CLEAN ENERGY GENERATION, INTEGRATION AND STORAGE (EEE-801)

Prepared By:
Dr. Abasin Ulasyar
Assistant Professor (NUST USPCAS-E)

NUST
NATIONAL UNIVERSITY
OF SCIENCES & TECHNOLOGY

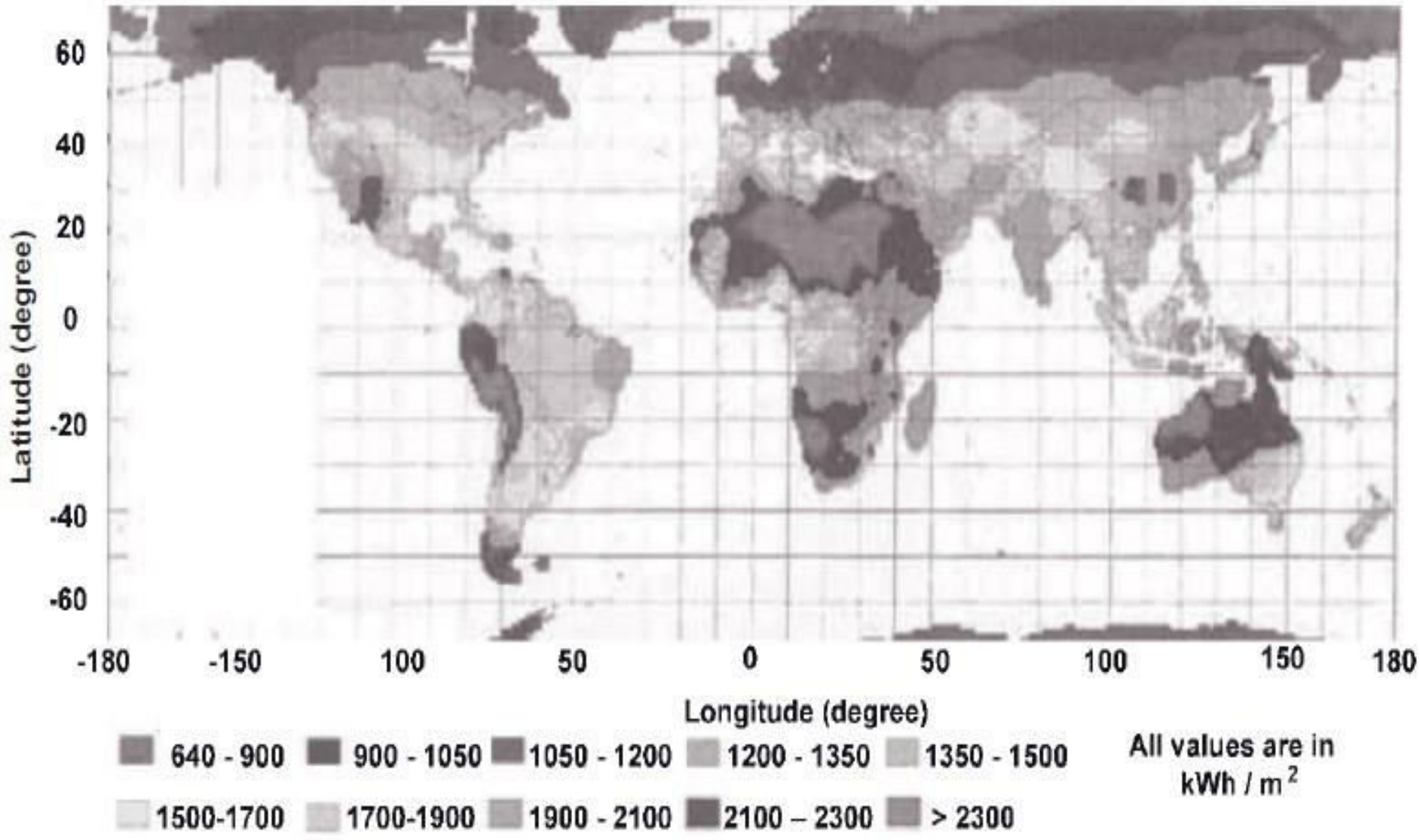
Department of Electrical Power Engineering
U.S.- Pakistan Center for Advanced Studies in Energy

