FACULDADE DE CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA
Departamento de Engenharia Electrotécnica

IPS Instituto Politécnico de Setúbal
Escola Superior de Tecnologia de Setúbal

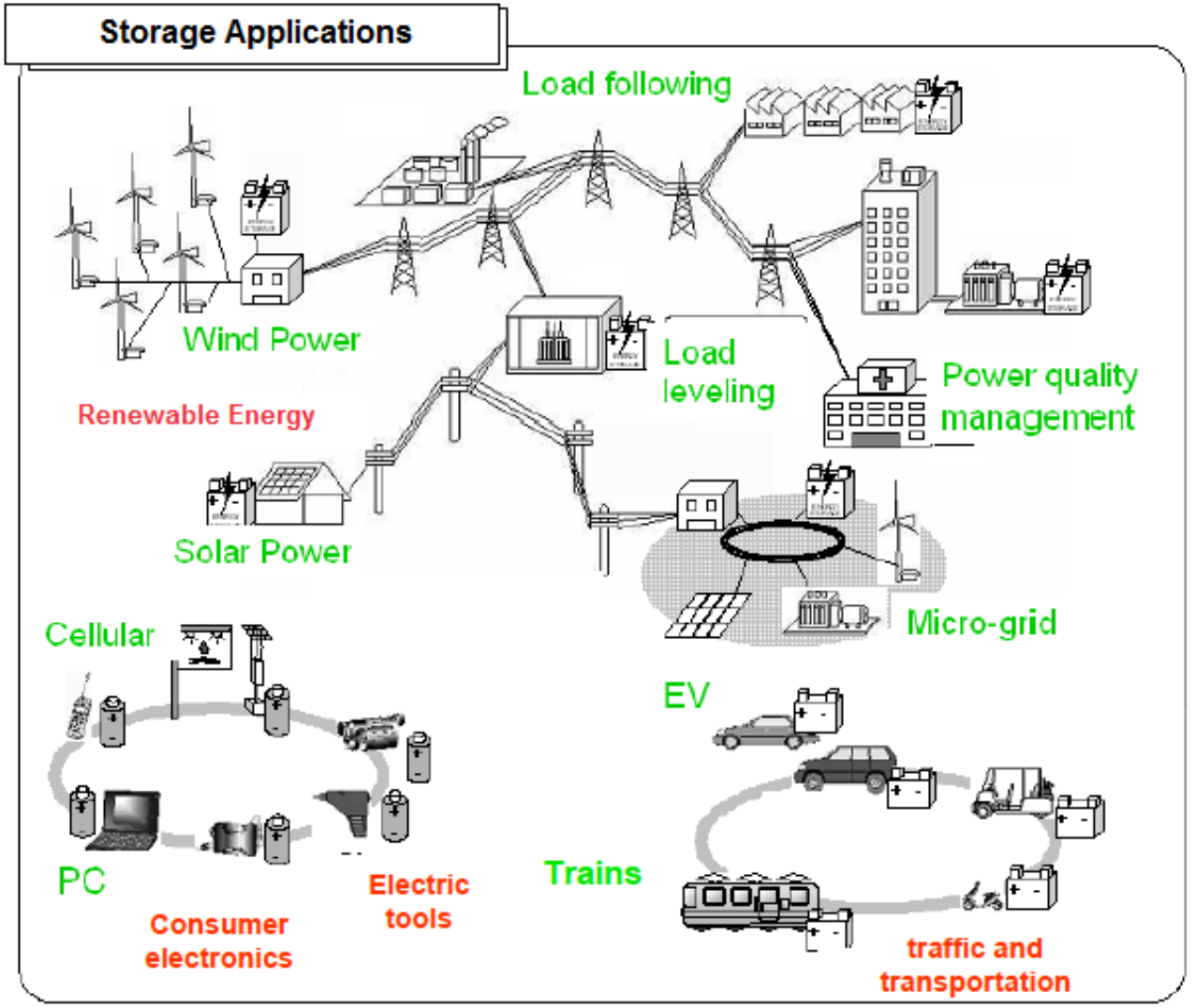
Energy Flow Management for Energy Storage

