



# **Tubular Solid Oxide Fuel Cell Power Systems Demonstration and Product Development Status**

---

***Fuel Cell Summit IV***  
**May 10, 2000**

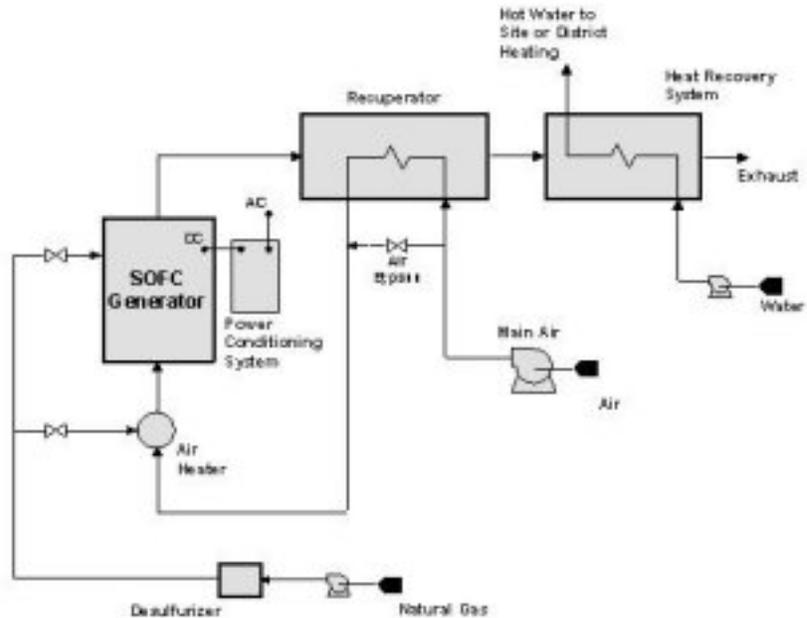
**L. A. Shockling**  
**Siemens Westinghouse Power Corporation**  
**SOFC Power Generation**  
**1310 Beulah Road**  
**Pittsburgh, Pennsylvania 15235-5098**



# **EDB/ELSAM 100 kWe SOFC-CHP Power System Demonstration**

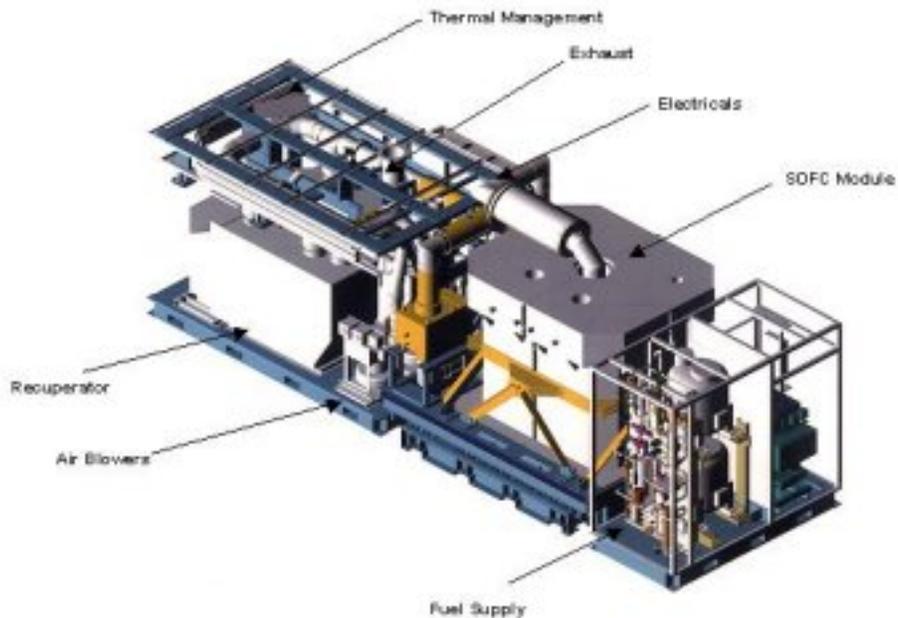
- Demo unit operating in The Netherlands.
- Over 12,000 hours total operating time on system.
- Over 8,000 hours operating time on Build 2 of SOFC module.
- No measurable stack degradation.