Lecture-5
15th February 2022

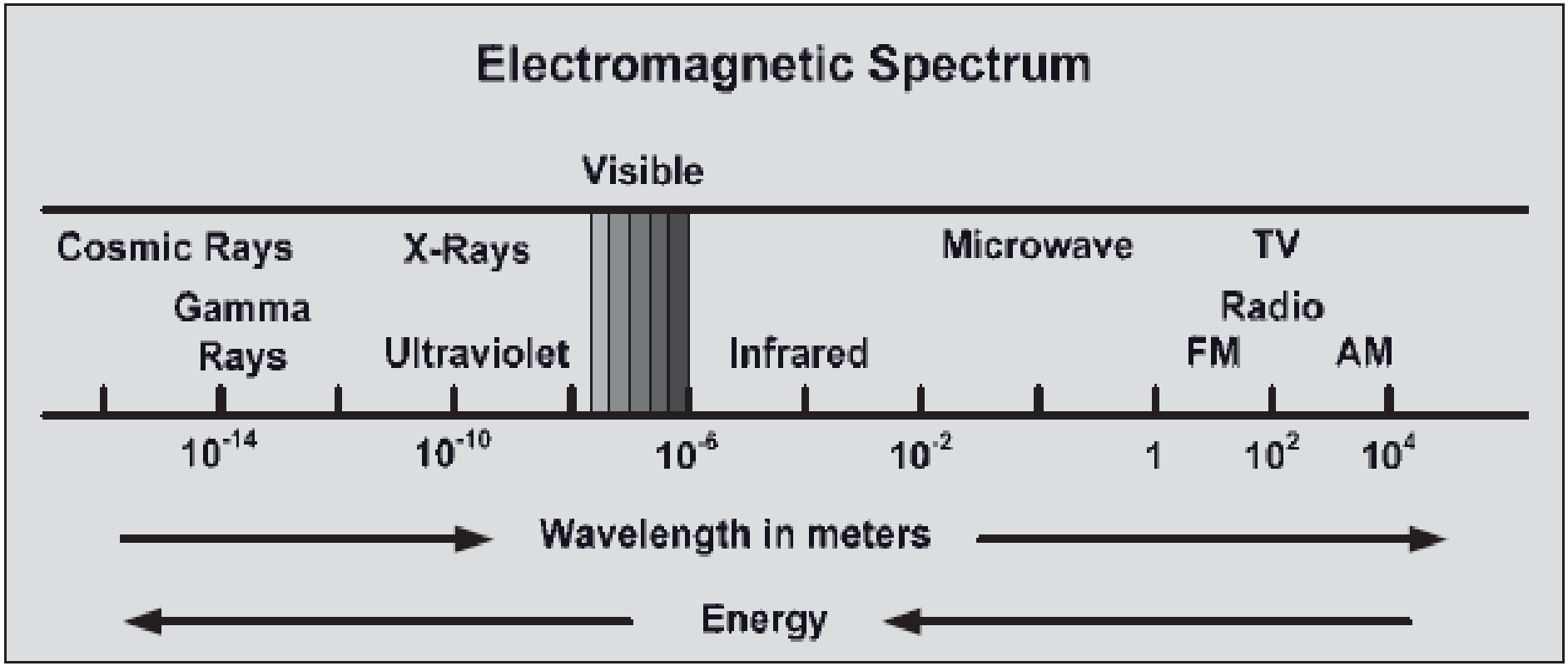
Introduction: Solar Energy

- The sun's energy is the primary source of energy for life on our planet. When the sun disappears from our universe, we will cease to exist.
- Solar energy is a readily available renewable energy; it reaches earth in the form of electromagnetic waves (radiation).
- Many factors affect the amount of radiation received at a given location on earth. These factors include location, season, humidity, temperature, air mass, and the hour of day.
- Insolation refers to exposure to the rays of the sun, i.e., the word insolation has been used to denote the solar radiation energy received at a given location at a given time. The phrase incident solar radiation is also used; it expresses the average irradiance in watts per square meter (W/m^2) or kilowatt per square meter (kW/m^2).