Victor Fernão Pires

Setúbal School of Technology - Polytechnic Institute of Setúbal

Introduction

Importance of the Storage



Storage Systems

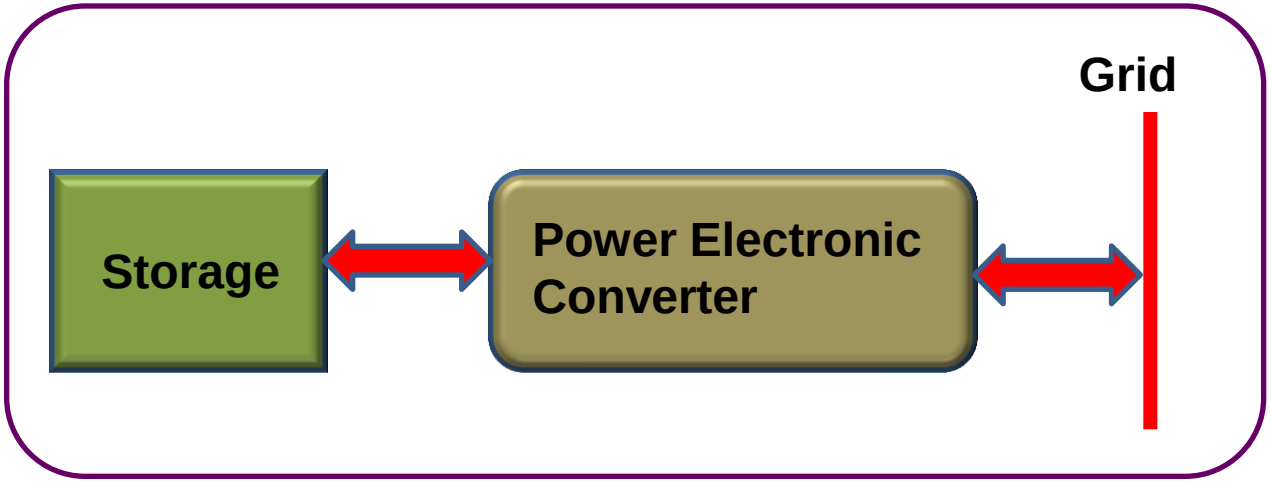
Technology-specific Issues

- Mechanical Storage
- Thermal Storage
- Electrical Storage
  - Magnetic
  - Flywheels
  - Electrochemical