## SOFC-CHP System Cycle (atmospheric pressure)





## EDB/ELSAM 100 kWe SOFC-CHP System – Major Components



**SIEMENS**  
Westinghouse

## EDB/ELSAM 100 kWe SOFC-CHP System – Photograph





## EDB/ELSAM 100 kWe SOFC-CHP System Performance Summary

|   |                |
|---|----------------|
| Cell Number   | 1152           |
| Current @ 167 Amps/cell                                     | 500 Amps       |
| Voltage @ 0.662 V/cell                                      | 254 Vdts       |
| Blower Air Intake Rate                                      | 0.31 kg/s      |
| Exhaust Flue Temperature                                    | 340°K          |
| SOFC DC Power   | 127 kWe        |
| SOFC Gross AC Power   | 118 kWe        |
| <b>System Net AC Power</b>                                  | <b>109 kWe</b> |
| <b>Efficiency (Net AC/LHM)</b>                              | <b>46%</b>     |
| Heat Recovery (kW/LHM)                                      | 28%            |
| Energy Efficiency [(kW <sub>e</sub> +kW <sub>t</sub> )/LHM] | 74%            |
| Operating Time  | ~12,000 hours  |
| MWh   | ~1,200 MWh     |
| NO <sub>x</sub> Emissions                                   | 0.004 kg/MWh   |



# **Southern California Edison (SCE) 220 kWe PSOFC/MTG Proof-of-Concept Power System**



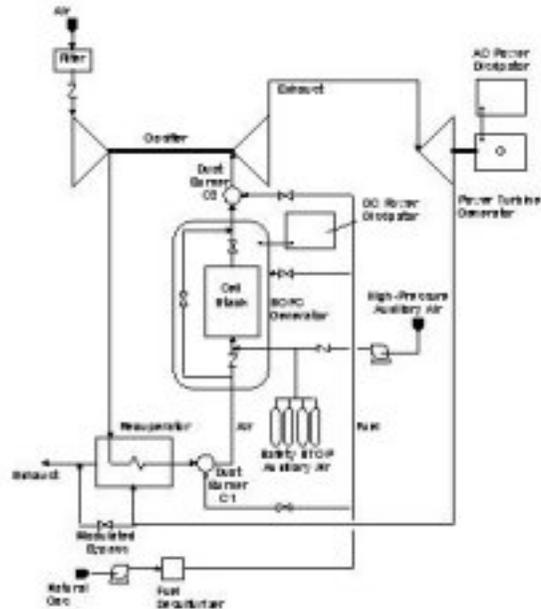
## SCE 220 kWe PSOFC/MTG Major Features

---

- First-of-a-kind hybrid system of
  - Microturbine generator
  - Pressurized solid oxide fuel cell module
- 1152 cell stack - commercial prototype
- Natural gas fueled
- In-stack reformation
- ASME Section VIII coded pressure vessel



# SCE 220 kWe PSOFC/MTG Power System Cycle





## **SCE 220 kWe PSOFC/MTG BOP Major Features**

---

- System on two major truck-transportable skids
  - PSOFC/fuel supply skid
  - TMS/electricals skid
- Utilizes a gas turbine supplied by Northern Research and Engineering Corporation (NREC)
- Turbine generator delivers AC power to an outdoor step-controlled commercial resistor load.
- SOFC delivers DC to an outdoor modulated resistor load.