Introduction: Global Irradiation Values for the World (kWh/m^2)



Introduction: Electromagnetic Specturm



Introduction: The Solar Energy Conversion Process: Thermal Power Plants

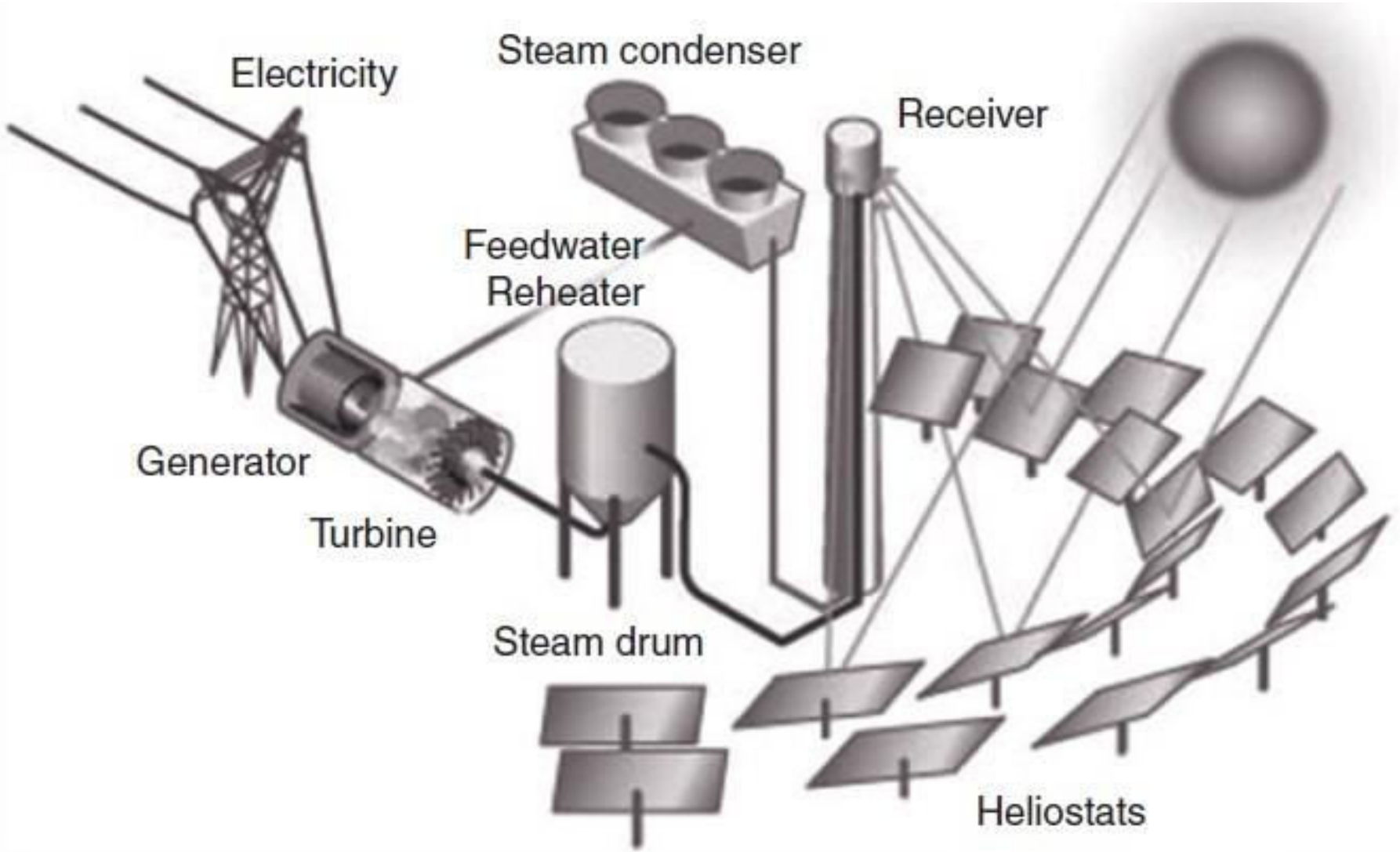
- Auguste Mouchout constructed a parabolic mirror to channel the sun's energy to power a steam engine in 1866. Today's thermal solar electric power plant also uses the sun's heat energy to generate steam power for running the turbines.
- Concentrating solar power (CSP) systems have locating lenses designed for concentrating the sunlight into the receiver, which acts as a boiler to generate steam. The system uses a tracking control system for maximum efficiency. A number of concentrating technologies exists; a parabolic mirror that uses materials that are silver - based or of polished aluminum is often used.
- Figure depicts the CSP system located in the Mojave Desert in California, which uses a parabolic mirror.