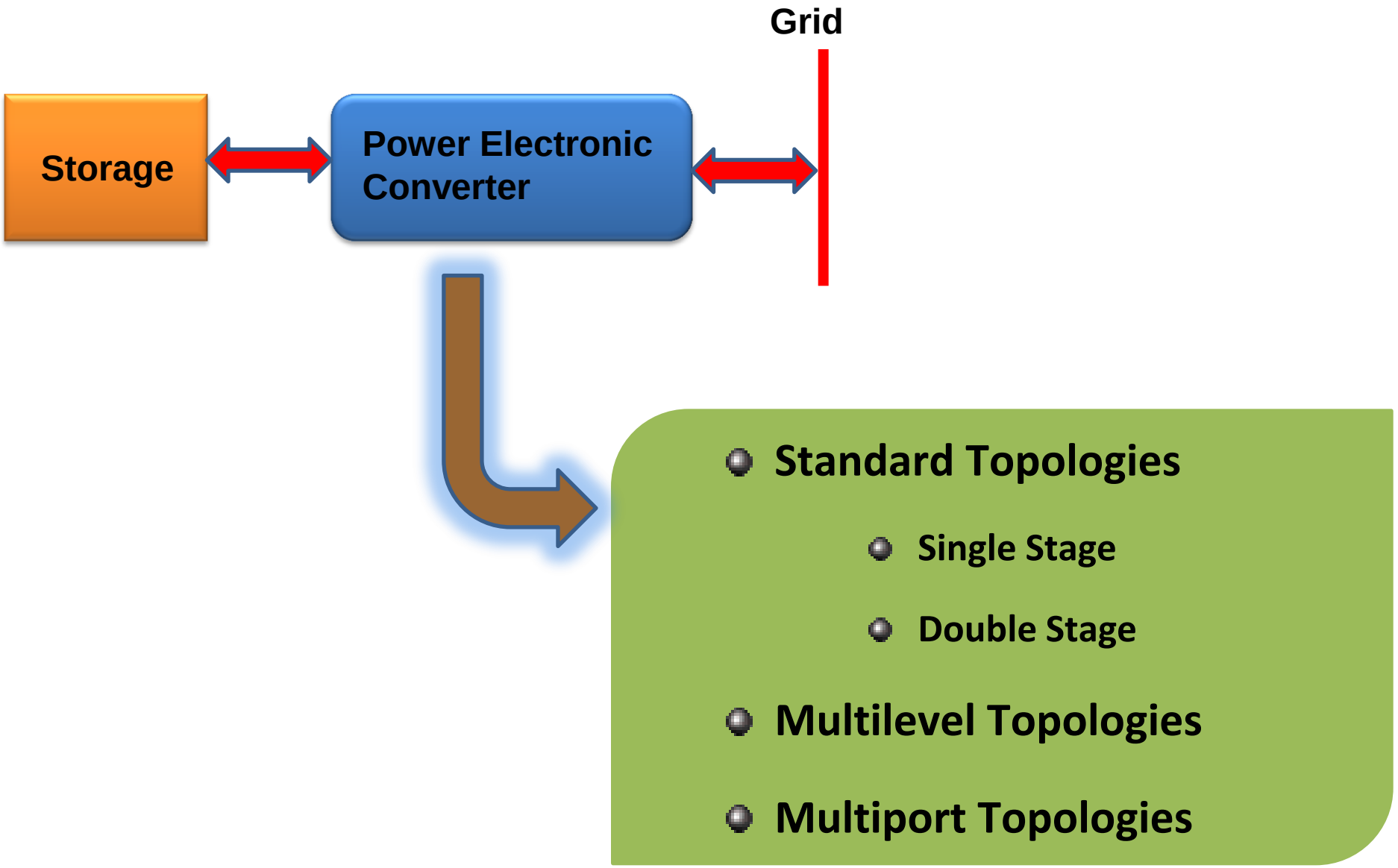
Storage Systems

Issues for the Connection of Electrochemical Storage to Grid

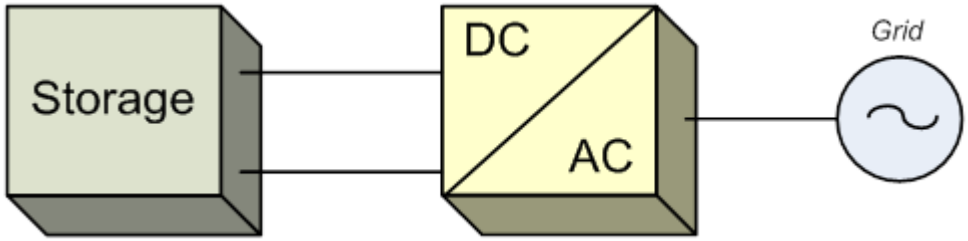
- Adaptation of the Voltage (from DC to AC and Level)
- Control the Charge and Discharge
- Reliability



