

## Renewable Energy Systems 402

### Tutorial 8

#### Fuel Cell Systems

1. The terminal voltage of a PEMFC in volts is given by the following equation.

$$V = E - (I + I_n)R - A \ln \left( \frac{I + I_n}{I_0} \right) + B \ln \left( 1 - \frac{I + I_n}{I_l} \right)$$

Where  $E = 1.2\text{V}$ ,  $I_n = 5\text{A}$ ,  $R = 12 \mu\Omega$ ,  $A = 0.06 \text{ V}$ ,  $I_0 = 0.1675 \text{ A}$ ,  $B = 0.05 \text{ V}$ ,  $I_l = 2250\text{A}$ .

- (a) Plot the V-I and P-I characteristics of the fuel cell.
- (b) Graphically or mathematically, determine the current and terminal voltage when the cell delivers maximum power.
2. A solid oxide fuel cell has the following approximate V-I characteristic.
- $$V = 1 - 1.2 \times 10^{-4} \cdot I \quad \text{where } V \text{ is in volts and } I \text{ is in amps.}$$
- (a) Determine the following per cell at maximum power point.
- (i) power (ii) voltage (iii) current
- (b) If a DC load requires a full-load power of 250 kW at a voltage of 100V:
- (i) What type of DC/DC converter would you use? How many cells would you connect in series with the selected type of DC/DC converter?
- (ii) If it is required that a step-down DC/DC converter must be used, what is the number of cells that would be connected in series?
3. A SOFC power plant with a terminal voltage of 300 V is connected to the 3.3kV, 3-phase grid through a boost-type DC/DC Converter, a 3-phase VSI operating with sinusoidal PWM modulation index of 0.8 and a 400/3300 V 3-phase step-up transformer, all in series. The system is operating at the given rated values of voltage when 833kW is supplied to the grid at unity power factor. Power efficiencies of different components are as given below.  
Transformer = 97%; VSI=90%; DC/DC Converter=93%;
- The V-I characteristic of a cell can be given by  $V = 0.92 - 1.0 \times 10^{-4} \cdot I$ . The change in Gibbs free energy of formation due to cell reaction at the operating condition is -177.4 kJ/mol. Determine the following:
- (a) Voltage, Current and Power at the terminals of each component. Note: rms line voltage and rms line current in the case of 3-phase systems.
- (b) Number of cells in series in the stack.
- (c) Flow rate of hydrogen in to the cell stack in kg/s considering a fuel utilization factor of 80%.