Introduction: The Solar Energy Conversion Process: Thermal Power Plants

Introduction: The Solar Energy Conversion Process: Thermal Power Plants

- Solar power towers (shown in next slide) generate steam power by creating intense concentrated solar energy that is directed via a tower heat processing system.
- The system uses a large number of sun - tracking mirrors, or parabolic reflectors. The number of mirrors depends on the system capacity.
- Another type of mirror used is called a heliostat (from Helios , the Greek word for sun). Earlier power towers used water/steam as the heat - transfer fluid. More recent advanced designs have used molten nitrate salt.

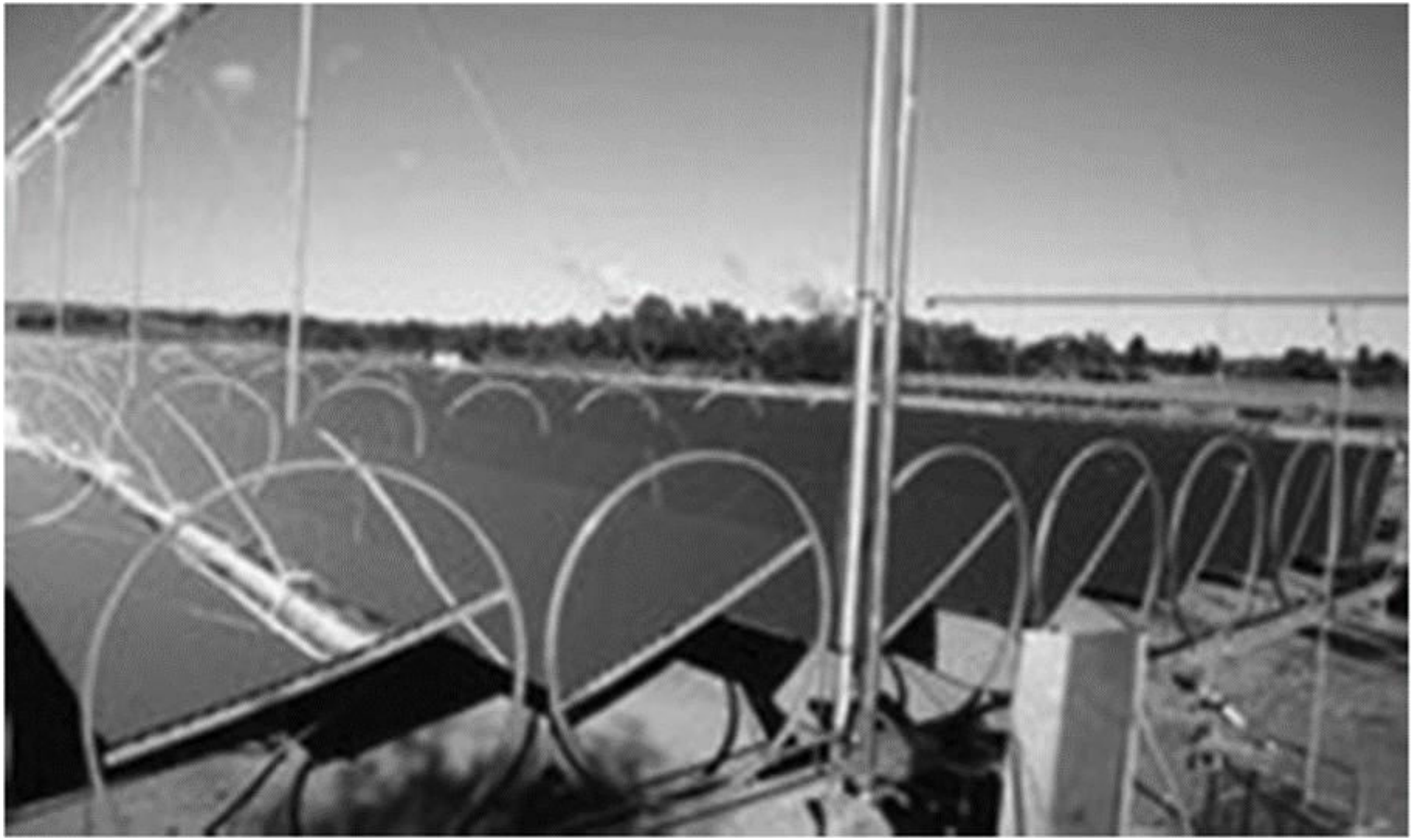
Introduction: The Solar Energy Conversion Process: Thermal Power Plants



Introduction: The Solar Energy Conversion Process: Thermal Power Plants

- A French physicist, Augustin - Jean Fresnel (1788 – 1827), developed the Fresnel lens, which has a large aperture and short focal length. Its construction requires less material than a conventional lens, and it allows for more light to pass through.
- The compact linear Fresnel reflector (CLFR) is used in solar power plants. The CLFR system uses Fresnel lens and reflectors that are located on a single axis to concentrate the solar energy to generate steam.
- The CLFR uses a number of thin mirror strips to focus high - intensity sunlight into a heat - processing system. Flat mirrors are much cheaper to produce than parabolic ones and they facilitate a greater number of reflectors for use in steam generation.
- Figure depicts a CLFR power generating station.