## SCE 220 kWe PSOFC/MTG Power System (right perspective)



Gas  
Turbine

SOFC  
Generator

**SIEMENS**  
Westinghouse

## SCE 220 kWe PSOFC/MTG Power Generation System (left perspective)





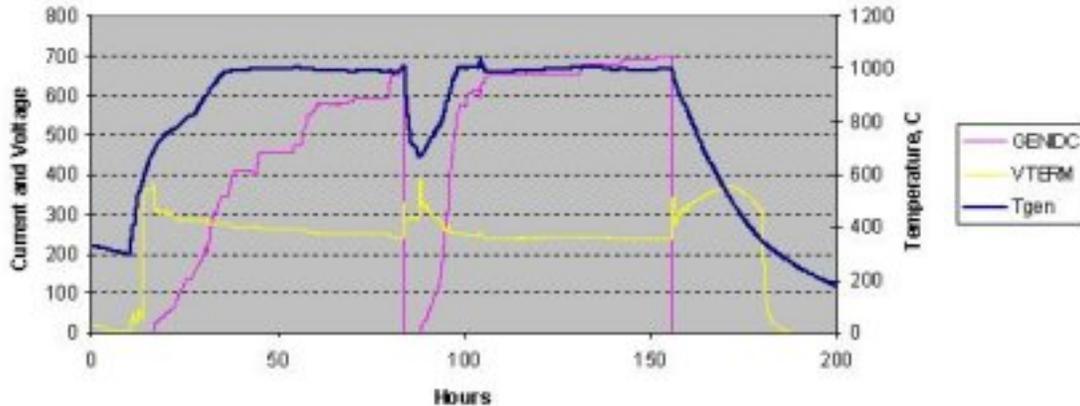


## SCE 220 kWe PSOFC/MTG Power System Estimated Performance (grid-connected basis)

|                           |              |
|---------------------------|--------------|
| Cell Number               | 1152         |
| Current @267 Amps/cell    | 800 Amps     |
| Voltage @0.610 V/cell     | 234 V        |
| Compressor Pressure Ratio | 29:1         |
| Air Intake Rate           | 0.58 kg/s    |
| Turbine Inlet Temperature | 1050°K       |
| SOFC DC Power             | 187 kWe      |
| SOFC Gross AC Power       | 176 kWe      |
| Gas Turbine AC Power      | 47 kWe       |
| System Net AC Power       | 217 kWe      |
| Efficiency (Net AC/LHV)   | 57%          |
| NO <sub>x</sub> Emissions | <0.01 kg/MWh |

