



Chapter 2

Smart Electricity Distribution Networks

SMART ELECTRICITY DISTRIBUTION NETWORKS

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Fundamentals of Distributed Energy Resources



2.1 Introduction



2.2 Combined Heat and Power plants



2.3 Photovoltaic Energy Systems



2.4 Wind Energy Systems



2.5 Electrical Energy Storage



2.6 Flexible demand



2.1 Introduction

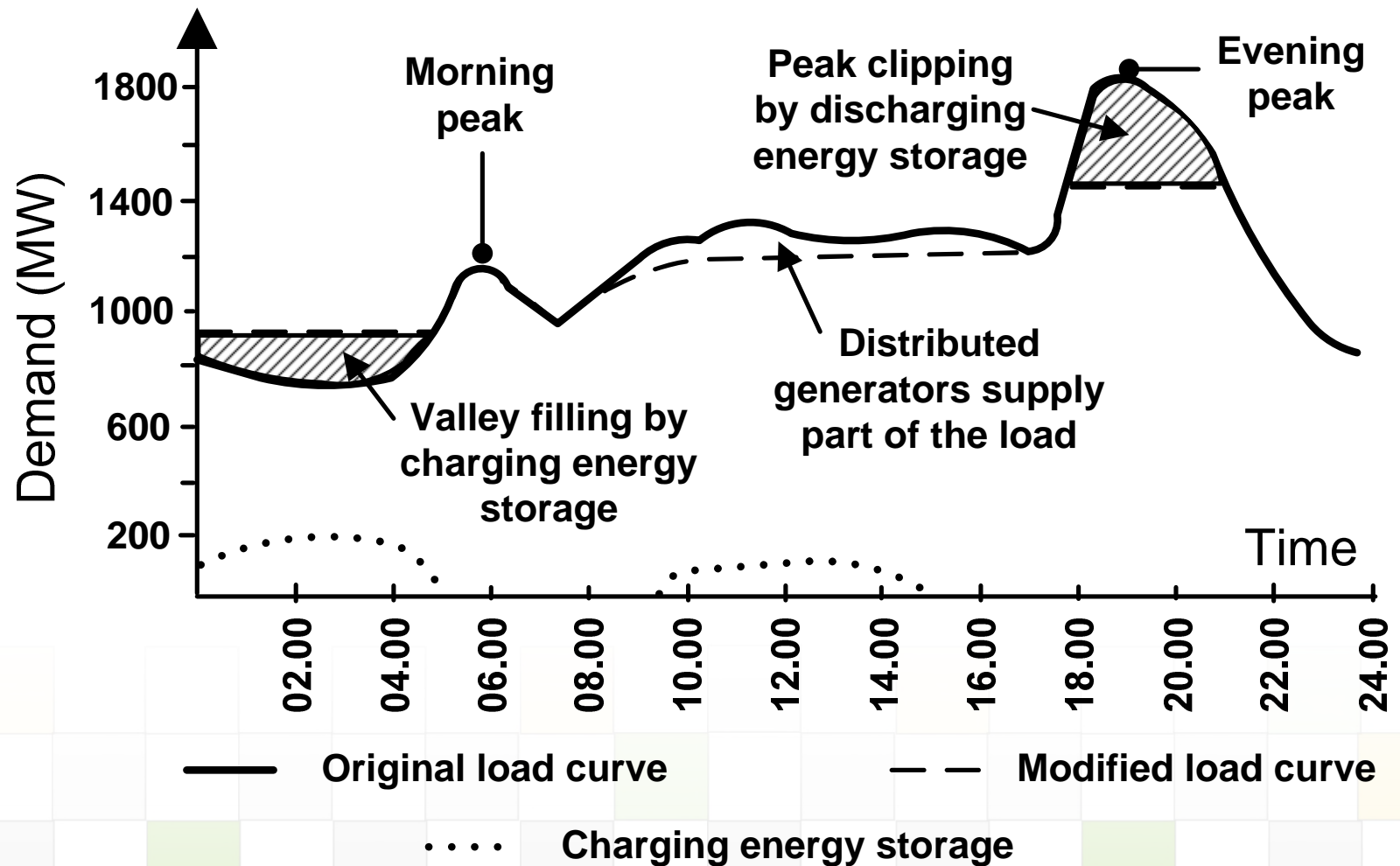


Figure 2.1 Benefits of DER



2.2 Combined Heat and Power plants

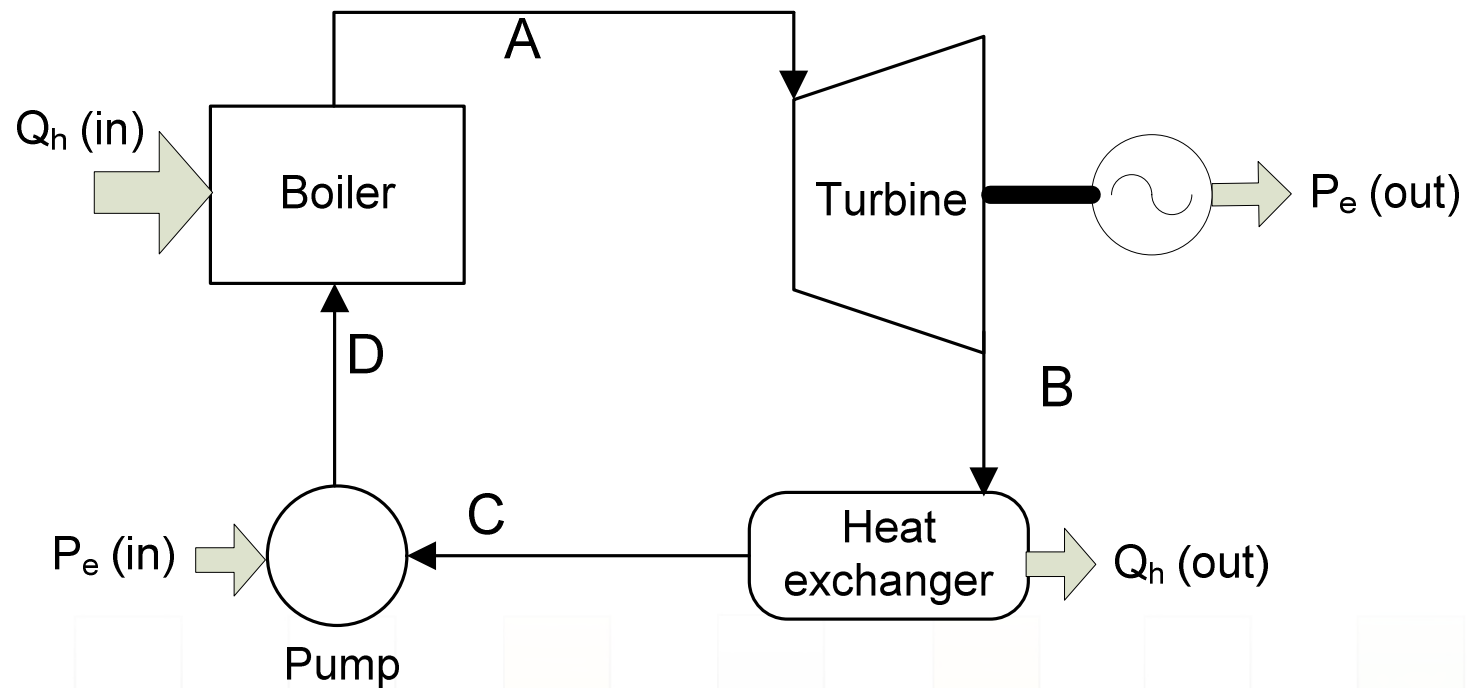


Figure 2.2 Elements of back-pressure steam turbine cycle



2.2 Combined Heat and Power plants

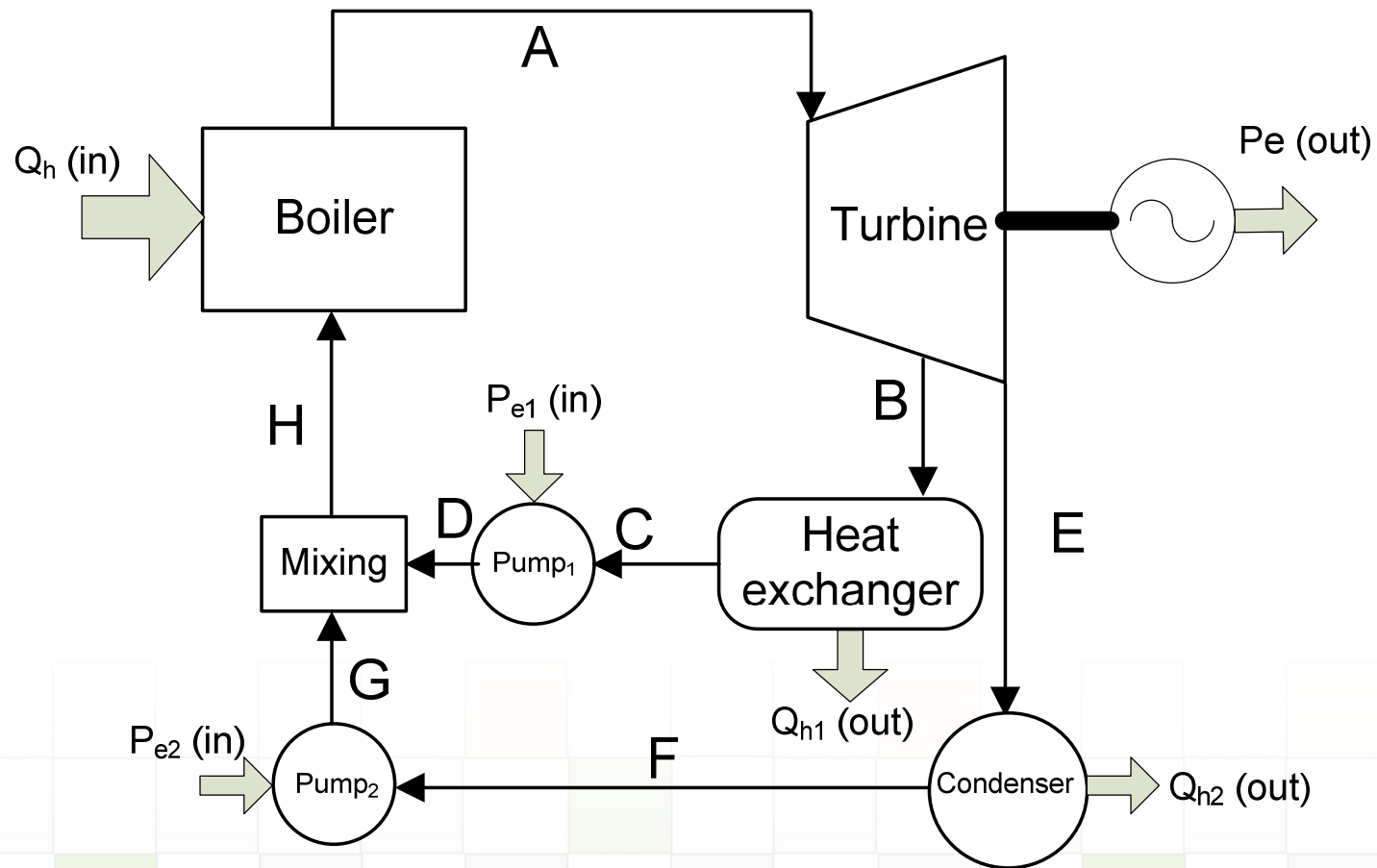


Figure 2.3 Elements of pass out condensing steam turbine cycle



2.2 Combined Heat and Power plants

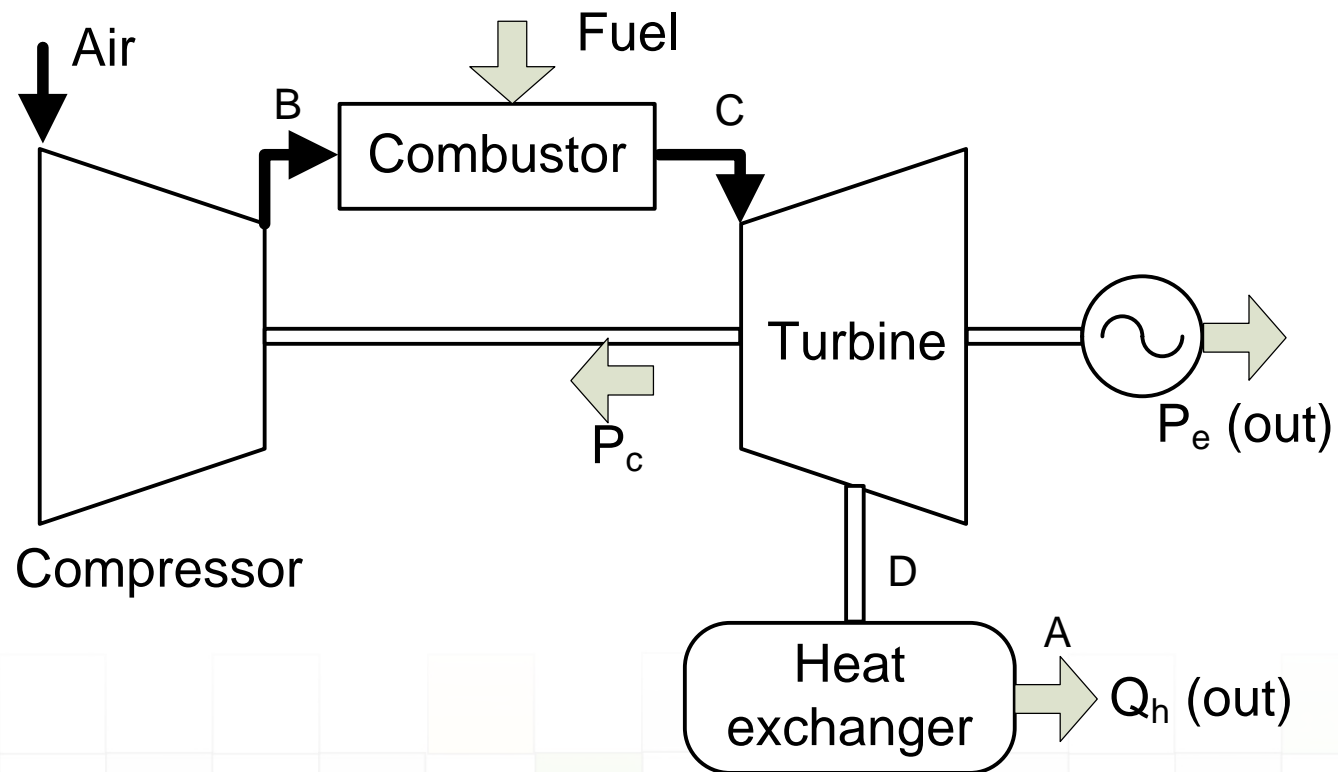


Figure 2.4 Simple cycle, single shaft gas turbine



2.2 Combined Heat and Power plants