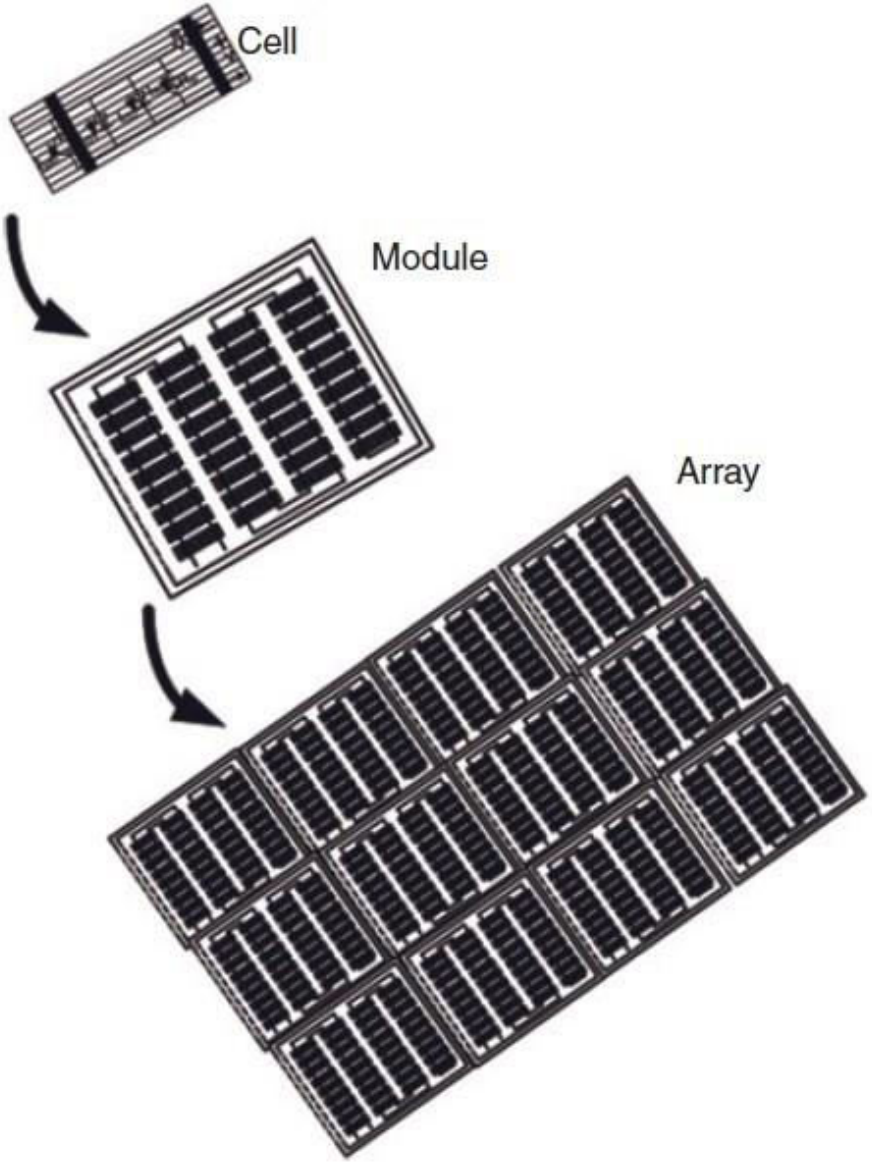
Introduction: The Solar Energy Conversion Process: Thermal Power Plants