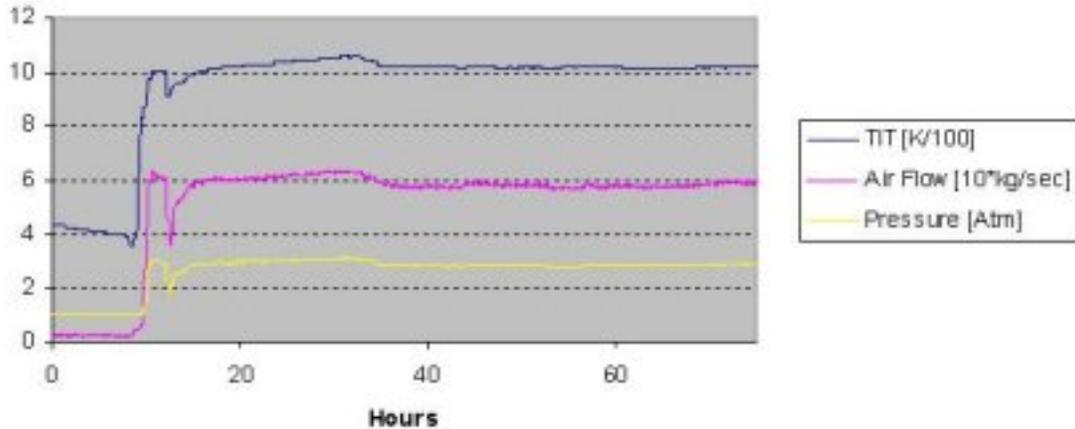


## SCE 220 kWe PSOFC/MTG FAT – SOFC *Parameters*





## SCE 220 kWe PSOFC/MTG FAT – MTG *Parameters*





# 250 kWe SOFC-CHP System



## 250 kWe SOFC-CHP System Design Objectives

|   |   |
|---|---|
| Application                                     | <ul style="list-style-type: none"> <li>• Base load electric power supply.</li> <li>• Hot water supply.</li> </ul> |
| Rated Electric Power Output                     | 225 kW Net AC   |
| Electric Efficiency (Net AC) LHV                | 46%   |
| Thermal Output (Hot Water)                      | ~150 kWt  |
| Return Water Temperature                        | 65°C  |
| Water Delivery Temperature                      | 80°C  |
| Heat Recovery (kW) LHV                          | ~30%  |
| System Energy Efficiency (kWe + kWt) LHV        | ~75%  |
| NOx Emission                                    | <0.01 kg/MWh  |
| Noise   | <76 dbA, at 7 m distance.   |
| Availability for operation at rating conditions | 96%   |
| Packaging and Transport                         | <ul style="list-style-type: none"> <li>• Skid-mounted package</li> <li>• Truck shipment</li> </ul>                |



# **Planned Commercial Product 300 kWe-Class PSOFC/MTG CHP System**



# **Planned Commercial Product 300 kWe-Class PSOFC/MTG CHP System**



## 300 kWe-Class PSOFC/MTG-CHP System Performance Estimates (Current-Status Cell Characteristics)

(Preliminary Values, Pending Gas Turbine Selection)

|   |              |
|---|--------------|
| Cell Number                             | 1728         |
| Current @250 Amps/cell                  | 750 Amps     |
| Voltage @0.635 W/cell                   | 370 V        |
| Compressor Pressure Ratio               | 3.5:1        |
| Air Intake Rate                         | 0.64 kg/s    |
| Turbine Inlet Temperature               | 870°C        |
| Combustor and Air Heater Fuel Flow Rate | 0            |
| SOFC DCPower                            | 270 kWe      |
| SOFC Gross AC Power                     | 251 kWe      |
| Gas Turbine AC Power                    | 67 kWe       |
| System Net AC Power                     | 307 kWe      |
| Efficiency (Net AC/LHV)                 | 57%          |
| Hot-Water Heat Recovery @393°K          | 95 kWt       |
| Heat Recovery Efficiency (kWt/LHV)      | 18%          |
| Energy Efficiency [(net AC+ kWt)/LHV]   | 75%          |
| Exhaust Flue Temperature                | 60°C         |
| NOx Emissions                           | <0.01 kg/MWh |



# **Planned Commercial Product MWe-Class PSOFC/MTG Power System**



## MWe-Class PSOFC/MTG Power System Performance Estimates (Current-Status Cell Characteristics)

(Preliminary Values, Pending Gas Turbine Selection)

|   |                      |
|---|----------------------|
| Cell Number                             | 5760                 |
| Current @239 Amps/cell                  | 717 Amps             |
| Voltage @0.643 V/cell                   | 1235 V               |
| Compressor Pressure Ratio               | 3.3:1                |
| Air Intake Rate                         | 2.0 kg/s             |
| Turbine Inlet Temperature               | 870°C                |
| Combustor and Air Heater Fuel Flow Rate | 0                    |
| SOFC DC Power                           | 879 kW <sub>e</sub>  |
| SOFC Gross AC Power                     | 818 kW <sub>e</sub>  |
| Gas Turbine AC Power                    | 218 kW <sub>e</sub>  |
| System Net AC Power                     | 1014 kW <sub>e</sub> |
| Efficiency (Net AC/LHV)                 | 59%                  |
| Exhaust Flue Temperature                | 240°C                |
| NO <sub>x</sub> Emissions               | <0.01 kg/MWh         |