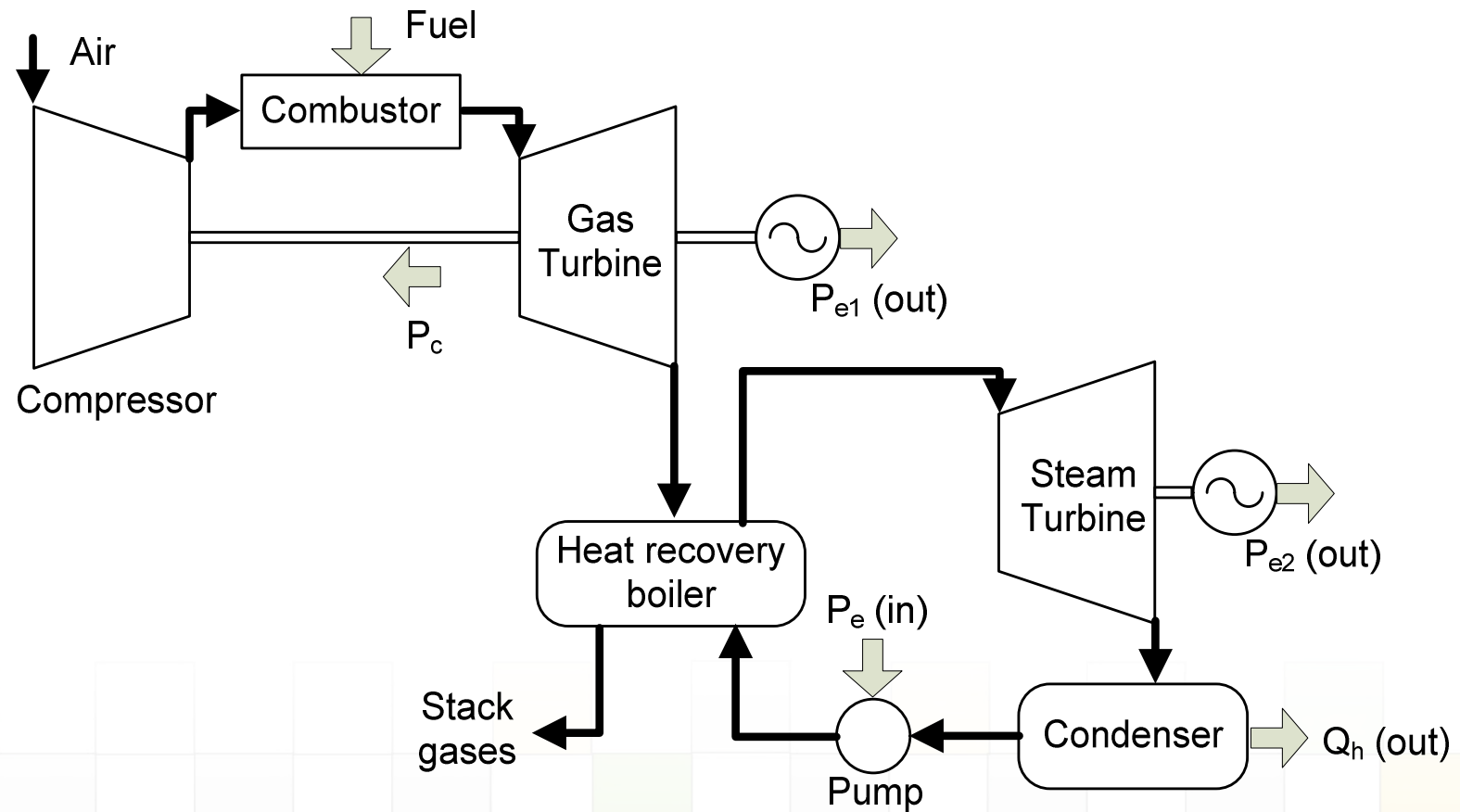


Figure 2.5 Combined cycle gas turbine



2.2 Combined Heat and Power plants

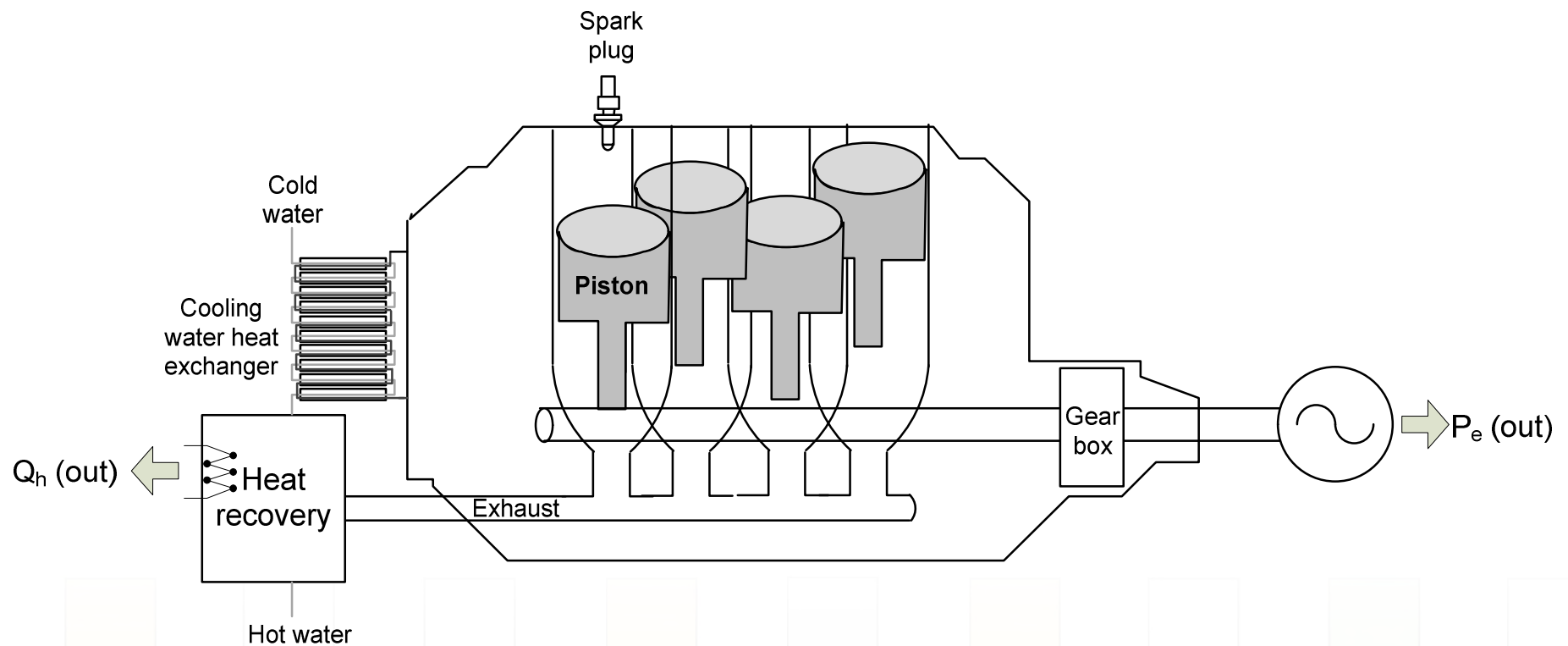


Figure 2.6 Components of an Otto engine based CHP unit

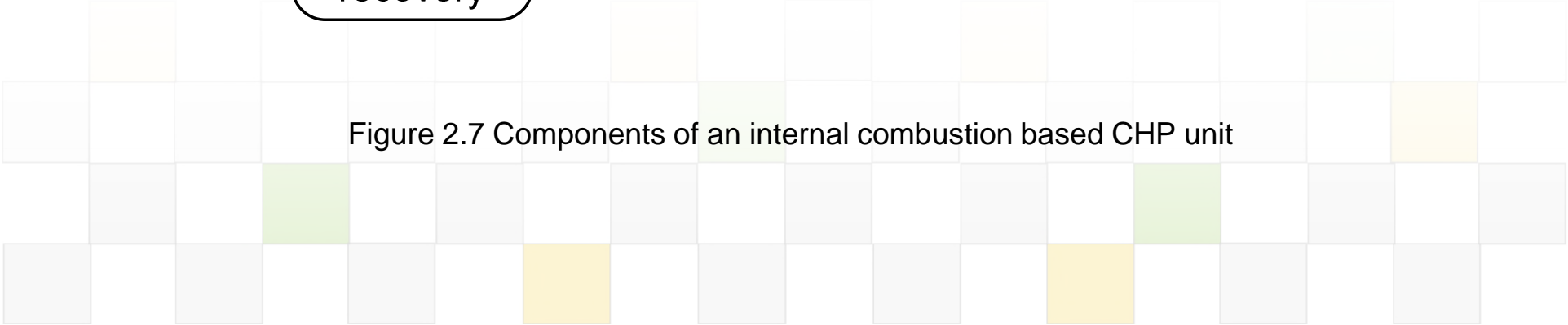


Figure 2.7 Components of an internal combustion based CHP unit

2.2 Combined Heat and Power plants

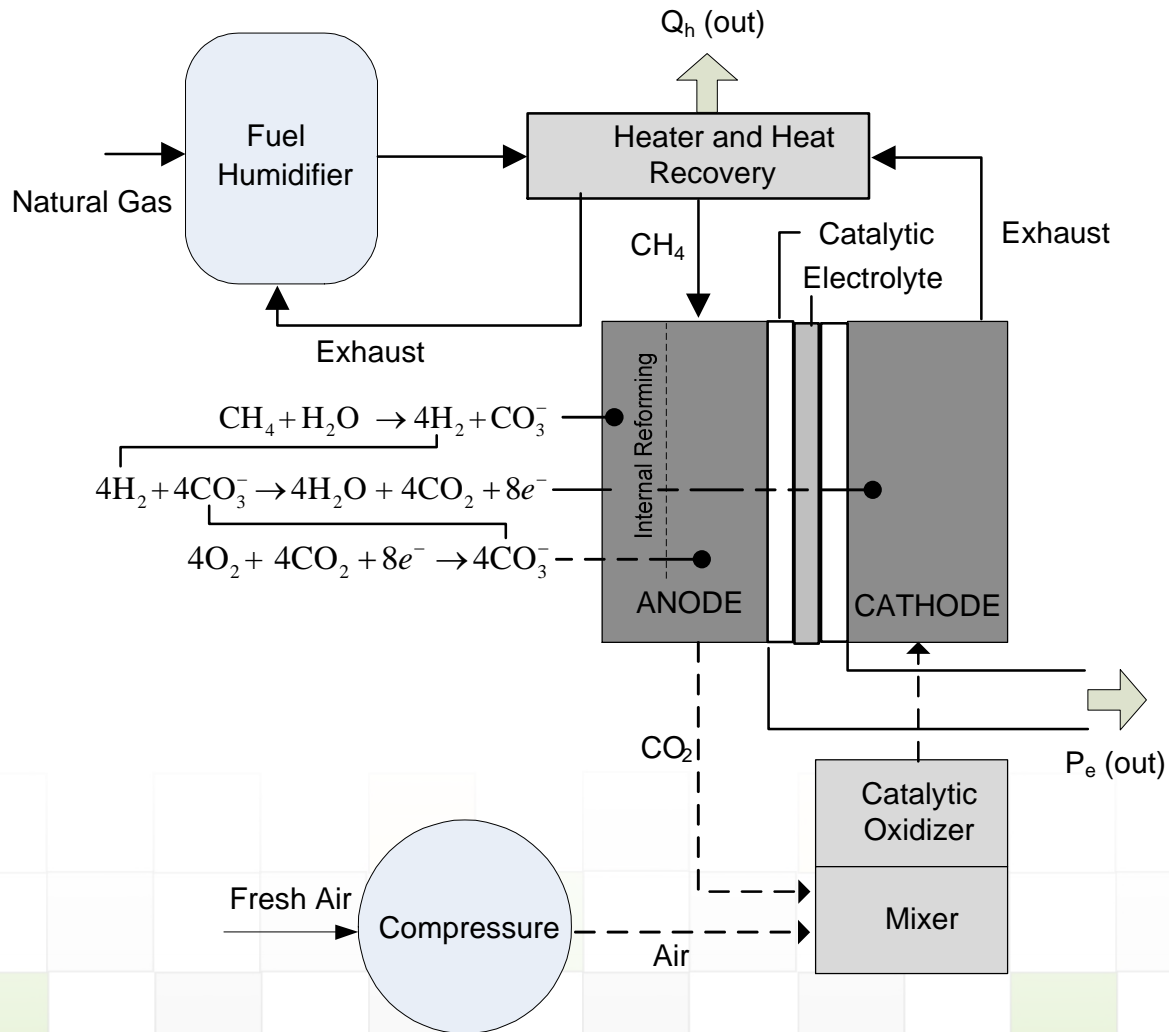


Figure 2.8 Fuel cell based CHP



2.3 Photovoltaic Energy Systems

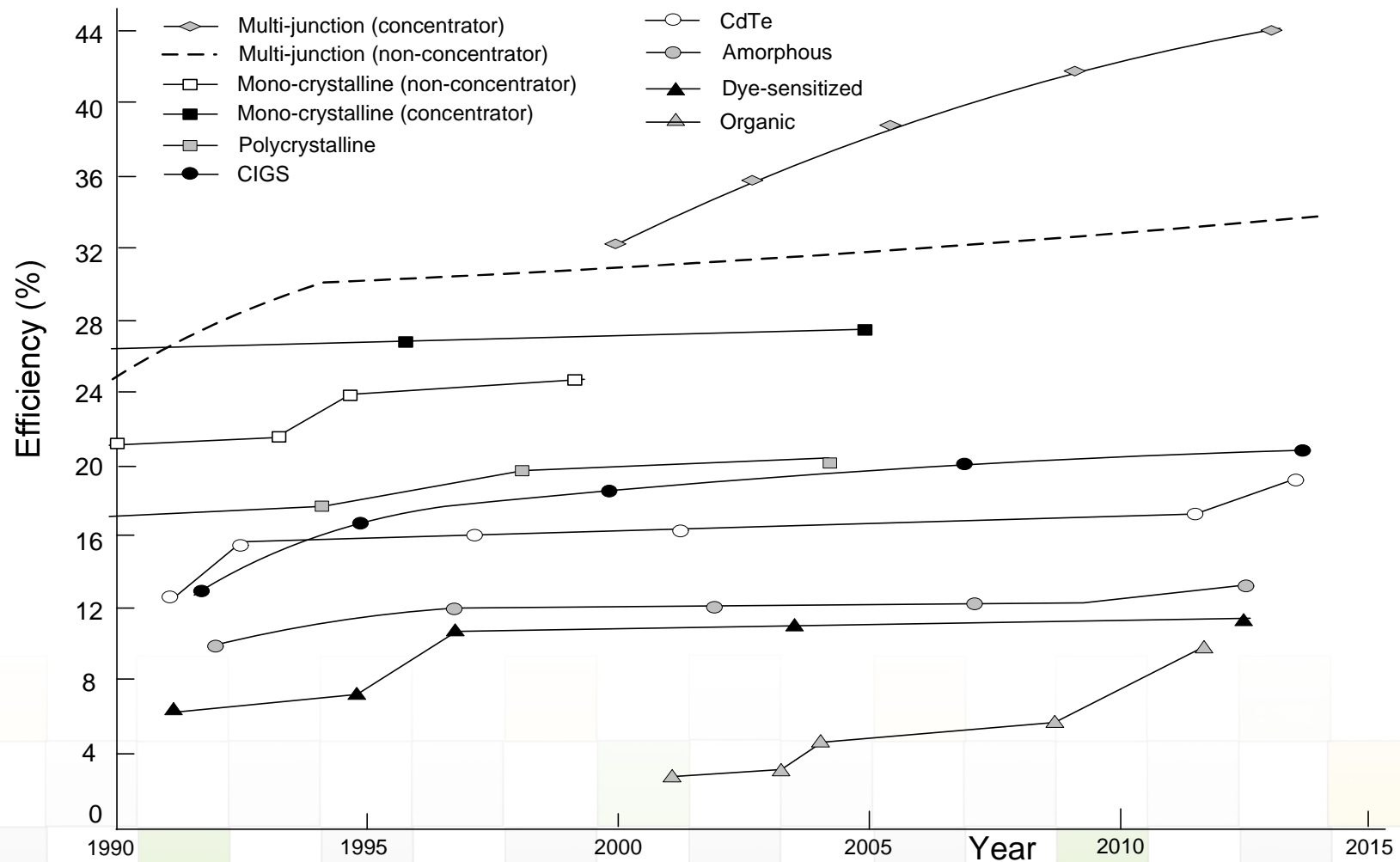
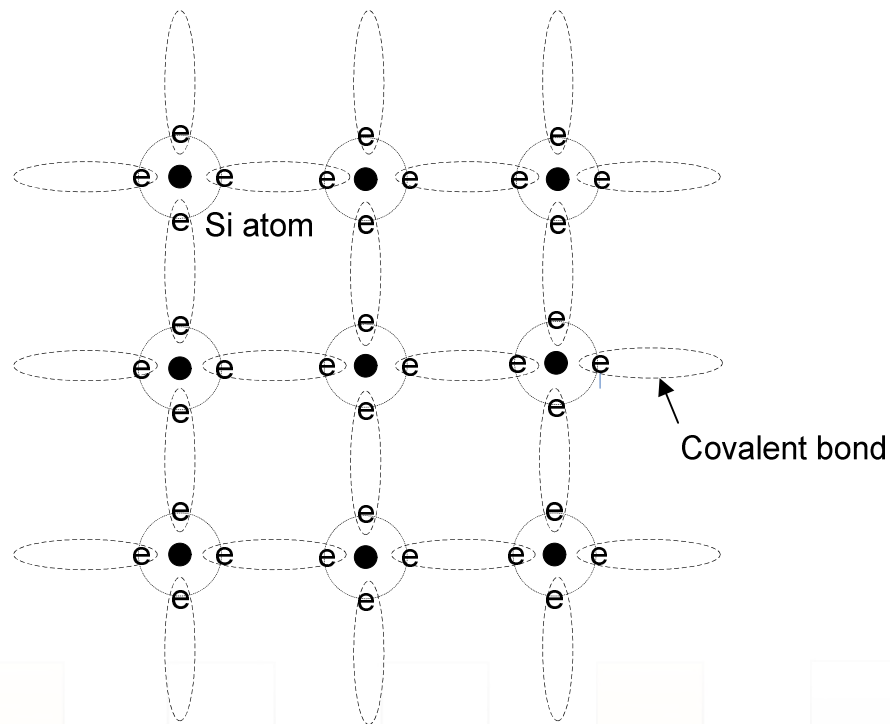


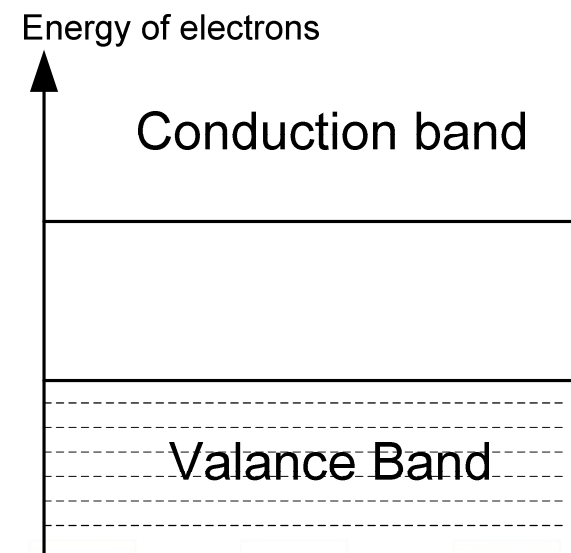
Figure 2.9 Trend lines of efficiencies of different PV technologies



2.3 Photovoltaic Energy Systems



(a) Crystalline Si structure

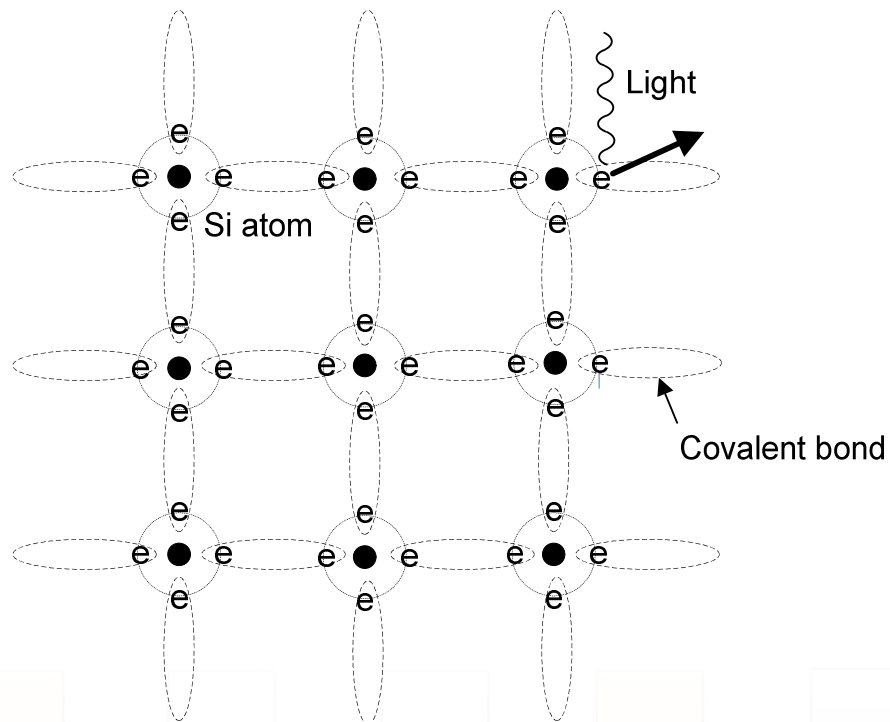


(b) Energy bands

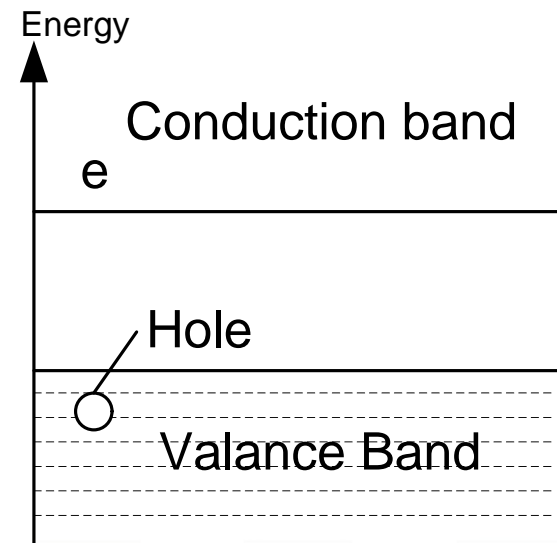
Figure 2.10 Intrinsic Si at absolute zero temperature