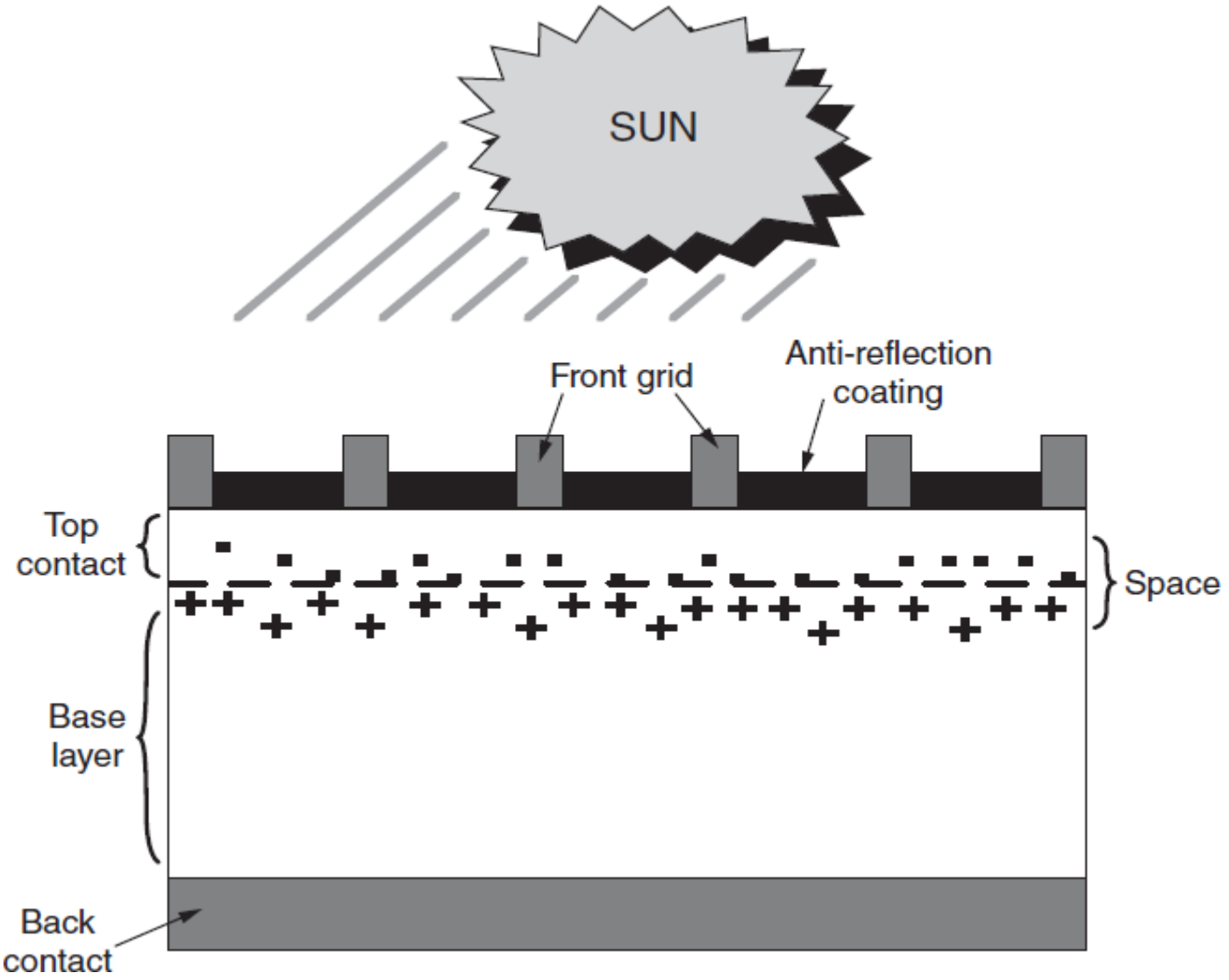
Introduction: PHOTOVOLTAIC POWER CONVERSION

- Solar cells convert the radiation energy directly to electric energy. Solar cells, also called photovoltaic (PV) cells, were developed by Carlson and Wronski in 1976.
- A PV module consists of a number of PV cells. When sunlight strikes the PV cell, electrons are freed from their atoms. The freed electrons are directed toward the front surface of the solar cell.
- This process creates a current flow that occurs between the negative and positive sides. The PV photon cell charge offers a voltage of 1.1 up to 1.75 electron volt^2 (ev^2) with a high optical absorption.
- Figure depicts a photovoltaic (PV) cell structure. A photovoltaic (PV) module connects a number cell of PV cells in series.

