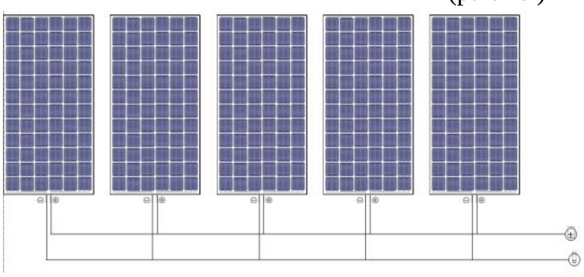

Fig. 10 Diagram of five solar module parallel

D. Controller Sizing

A MPPT solar charge controller is the charge controller embedded with MPPT algorithm to maximize the amount of current going into the battery from PV module. MPPT is DC to DC converter which operates by taking DC input from PV module, changing it to AC and converting it back to a different DC voltage and current to exactly match the PV module to the battery.

Array circuit current = Solar Module current × module in parallel × safety
= 8.72 ×5
= 43.6 A (minimum controller input current)

It is advised multiply the result by a safety factor of 1.25. So, array circuit current = 54.5A. Therefore, 60A MPPT charge controller is used.

Fig. 11 MPPT charge controller

Table II. Detailed design results data

Daily water usage	5100 litres/day
Submersible pump	300 W
Battery	Lead-acid, 24V, 120Ah, 4 nos
Solar module	200W, 5 modules parallel
Controller	MPPT, 60A

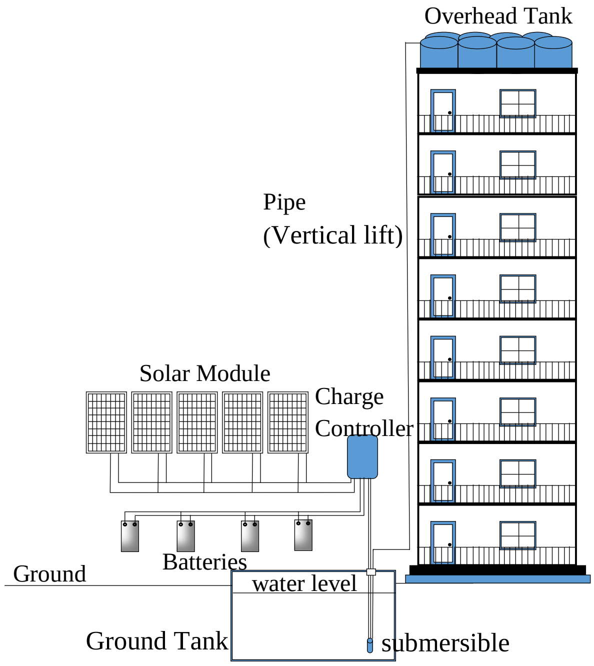

Fig. 12 Detail design of eight household solar water supply system

IV. CONCLUSION

Photovoltaic power for households water supply system is cost-competitive with traditional energy sources for small, remote applications, if the total system design and utilization timing is carefully considered and organized to use the solar energy as efficiently as possible. In the future, when the prices of fossil fuels rise and the economic advantages of mass production reduce the peak watt cost of the photovoltaic cell, photovoltaic power will become more cost-competitive and more common.

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