2.3 Photovoltaic Energy Systems



(a) Crystalline Si structure



(b) Energy bands

Figure 2.11 Intrinsic Si at when exposed to light



2.3 Photovoltaic Energy Systems

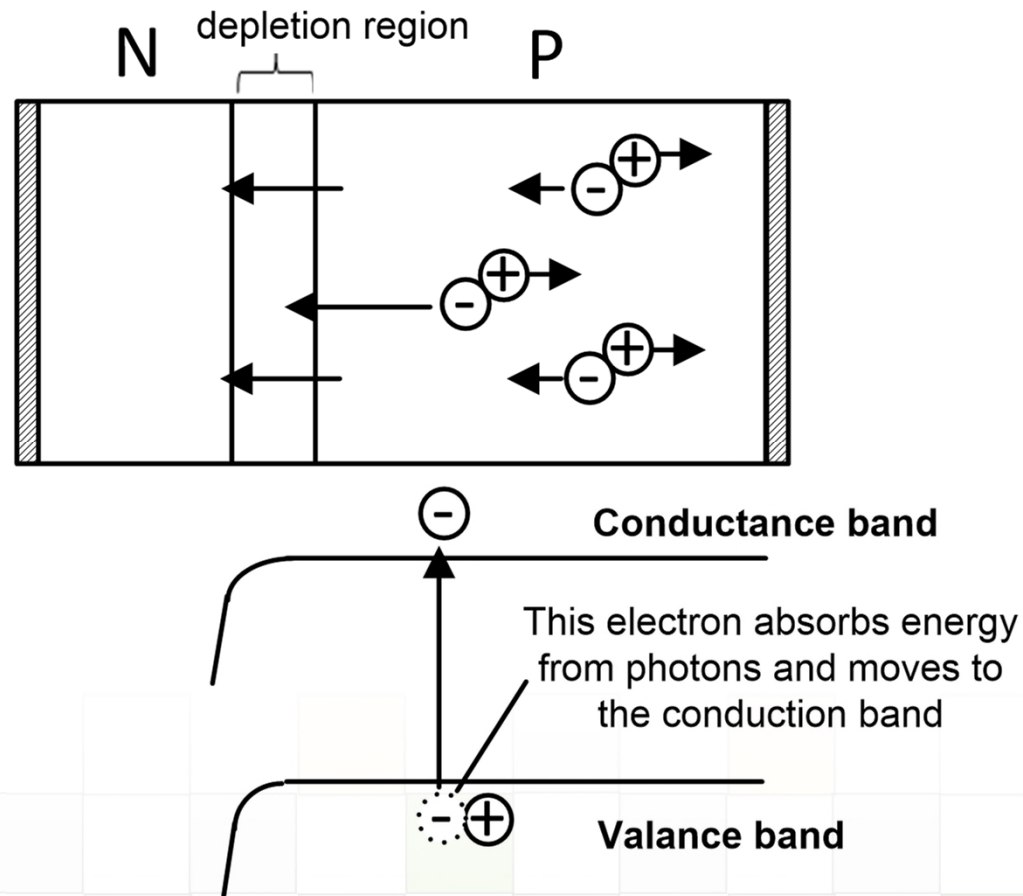


Figure 2.12 PN junction



2.3 Photovoltaic Energy Systems

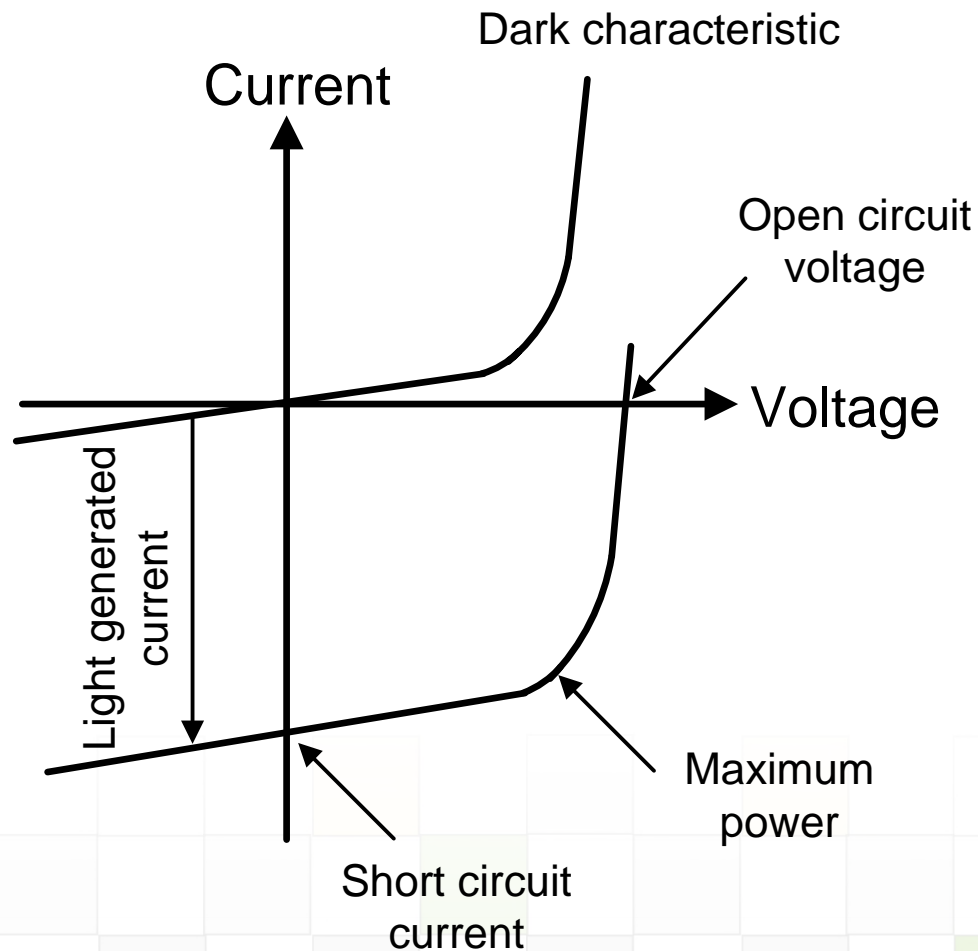


Figure 2.13 I-V characteristic



2.3 Photovoltaic Energy Systems

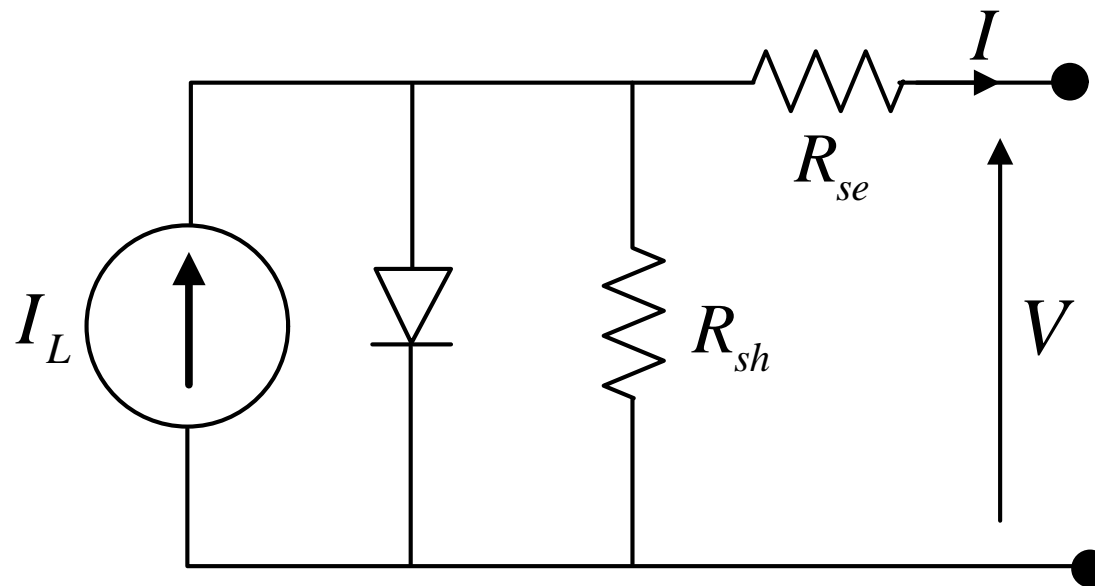


Figure 2.14 Equivalent circuit of a PV cell



2.3 Photovoltaic Energy Systems

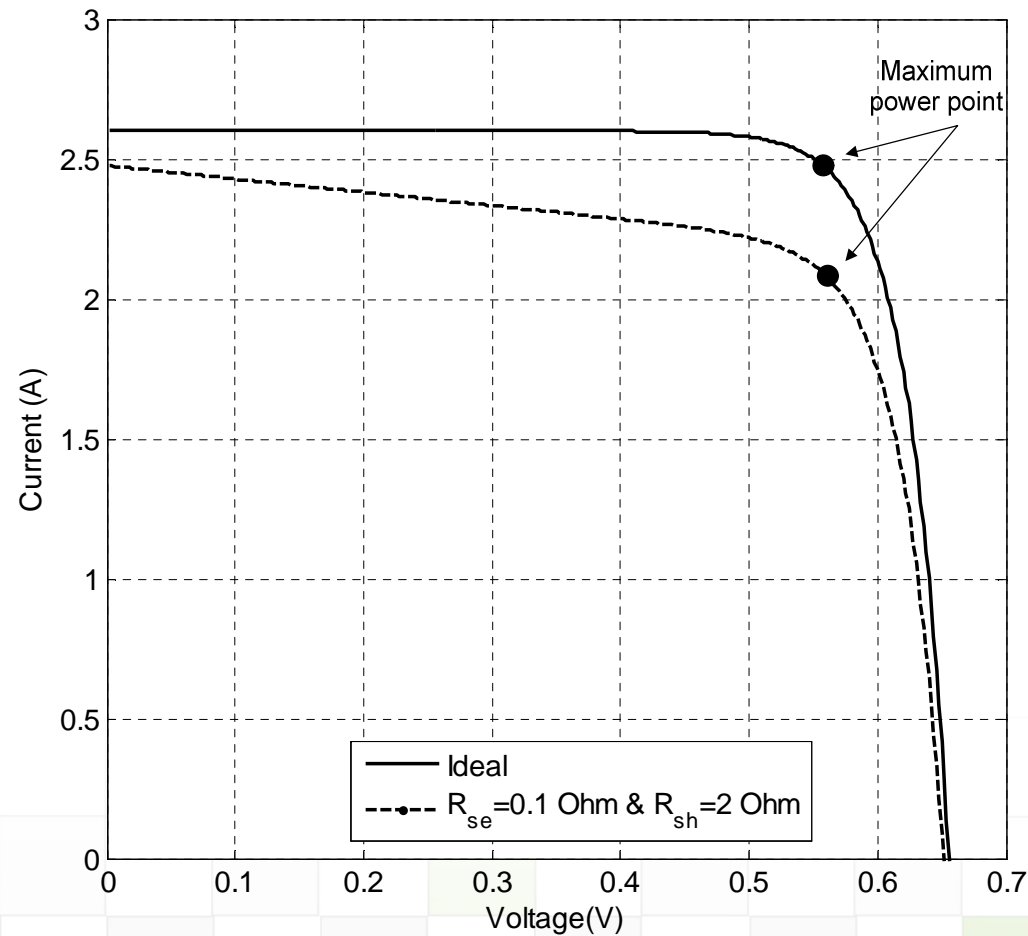


Figure 2.15 The effect of series and shunt resistance



2.3 Photovoltaic Energy Systems

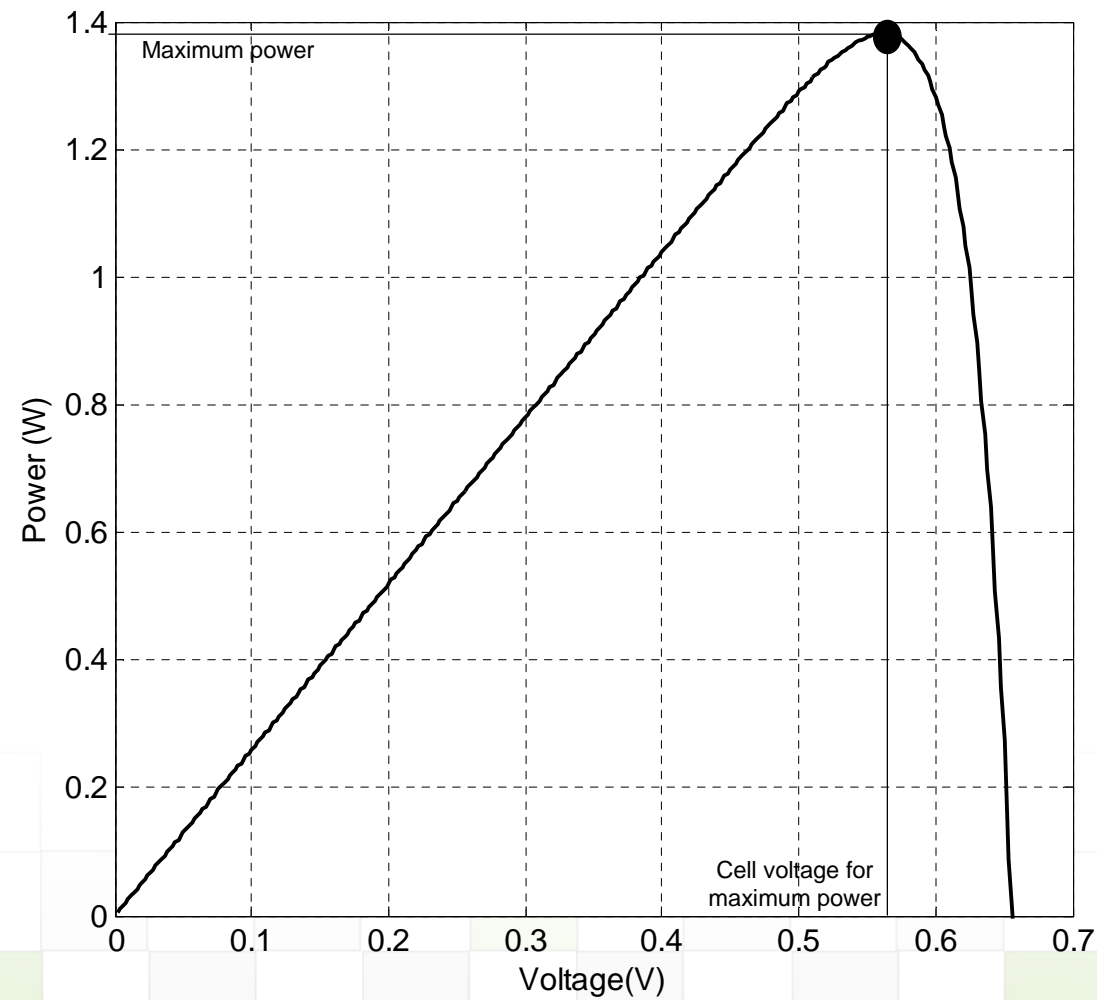
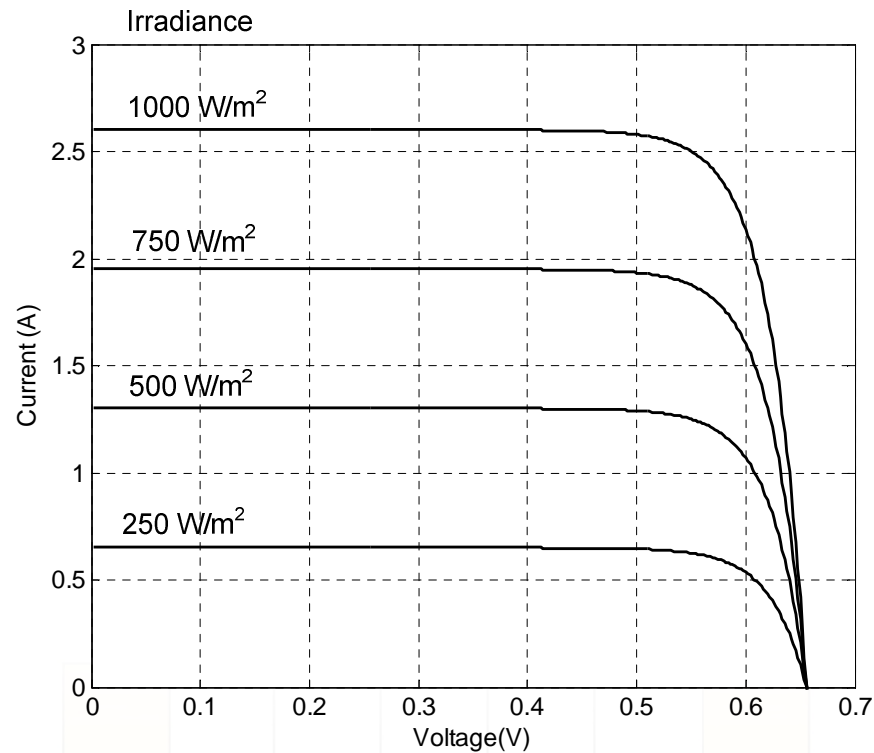


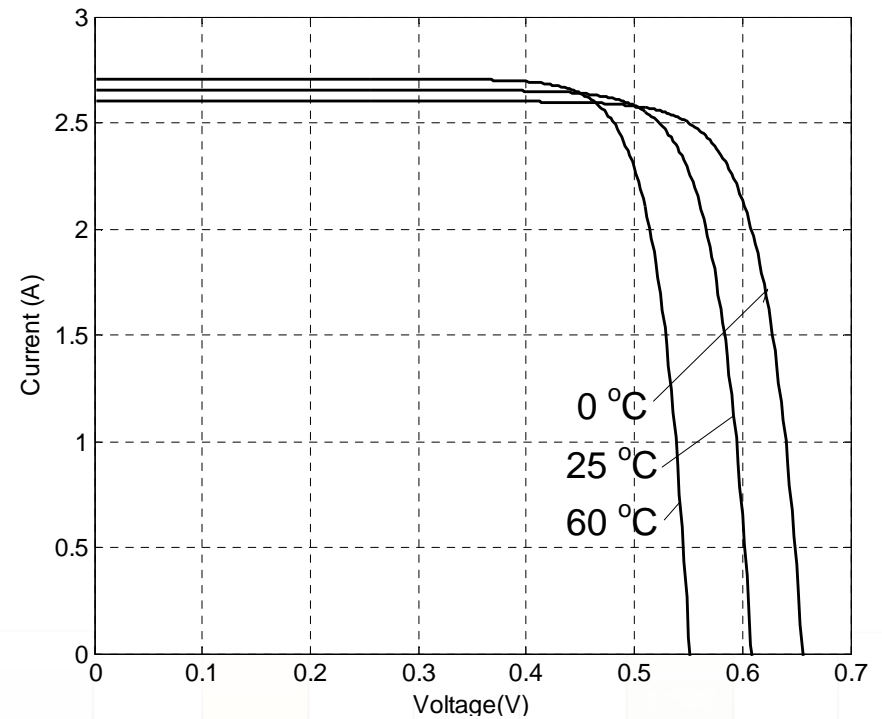
Figure 2.16 Power vs voltage characteristic