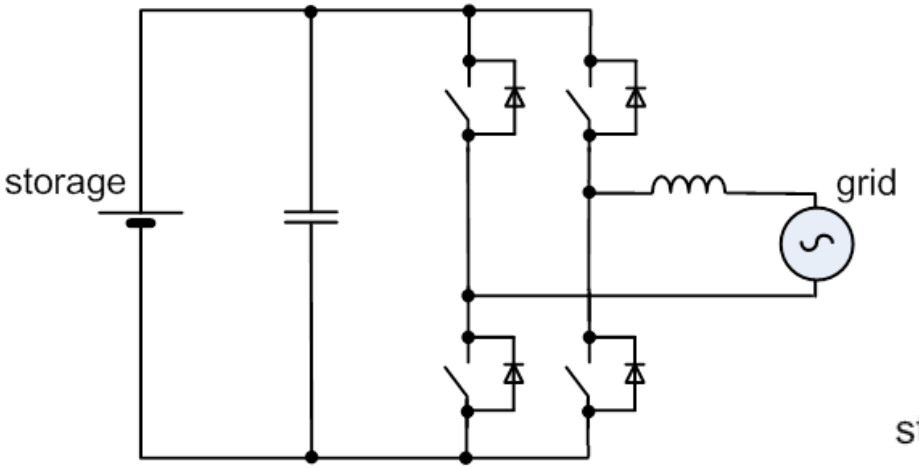
Power Converter Technologies



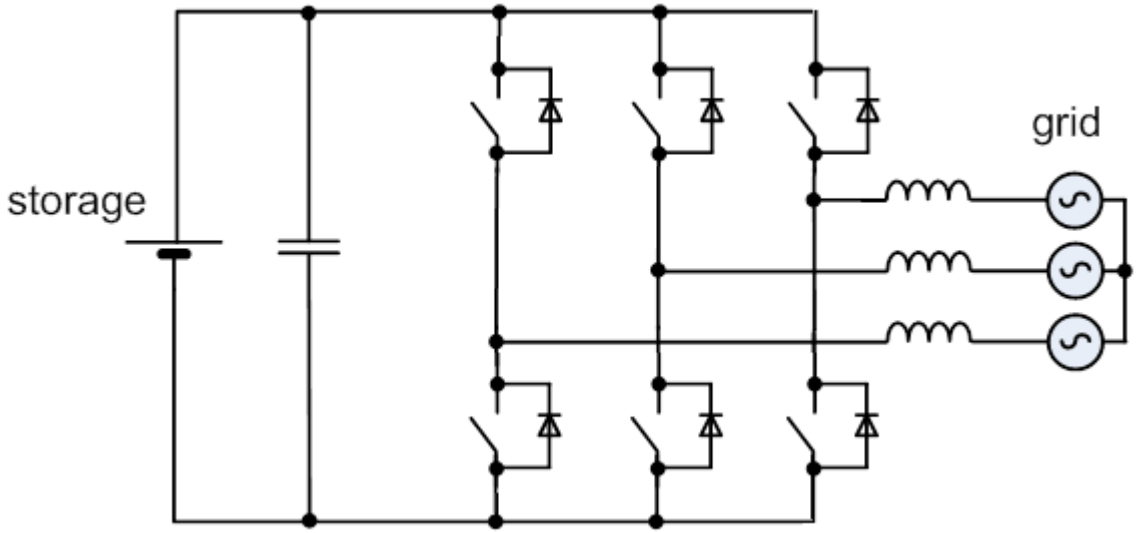
Standard Topologies – Single Stage



