Worksheet 4 Solutions – PV systems & issues

1. Batteries are dangerous for the following reasons:

- Fire or explosion by ignition of the gases that evolve (require ventilation).
- Short-circuiting of the terminals to generate heat & fire.
- Acid burns from wet, lead-acid batteries.

2: Both types of cause sever burns, particularly at the contact points with the electrocuting circuits. Here are some of the specific differences:

DC Electrocution	AC Electrocution
Only very small currents required Muscular tetanus (contraction) Tends to stop the heart (easier to revive)	Voltage passes through zero 50× per sec Easier to release grip than DC Tends to cause heart defirbillation

Both AC and DC are dangerous in a biological sense for different reasons. Direct current (DC) moves in one direction through a conductor, and has the tendency to induce muscular tetanus (involuntary contraction) quite readily. Victims are often unable to let go of a DC conductor because of the continuous motion and stable voltage. Alternating current (AC) however passes through zero voltage (and current) 50 times every second, and thus provides moments of relaxation for the muscle to relax

3: Use $P = I_1V_1 = I_2V_2$. (since the power into the transformer must be equal to the power leaving it if the device itself consumes no power). P_{in} = 200A * 240V = 48,000W_{ac} = P_{out} = I_2 * 2400V → I_2 = 20A. Note that 2.4kV = 2400V.

If $V_2 = 12V_{ac}$, then $P_{in} = 48{,}000W_{ac} = P_{out} = 12V_{ac} * I_2$ → I_2 = 4000A = 4kA. Currents this large will cause HUGE power losses in the transmission lines according to $P_{loss} = I^2R$ as I^2 = 16,000,000!!

Transformers use a rotating magnetic field which surrounds a current carrying wire. This rotating magnetic field output by one wire (I_1,V_1) can be detected by another stationary wire, such that it causes a current to be generated in the second wire (I_2,V_2). However, a rotating magnetic field can only be generated if the current is NOT constant and is continually varying (i.e. AC). DC is a fixed voltage and fixed current, and thus cannot induce this change.

4: The current being carried is calculated using P=VI (since the PV system is a power source and the output power is the product of the output voltage and current), giving I = 300W/12V = 25A

The resistance of the transmission line is given by R = (1.7×10^{-8} m*3000m)/0.0002m^2 = 0.255. Now the power loss over this length of line is $P_{loss} = I^2R = 25^2*0.225$ = 159.38W.

This means that the power that needs to be generated by the PV system 3km up the road is 300W + 159.38W = 459.38. This is 53% more power than is finally reaching the load!

5. **(a)** A chemical process where silicon is separated from the oxygen also contained in sand. Other impurities are also removed at this stage. For photovoltaics the silicon must be 99.999% pure. For use in the solar cell industry it is doped (p-type) so that a p-n junction can be produced by adding the n-type layer later.

(b) During the purification the silicon is made molten. In this step the silicon is solidified to form crystalline structures. The Czochralski method is where a single crystal is slowly drawn from a molten silicon vat. This creates a long cylinder of silicon that is all one crystal and is known as single crystalline silicon.

(c) By using a chemical etching solution which etches away diagonal planes at the silicon surface to produce pyramids. These pyramids give incoming light to the solar cell multiple opportunities of penetrating the silicon as the light is reflected off the other planes.

(d) A fixed thickness dielectric is applied to the surface of the cell to maximize the incident radiation absorbed by the solar cell. ARCs do this by causing reflected light to interfere with incoming light and thereby cancel each other and be absorbed in the dielectric layer. Untextured wafers can have their reflection reduced from 30% to under 5%. The ARC thickness is optimized to be most effective at reducing reflection for the dominant wavelengths of sunlight.

(e) The metal grid is applied to the front of the cells to collect electrons produced in the sunshine. Silver is used almost universally here. The rear contact is solid and also acts to carry electrons. It is usually made of Aluminium, which is cheaper. These contacts are what link to the external circuit and allow current to be taken from the cell.

(f) End of manufacturing process quality control is performed on the final cells. This is done with a dummy electrical load and computerized testing station to produce IV graphs for the cells. However, it is vitally important to detect faults in the manufacturing process as early as possible. If a process early in the chain is faulty, millions of wafers can be lost before cell damage is detected at the end. Intermediate testing tools are therefore what is required. This is called 'inline quality control.'

6. There are major hazards that arise if the electricity supply authority switches the grid off in a certain area to undertake maintenance work, but a residential PV system was still operating and exporting power to the grid 'island' remaining. Workers will unknowingly be exposed to DC currents as the solar array feeds the loads of all the houses in the nearby network. The Australian & international standards require that grid-connected inverters detect when the grid has failed and disconnects the PV system from it. To detect a tripped grid is challenging and present methods can be unreliable. Inverters sense the grid frequency (should be around 50Hz), the grid voltage (around 240V) and other parameters for any changes in the electrical signal that may indicate a portion of the grid tripping out.

7. **(a)** With utilities deregulated, remote customers needing power can be charged the full cost of extending transmission lines to their site. This can amount to tens of thousands of dollars per kilometer. Commonly petrol or diesel generators would supply the power through combustion of the fuels that need to be purchased regularly. Some of the problems with these generators can be solved by PV. Off-grid

applications where entire loads are to be provided by PV require more accurate sizing processes. Such systems almost always require battery storage, which significantly add to the cost of the systems. The more days of power required without sunlight, the greater the size of the battery bank and cost of the system.

(b) Diesel or wind generators are commonly coupled with PV. This reduces the cost of the total system compared to the pure PV remote power system, because the other generators can meet the short periods of very high energy demand (or cloudy days), rather than having to size a large and expensive PV array (and battery bank) to meet these short spells. It is very important to have an intelligent controller to make decisions based on load demand, battery state of charge, and the generator run-time to ensure loads are continuously powered and equipment protected.

8. Charge controllers adjust the rate at which charge that a battery receives based on the state of charge of the battery. Regulators prevent batteries from being damaged by over-discharging during periods of low voltage (usually by disconnection). This is termed 'low voltage disconnect.' They also prevent overcharging during extended sunny periods when the battery is full, which would lead to corrosion of the plates and loss of electrolyte. This may be done by disconnection of the charging source, or by diverting the energy elsewhere (often water heating, or a dummy load).