2.3 Photovoltaic Energy Systems



(a) Variation with irradiance



(b) Variation with cell temperature

Figure 2.17 The effect of series and shunt resistance



2.3 Photovoltaic Energy Systems

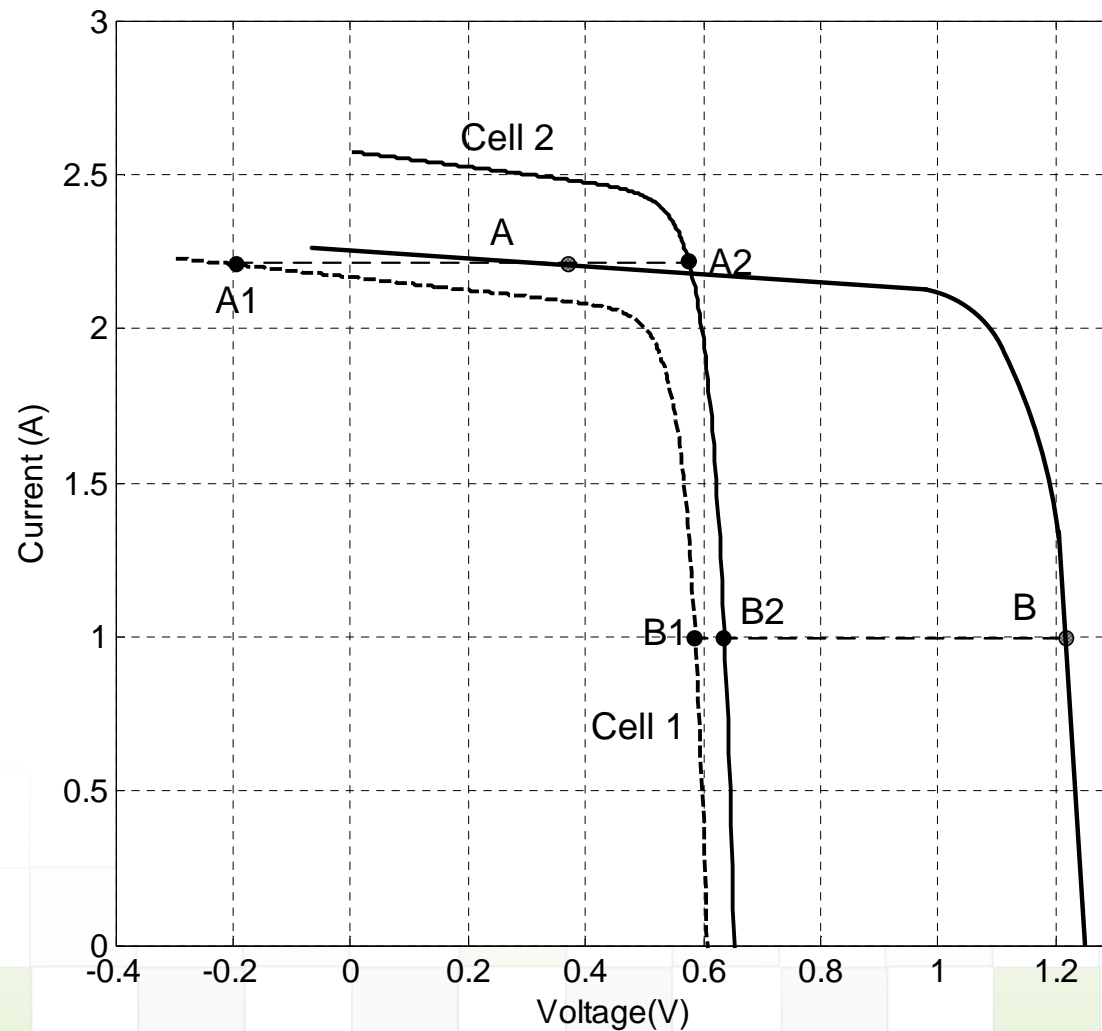


Figure 2.18 The effect of connection of non-identical PV cells in series



2.3 Photovoltaic Energy Systems

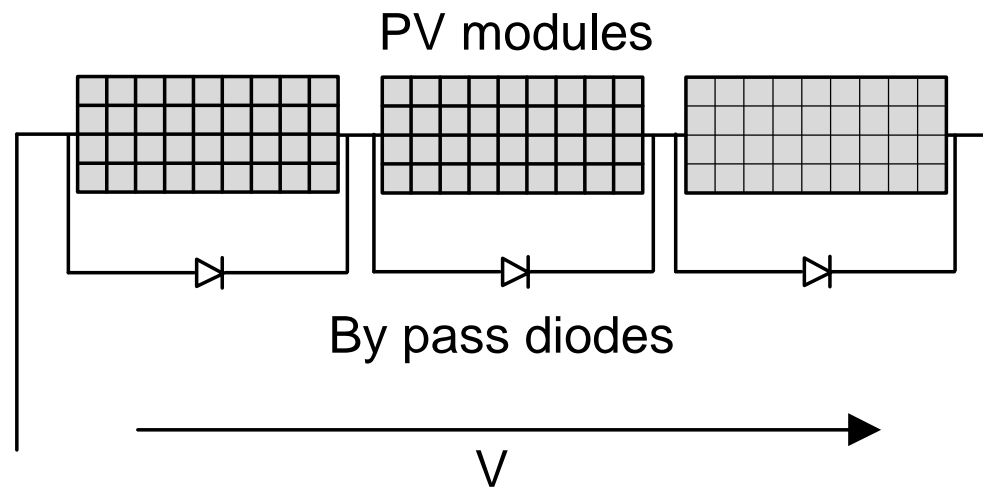
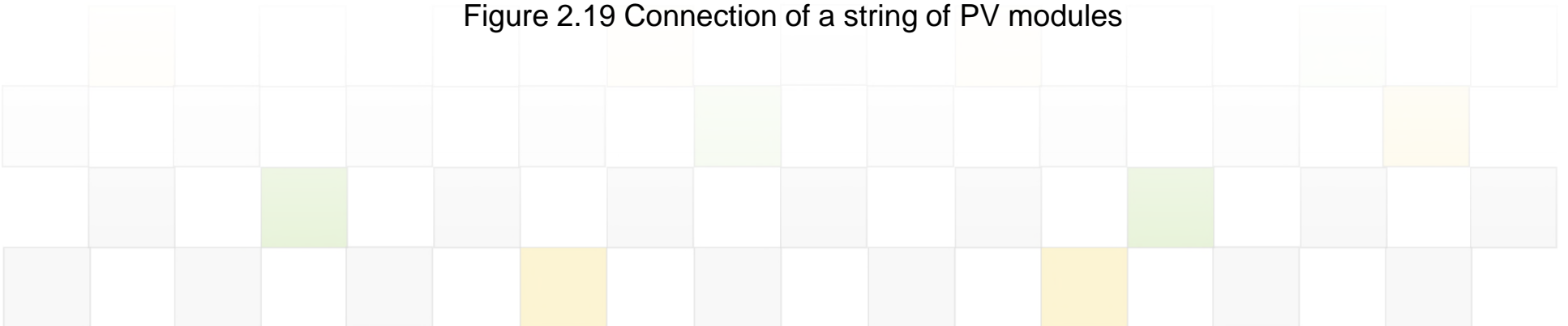