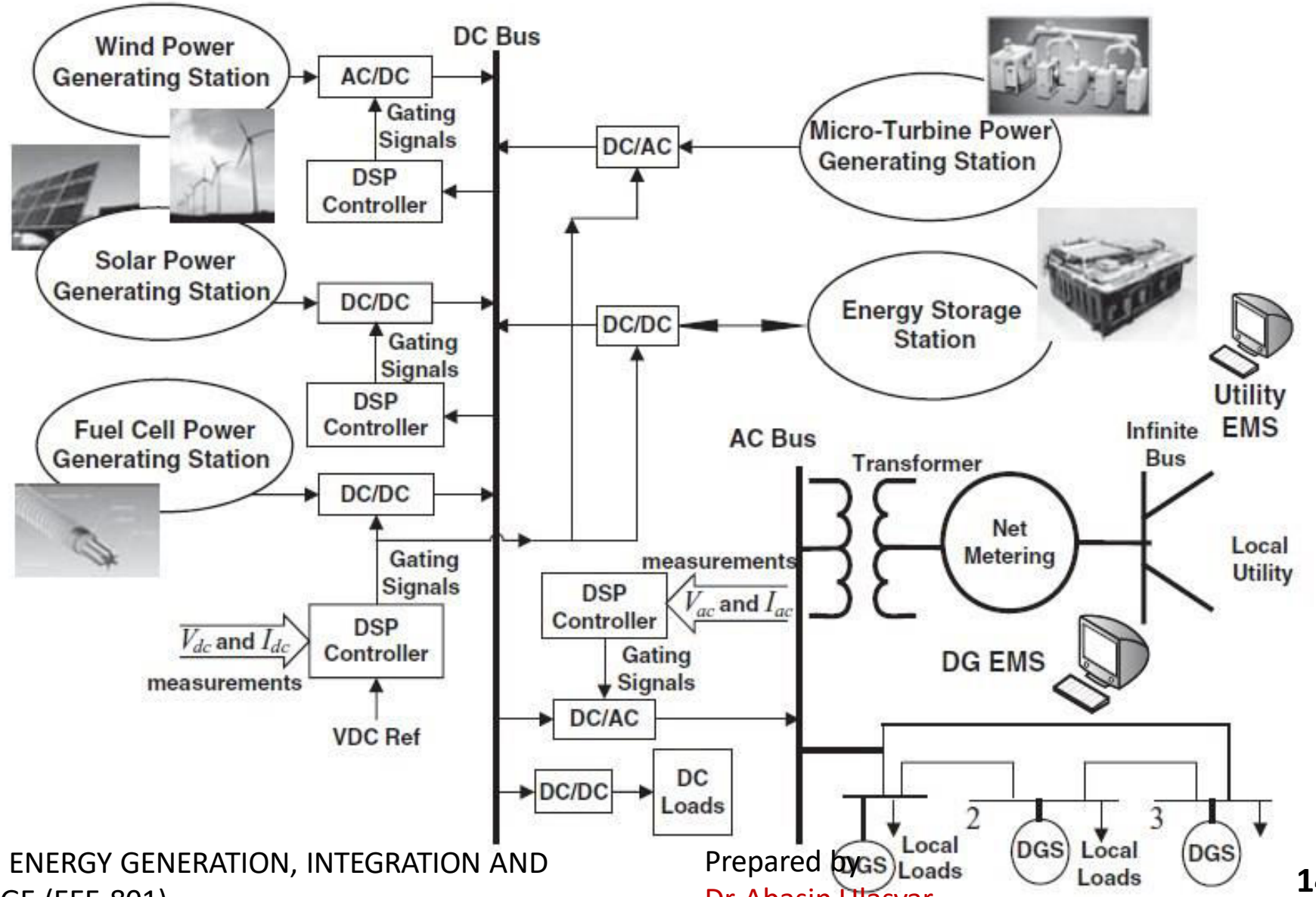
Introduction: A Solar Cell or Photovoltaic Cell Structure