Single-phase bidirectional AC/DC converter

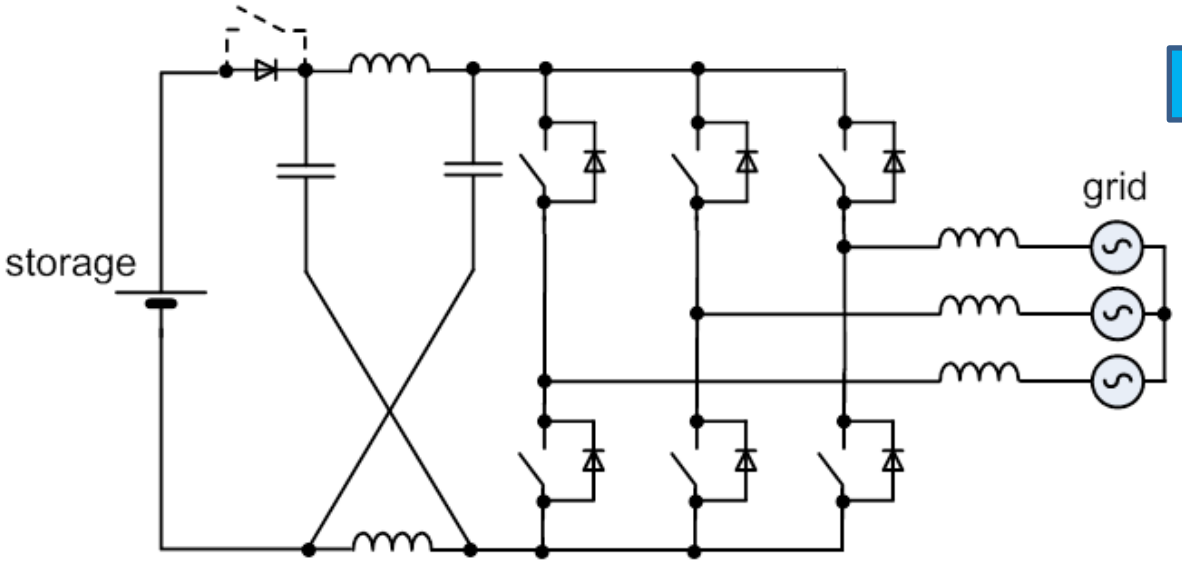


Three-phase bidirectional AC/DC converter

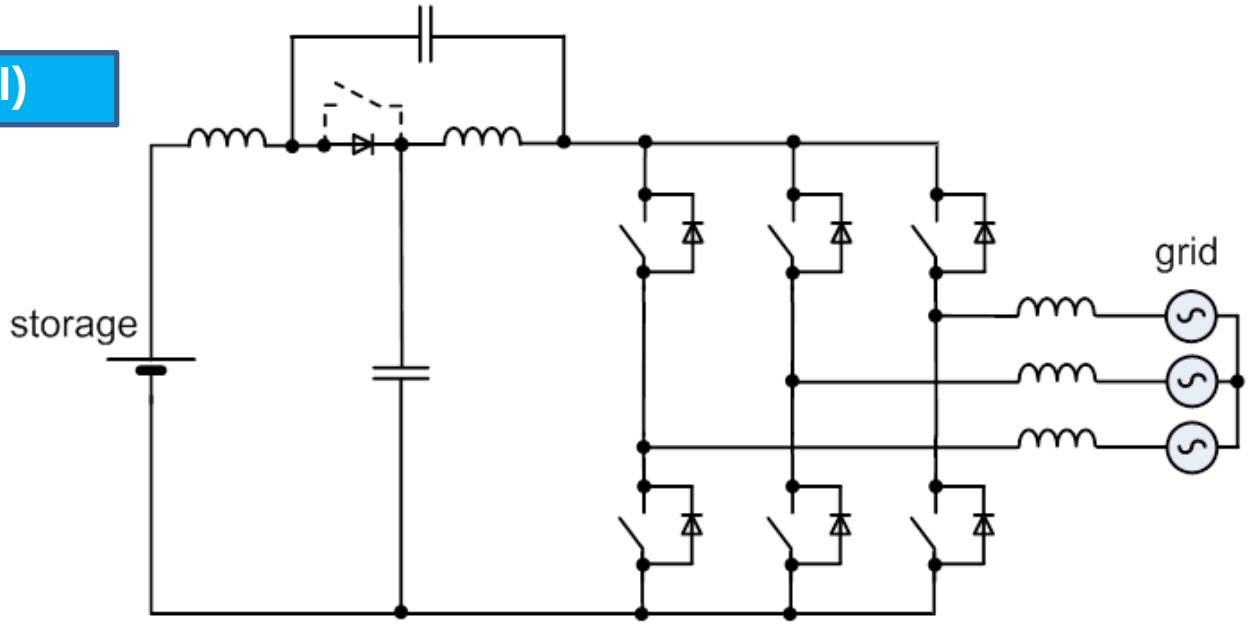