Figure 2.19 Connection of a string of PV modules





2.3 Photovoltaic Energy Systems

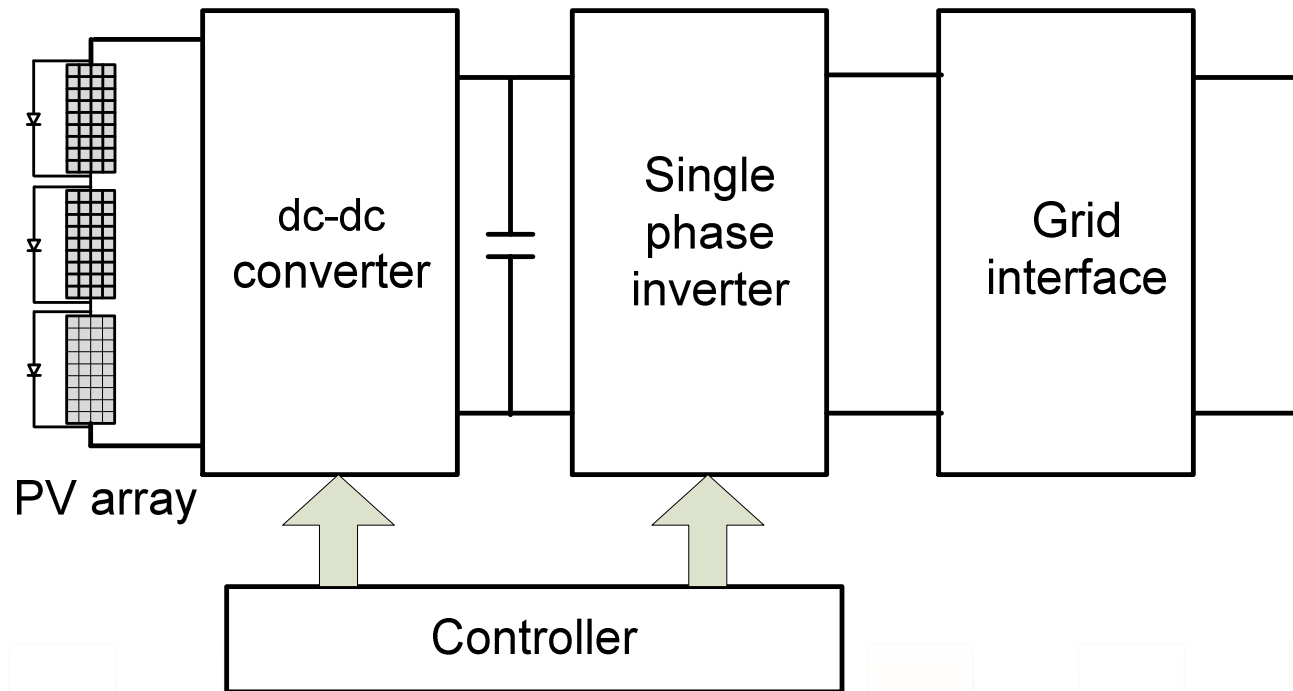


Figure 2.20 Grid connected PV arrays



2.3 Photovoltaic Energy Systems

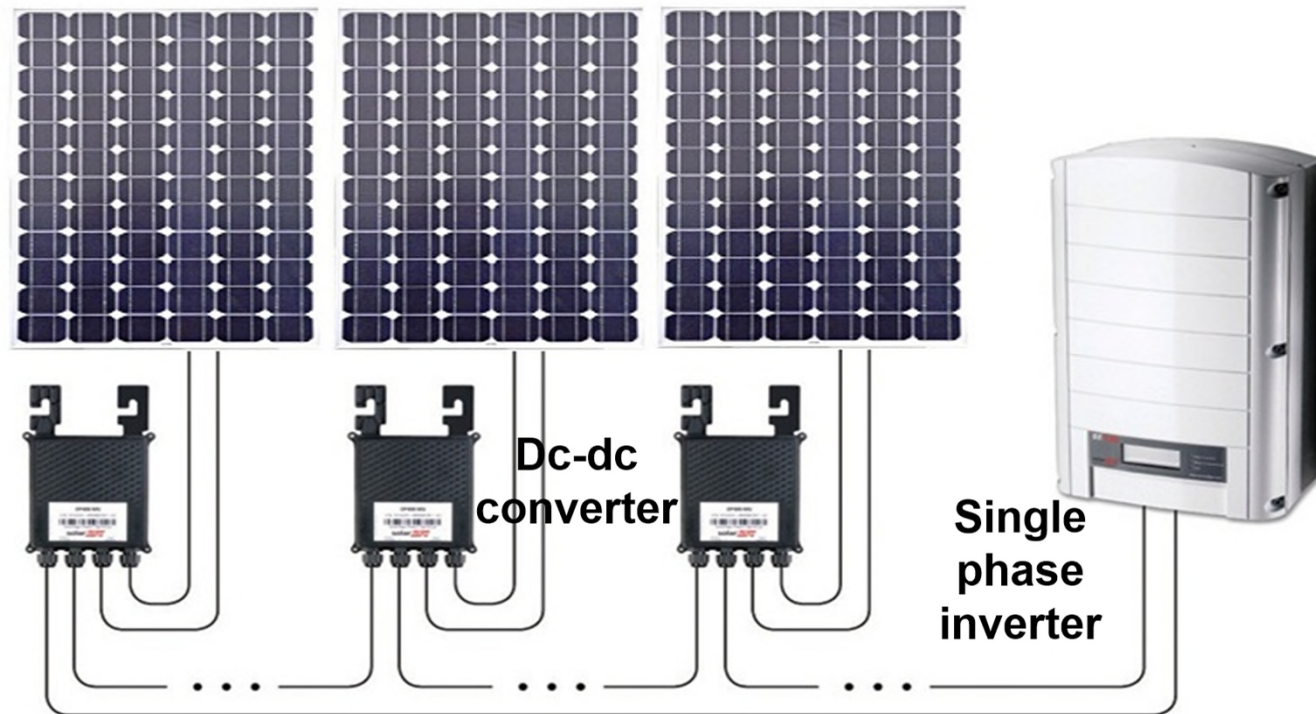


Figure 2.21 PV array with a single inverter and dc-dc converter for each module



2.3 Photovoltaic Energy Systems

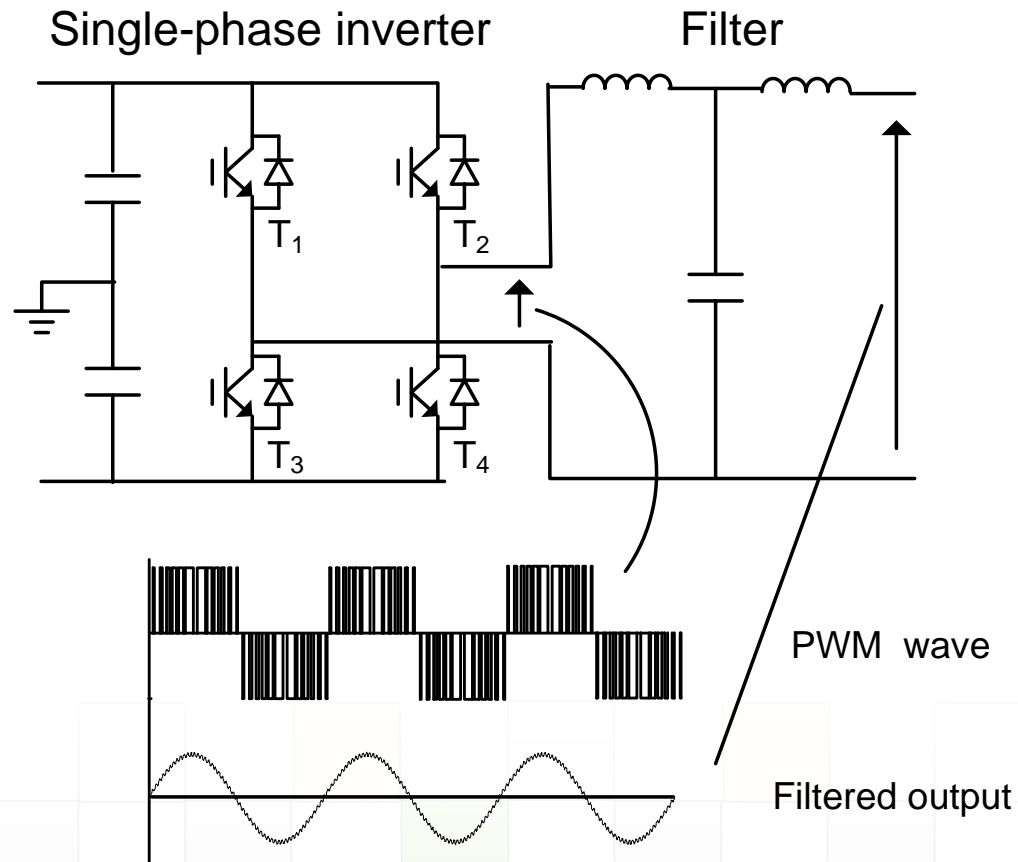
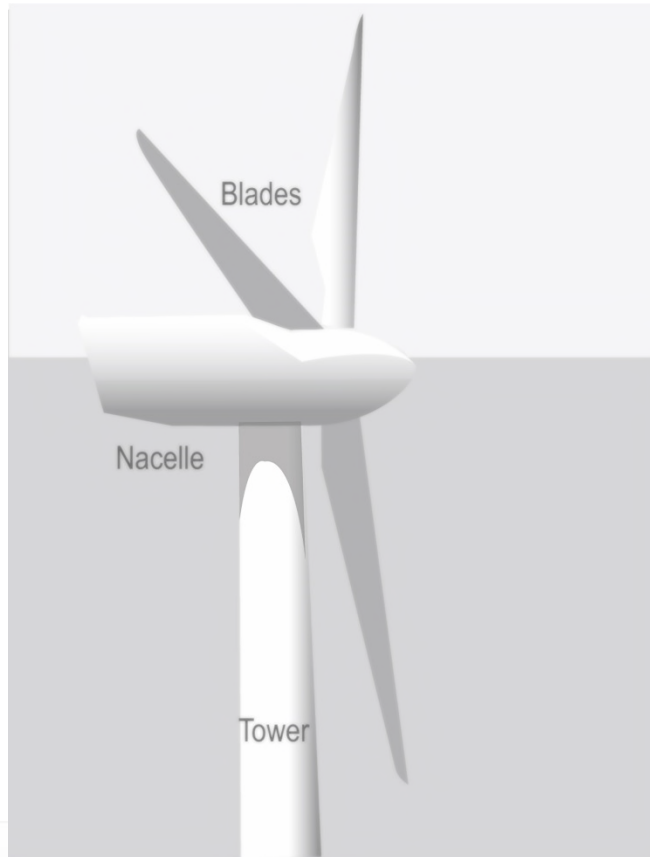


Figure 2.22 Single phase inverter



2.4 Wind Energy Systems



(a) Horizontal axis wind turbine (Courtesy of Wind Force (Pvt) Ltd)