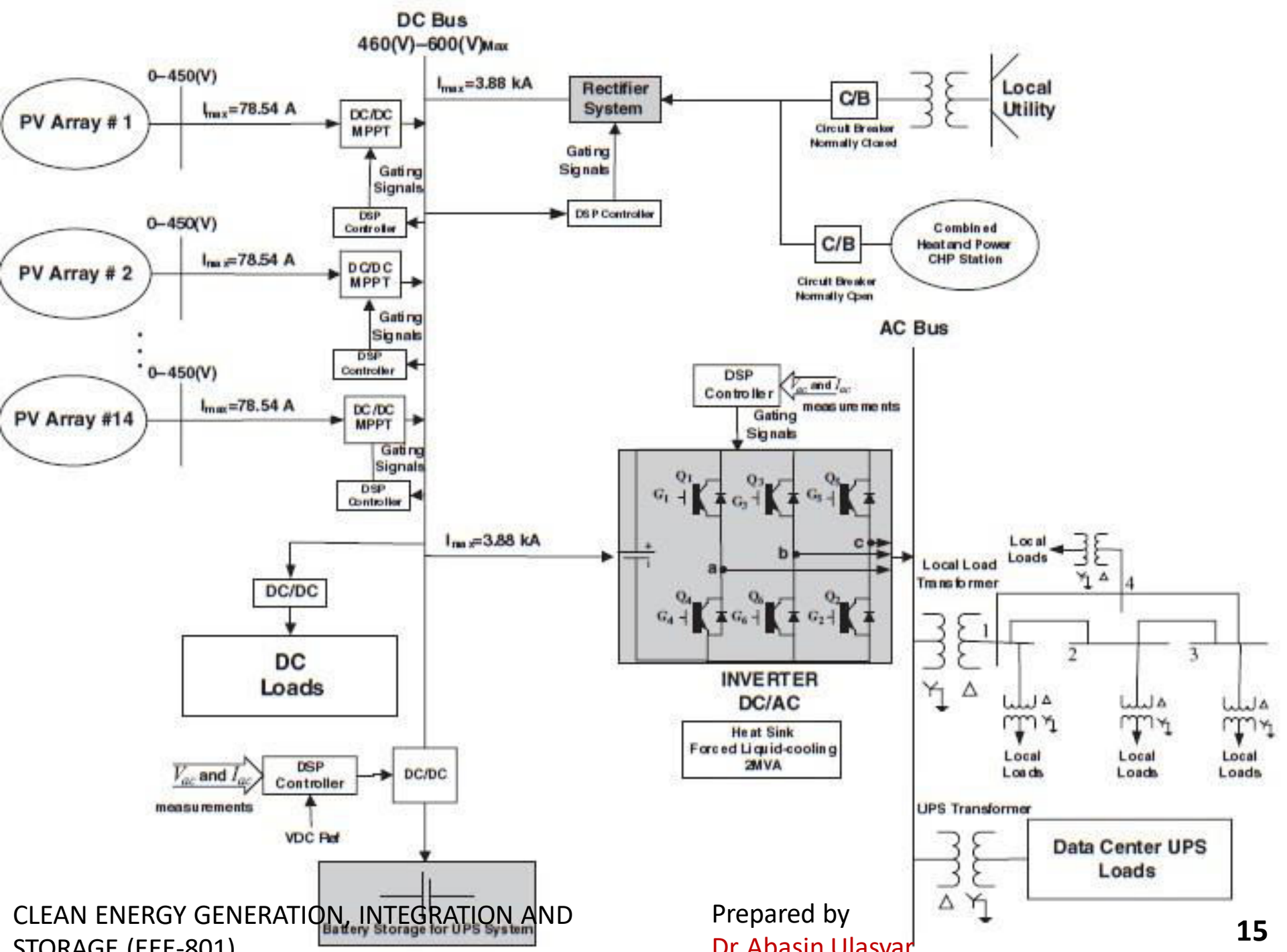


Introduction: A Solar Cell or Photovoltaic Cell Structure



Introduction: Architecture Overview




DC Bus
460(V)–600(V)Max
0–450(V)
PV Array # 1
I_{max}=78.54 A
DC/DC MPPT
Gating Signals
DSP Controller
I_{max}=3.88 kA
Rectifier System
Gating Signals
DSP Controller
C/B
Circuit Breaker Normally Closed
Local Utility
0–450(V)
PV Array # 2
I_{max}=78.54 A
DC/DC MPPT
Gating Signals
DSP Controller
C/B
Circuit Breaker Normally Open
Combined Heat and Power CHP Station
0–450(V)
PV Array #14
I_{max}=78.54 A
DC/DC MPPT
Gating Signals
DSP Controller
AC Bus
DSP Controller
V_{ac} and I_{ac} measurements
Gating Signals
I_{max}=3.88 kA
DC/DC
DC Loads
INVERTER DC/AC
Heat Sink Forced Liquid-cooling 2MVA
Local Load Transformer
Local Loads
Local Loads
Local Loads
Local Loads
V_{dc} and I_{dc} measurements
DSP Controller
VDC Ref
DC/DC
Battery Storage for UPS System
UPS Transformer
Data Center UPS Loads