Standard Topologies – Single Stage

Z source inverter (ZSI)

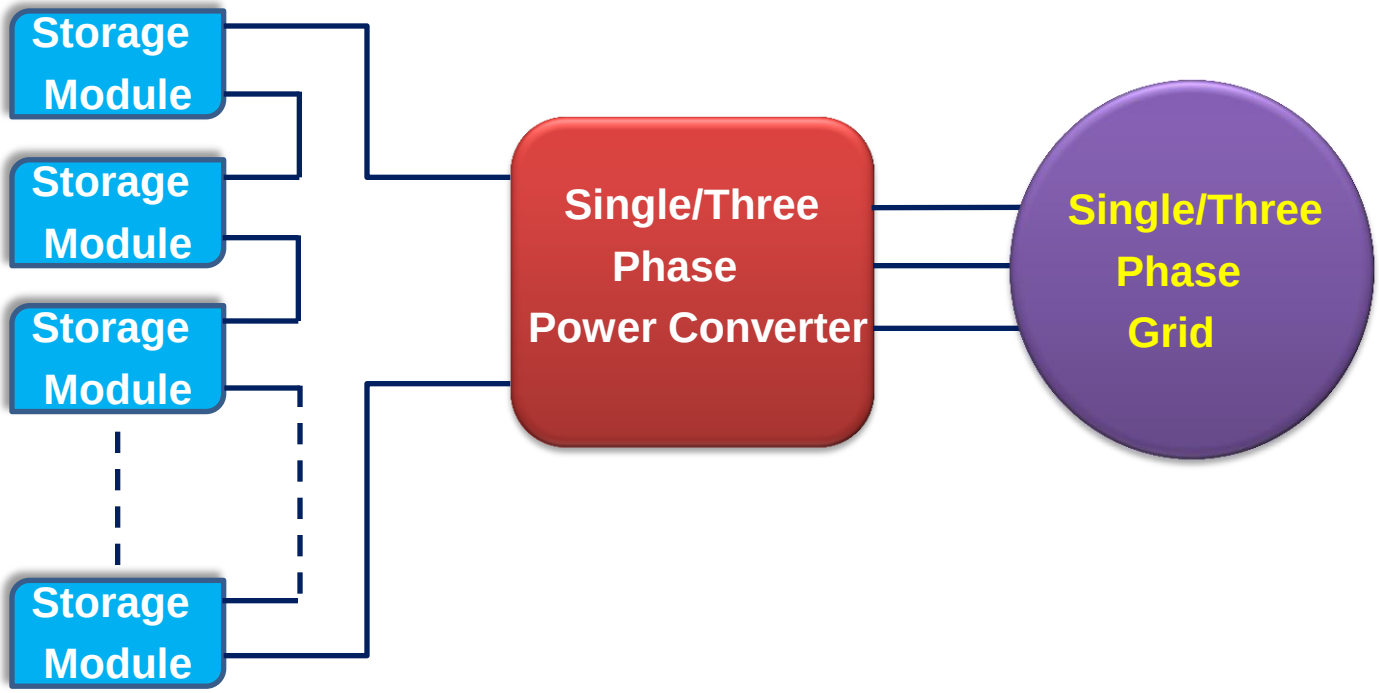


Quasi-Z source inverter (qZSI)