(b) Vertical axis wind turbine

Figure 2.23 Vertical axis wind turbine



2.4 Wind Energy Systems

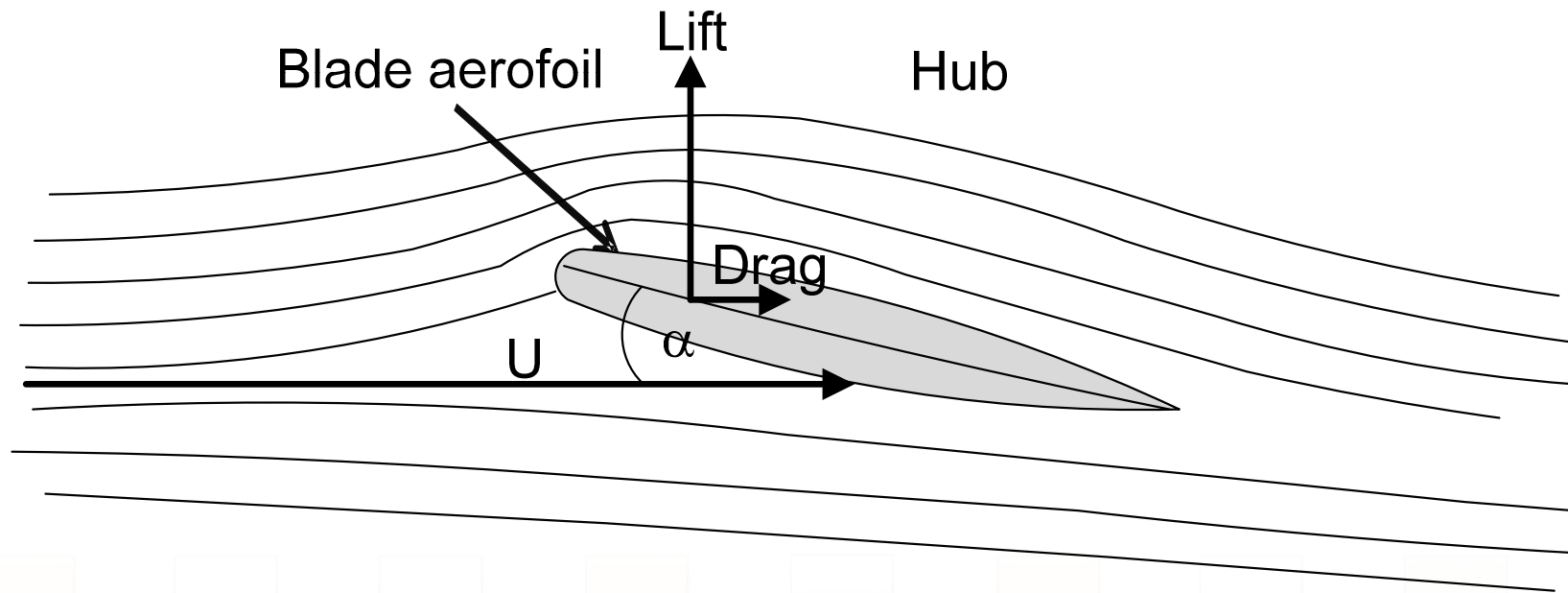


Figure 2.24 Flow of air past an aerofoil



2.4 Wind Energy Systems

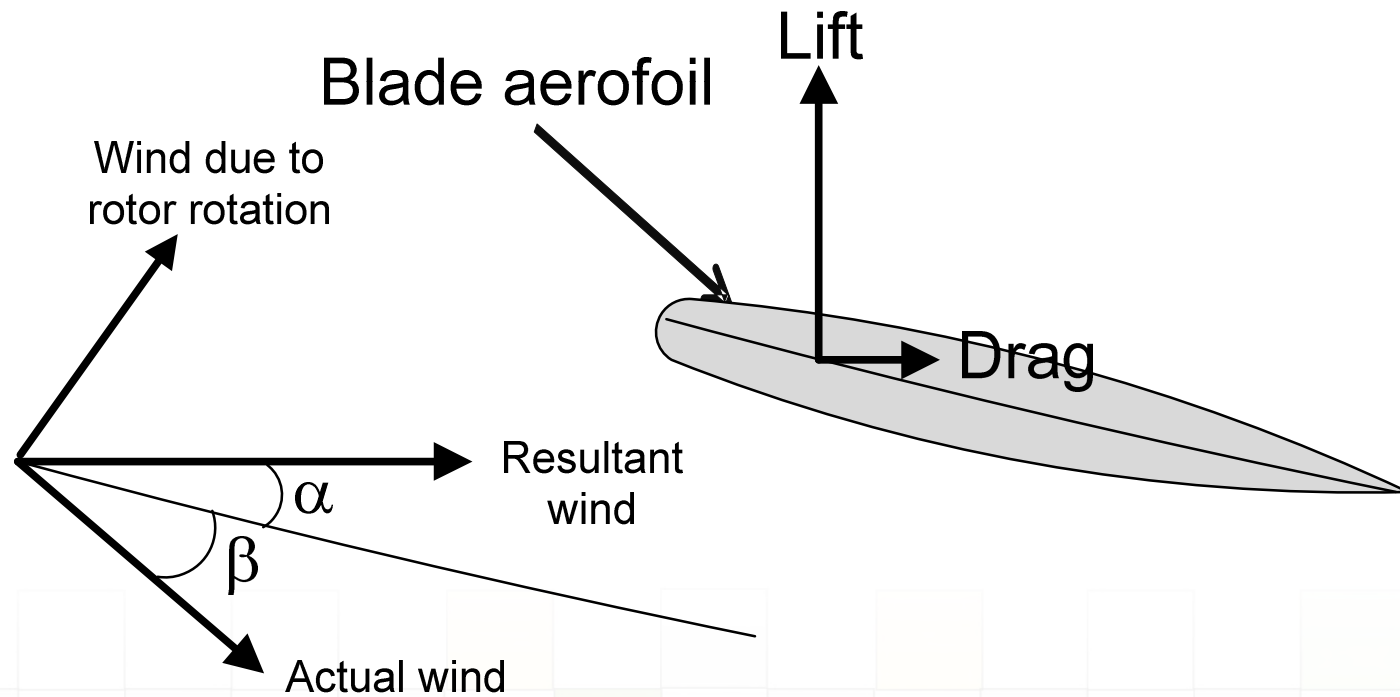


Figure 2.25 Relative wind



2.4 Wind Energy Systems

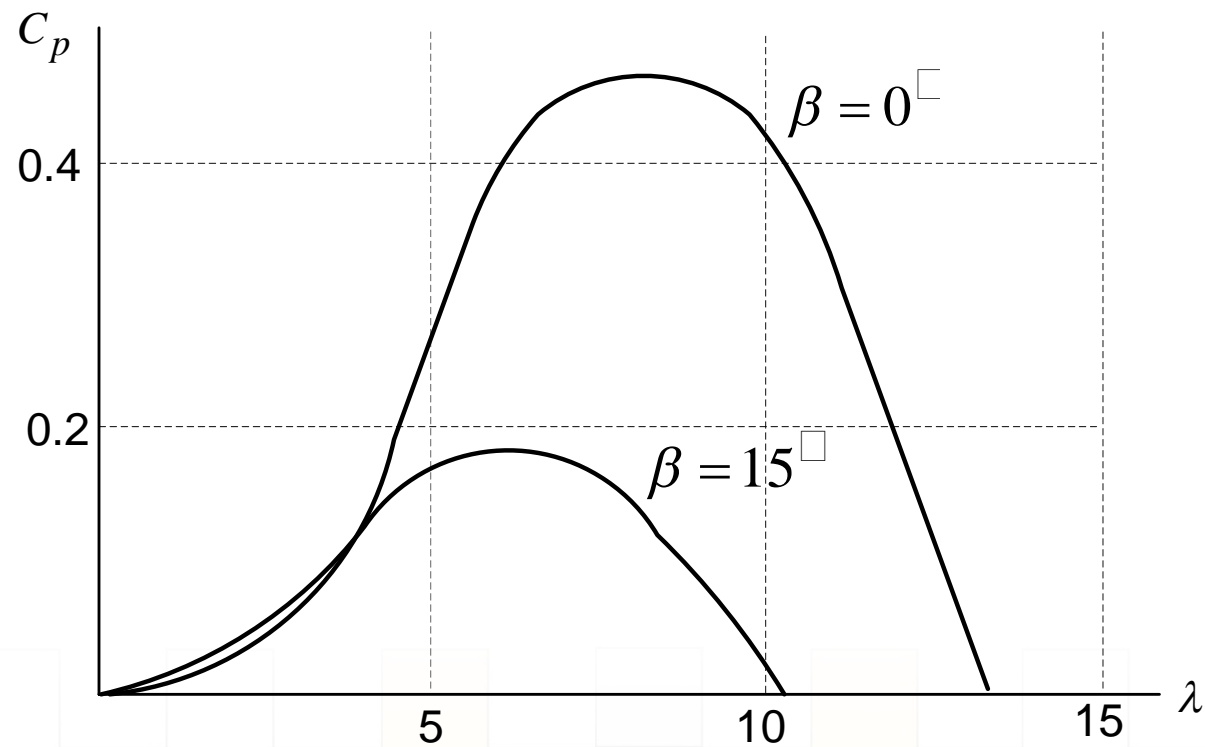


Figure 2.26 Variation of power coefficient with α and β



2.4 Wind Energy Systems

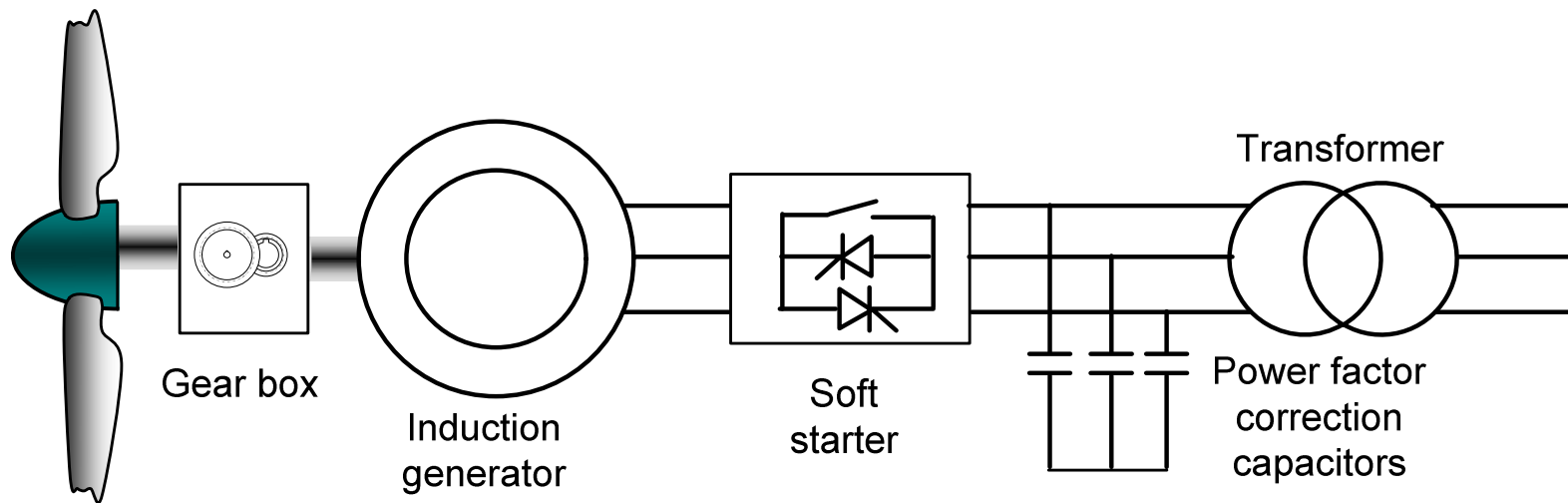


Figure 2.27 Component of a fixed speed wind turbine



2.4 Wind Energy Systems

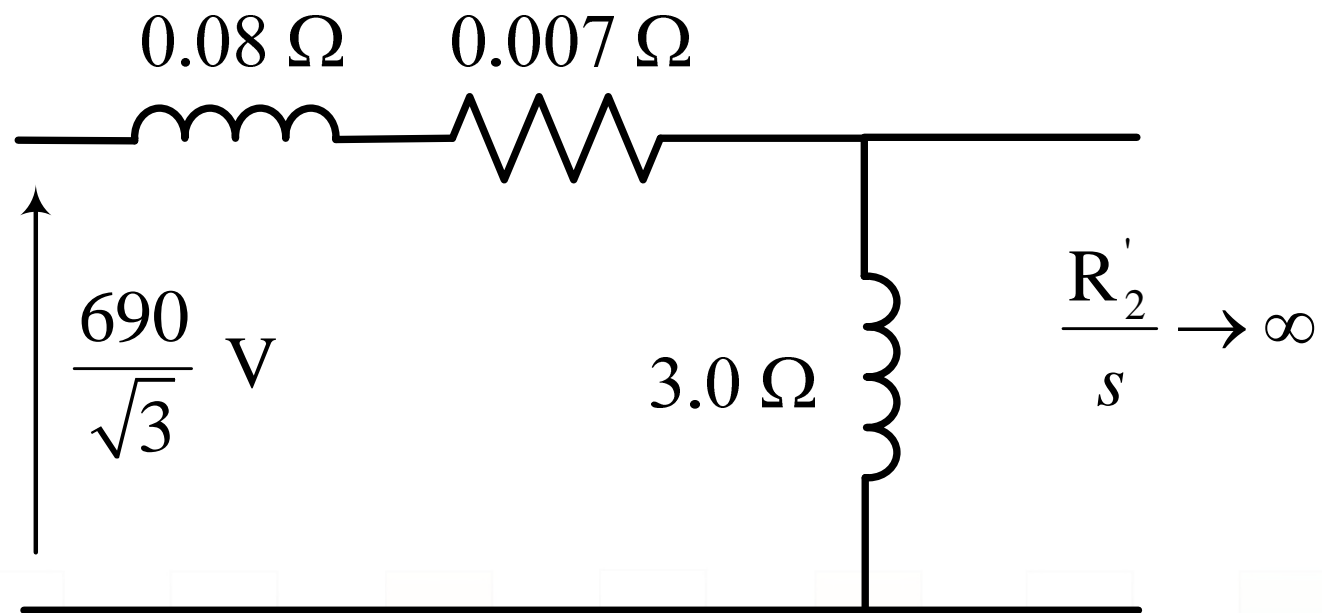


Figure 2.28 No-load equivalent circuit of the induction generator



2.4 Wind Energy Systems

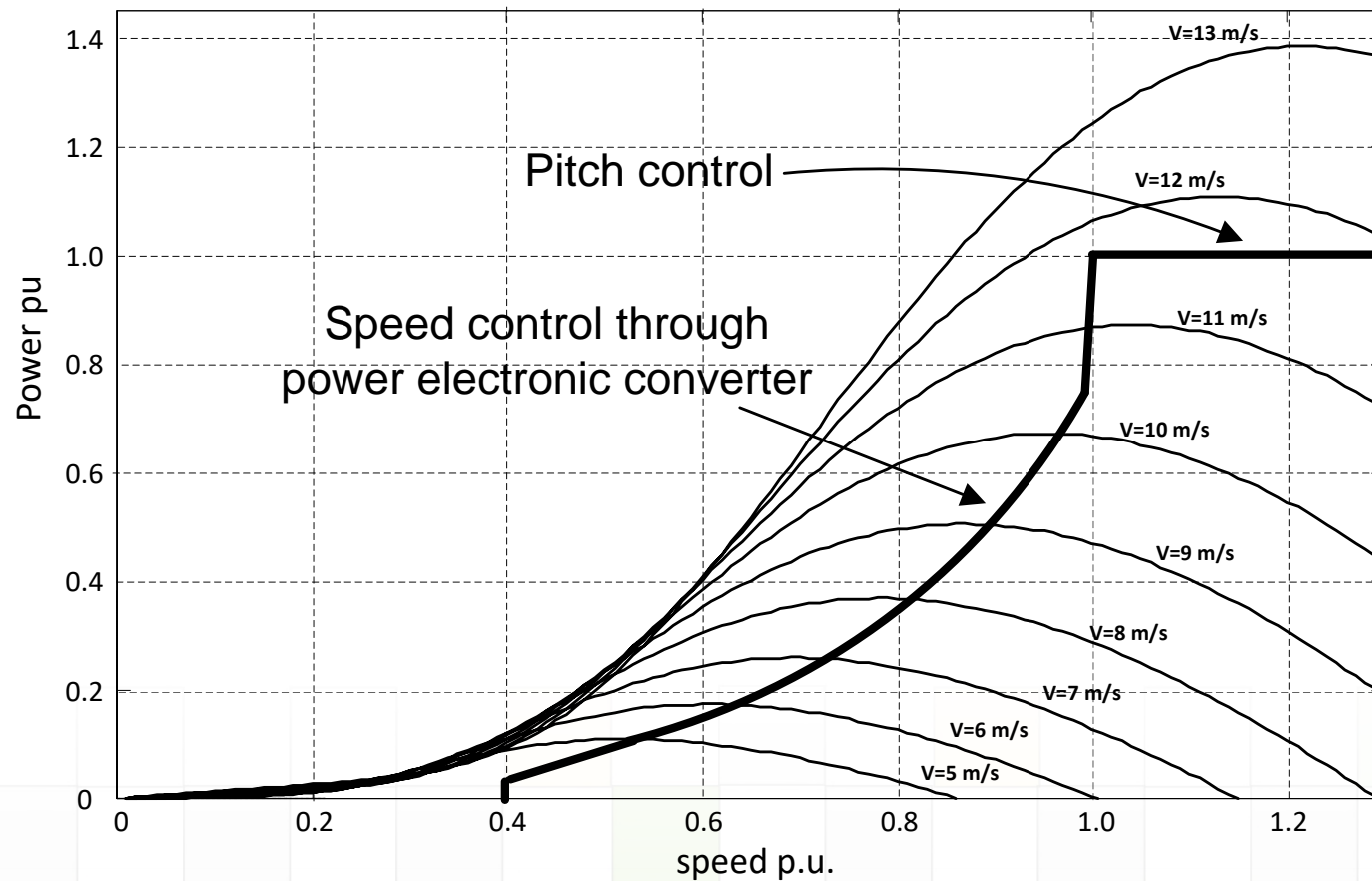


Figure 2.29 Operation of a variable speed wind turbine



2.4 Wind Energy Systems

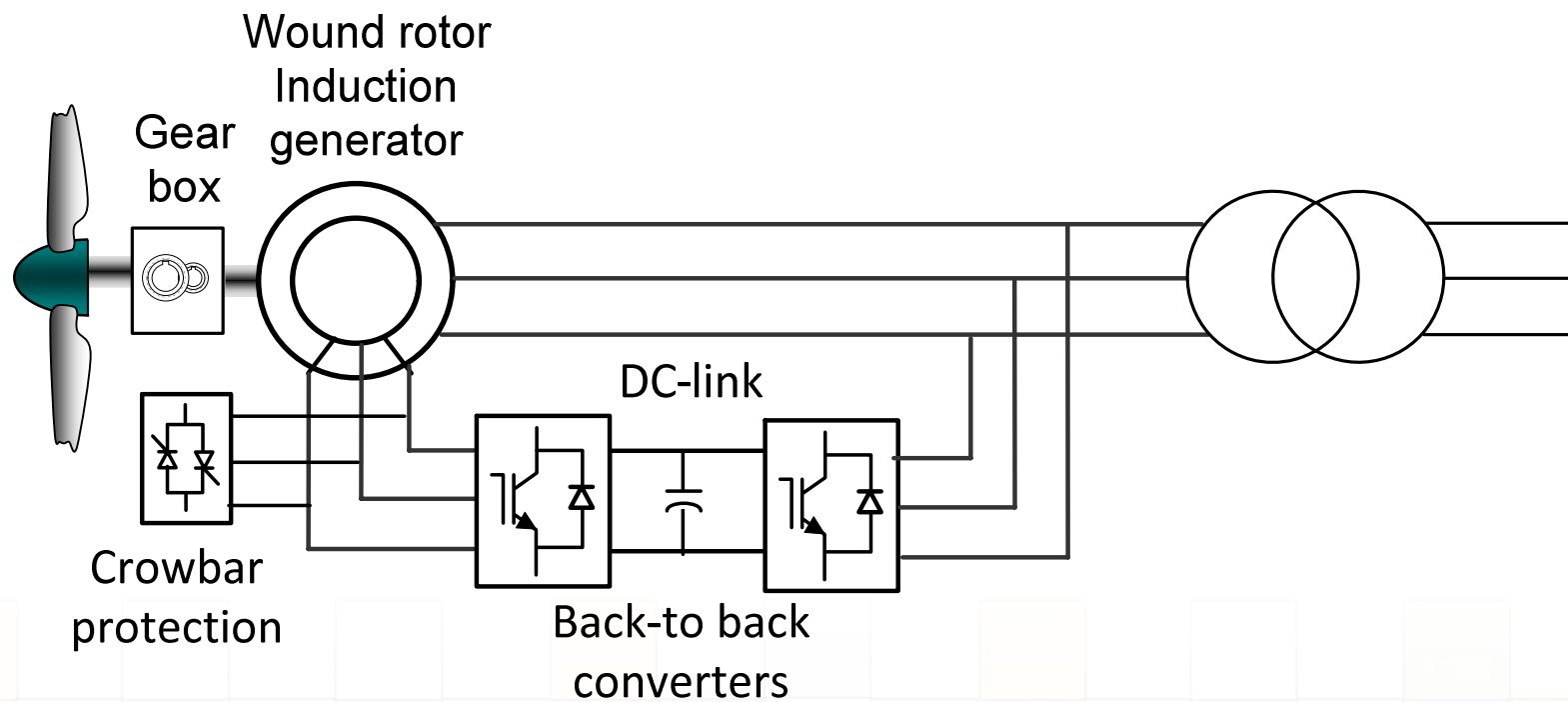


Figure 2.30 DFIG wind turbine



2.4 Wind Energy Systems

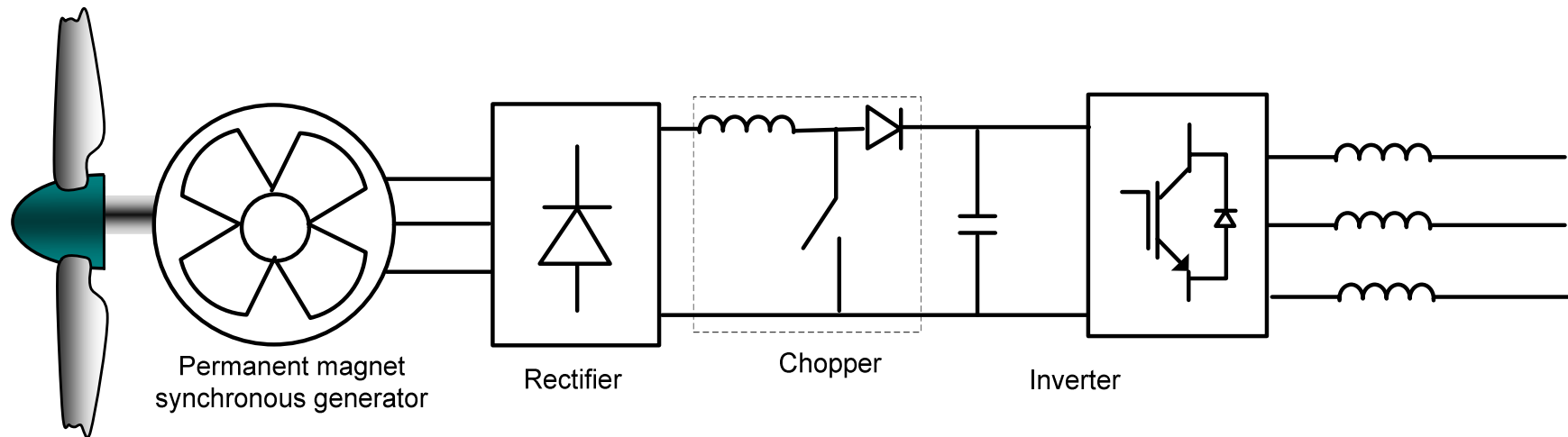


Figure 2.31 Gearless FSFC wind turbine with a diode rectifier



2.4 Wind Energy Systems