Standard Topologies – Single Stage

Series configuration of Storage Modules



Standard Topologies – Single Stage

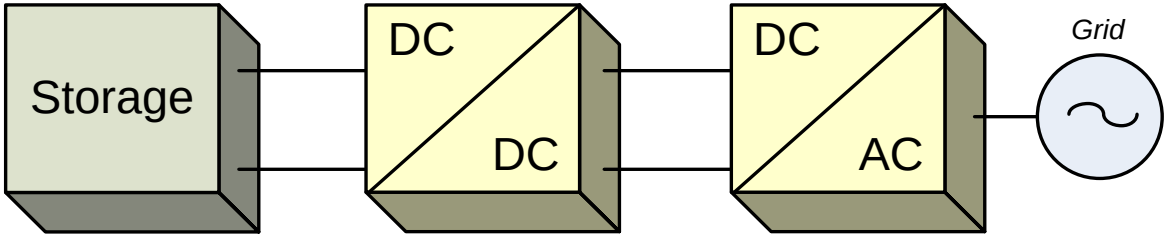
The advantages of Series Configuration are:

- The storage cells are connected in a simple series connection
- Low device count. Only four/six power switches are required when no dc/dc regulator is used
- Single/Three-phase inverter modules are commonly used and because of this they are inexpensive
- This is a simple configuration consisting of storage modules and an inverter module

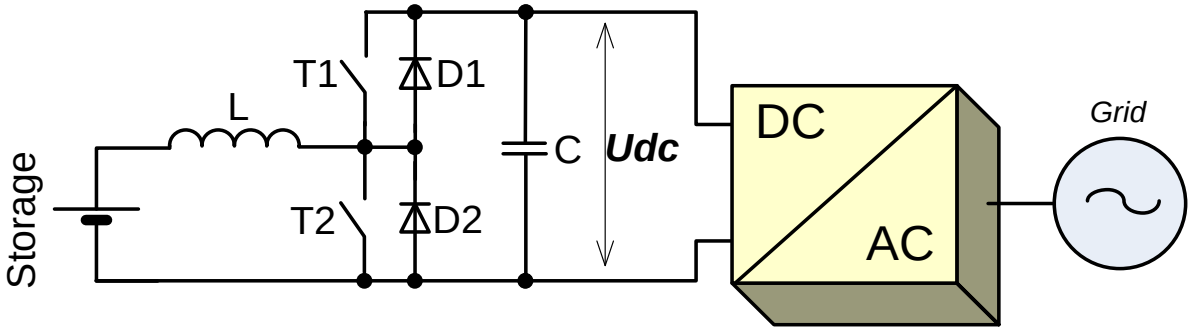
The disadvantages of Series Configuration are:

- If one storage unit (fuel cell) fails, the system will not work. The failing unit has to be replaced or bypassed externally. This causes reliability concerns
- Difficulty in control the storage unit voltage and load
- DC high current ripple