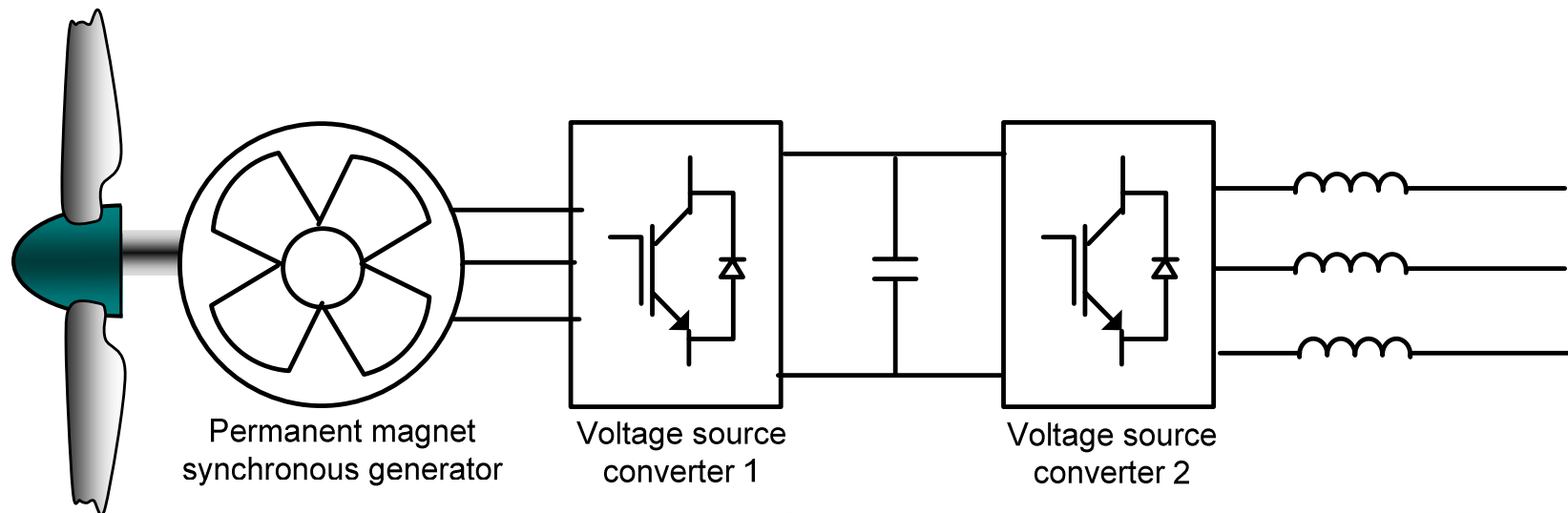


Figure 2.32 Gearless FCFS wind turbine with back-to-back converters



2.5 Electrical Energy Storage

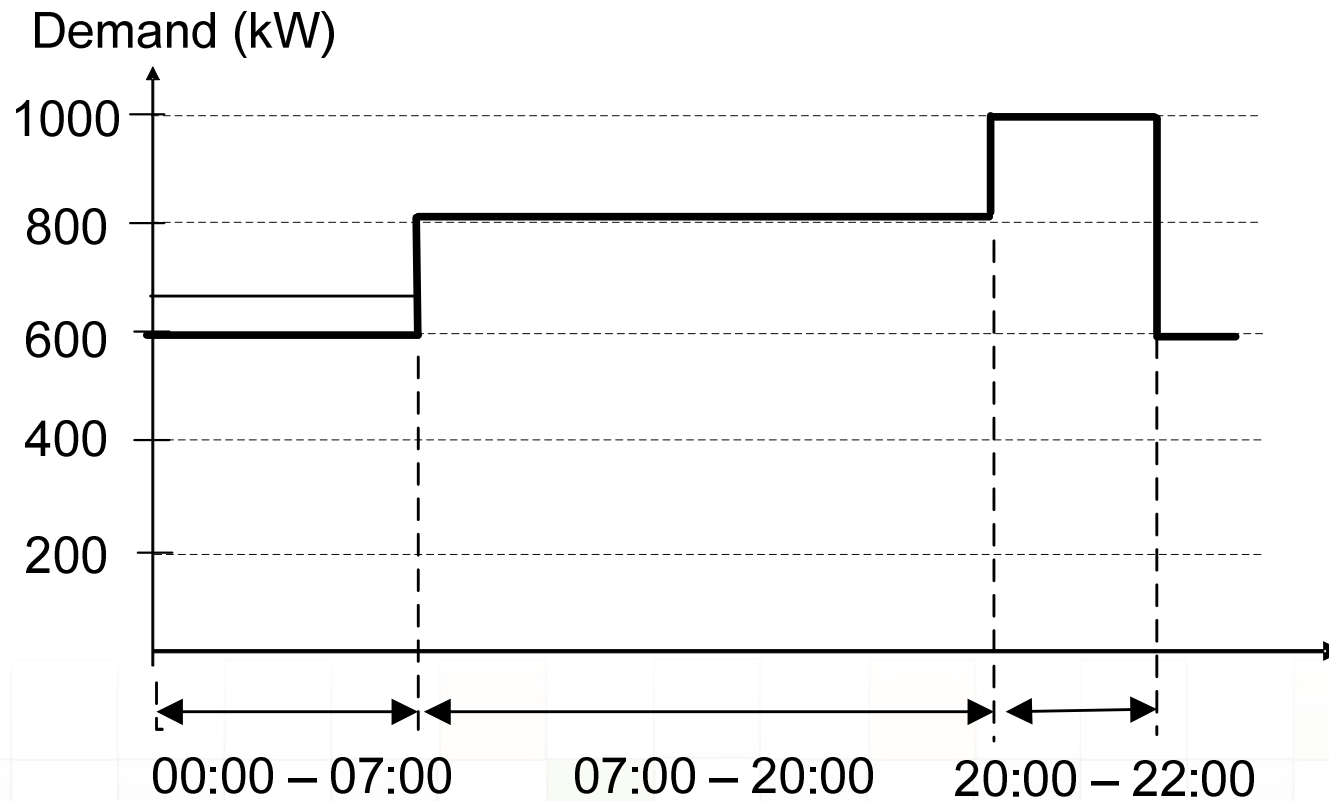


Figure 2.33 Demand profile



2.5 Electrical Energy Storage

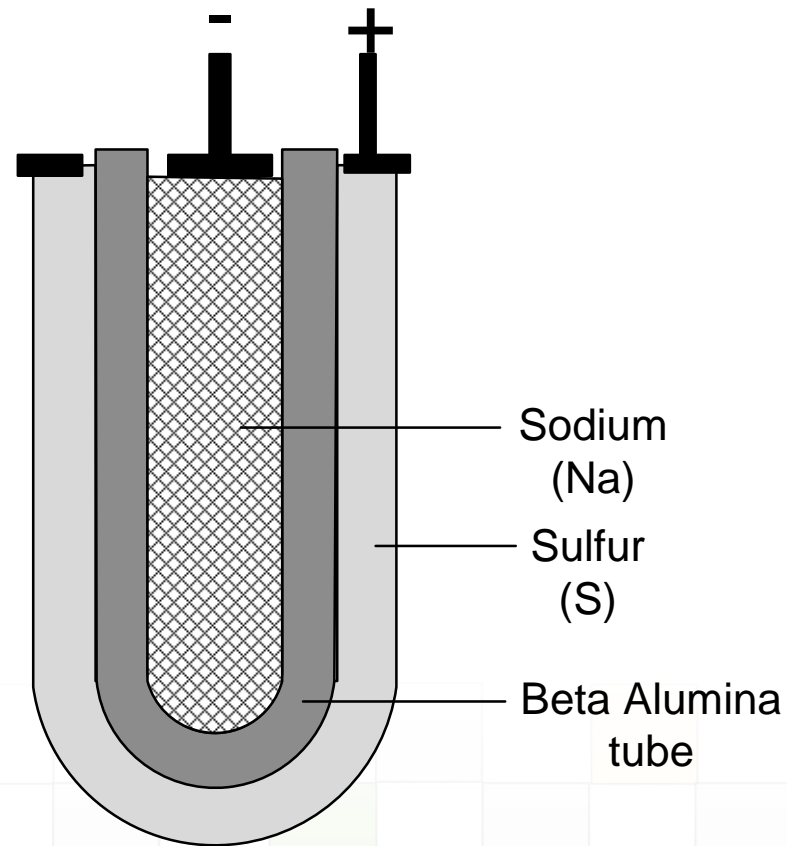


Figure 2.34 NaS battery



2.5 Electrical Energy Storage

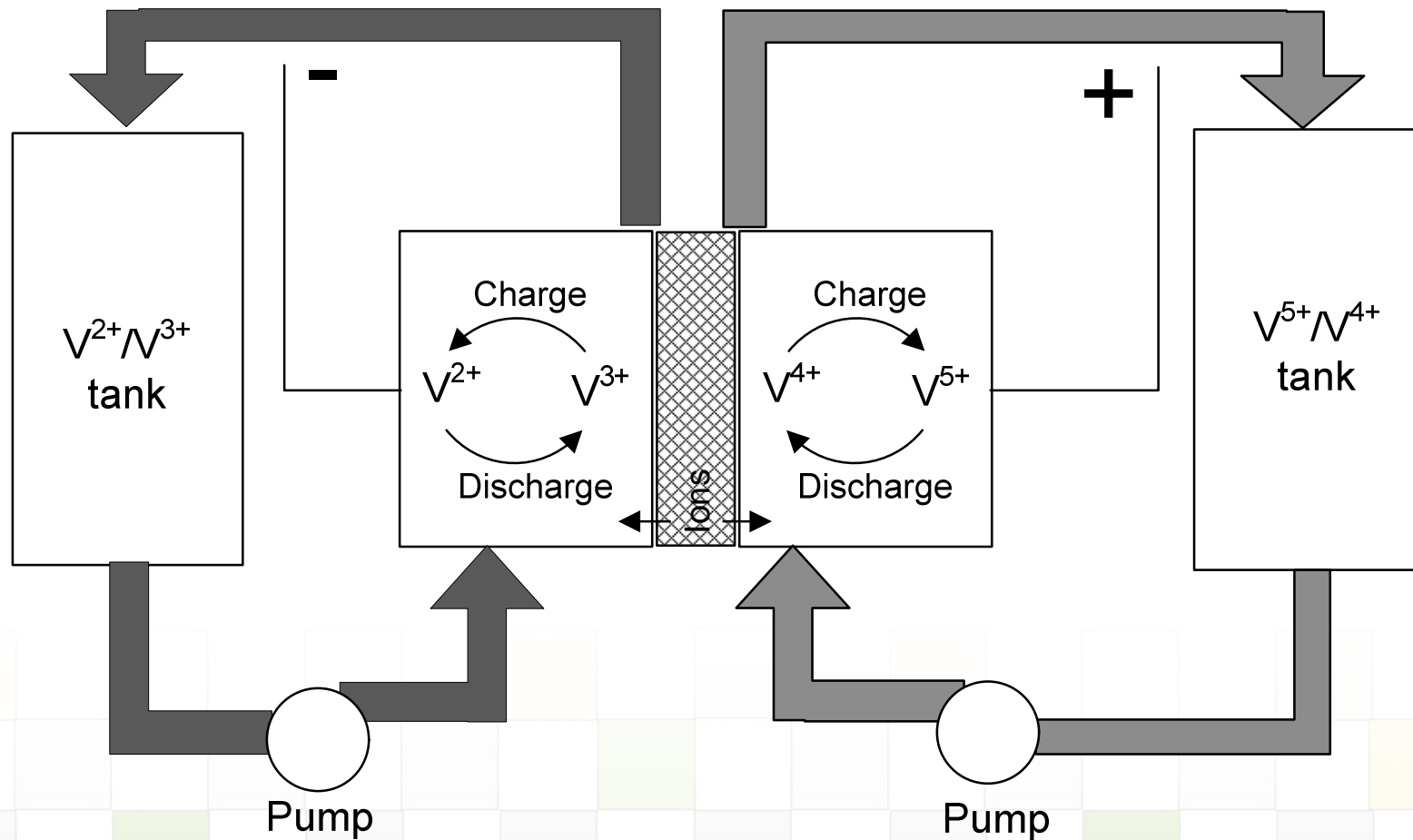


Figure 2.35 VRB flow battery system



2.6 Flexible Demand

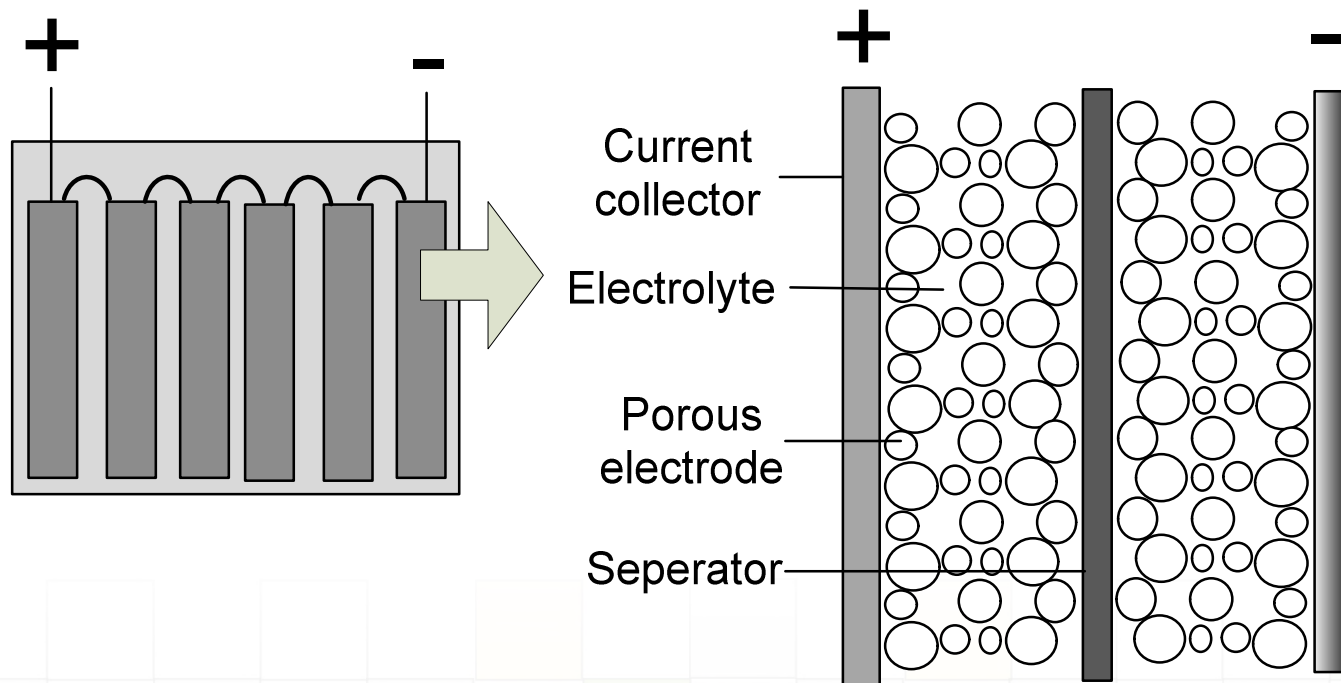


Figure 2.36 Ultra-capacitor module and cell



Thank You!