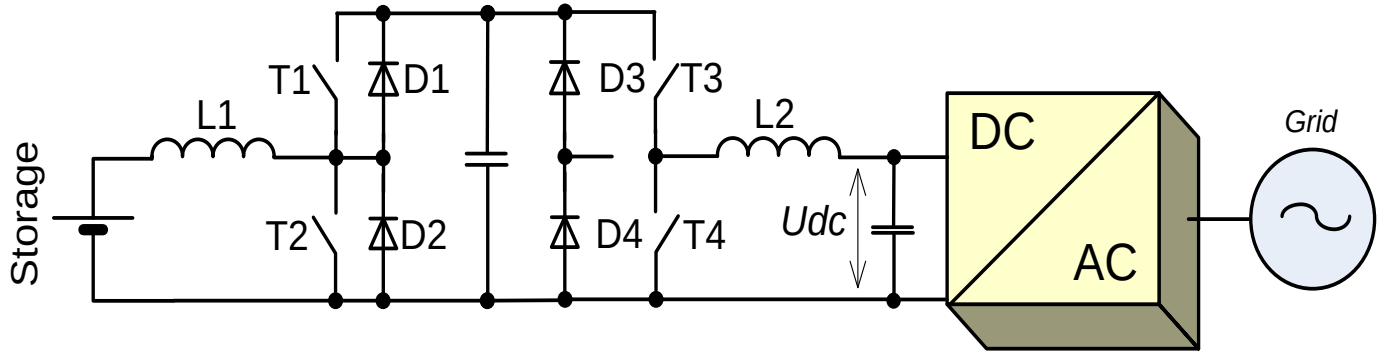
Standard Topologies – Double Stage



Step-up DC/DC converter (bidirectional half-bridge)



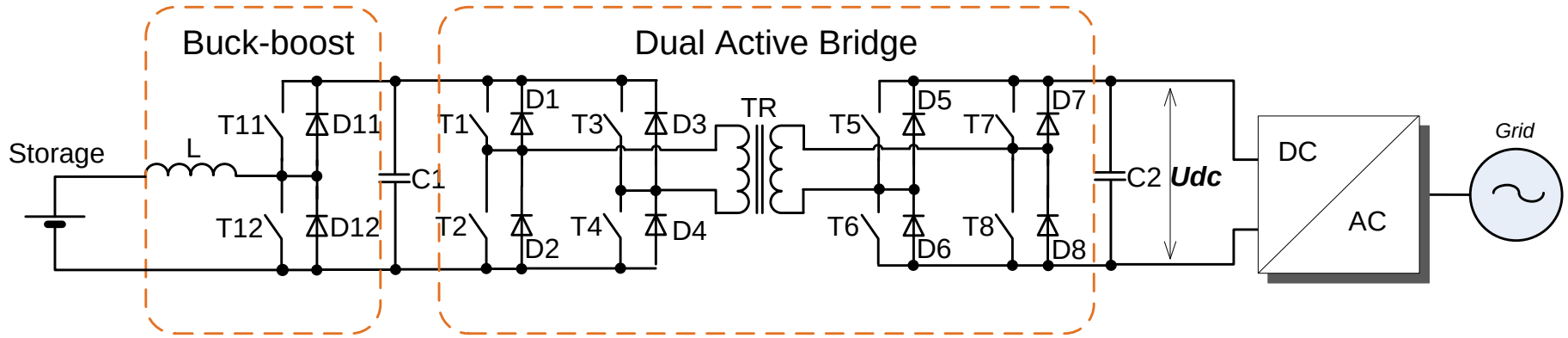
Step-up DC/DC converter (double bidirectional half-bridge)



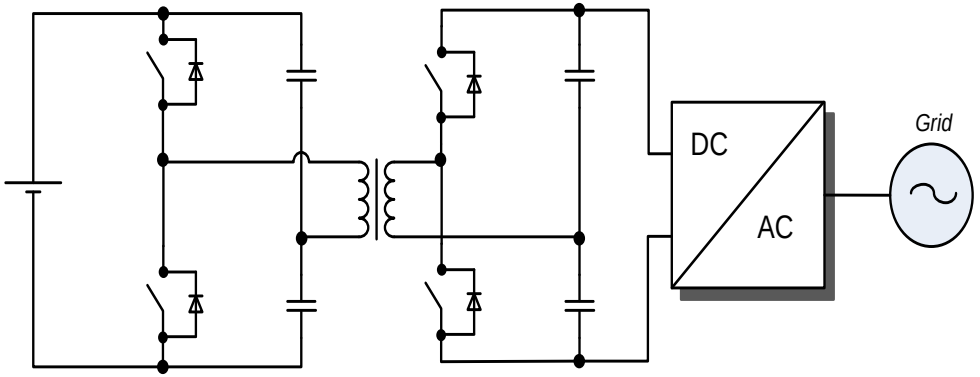
Standard Topologies – Double Stage

With Galvanic Isolation of the Energy Storage

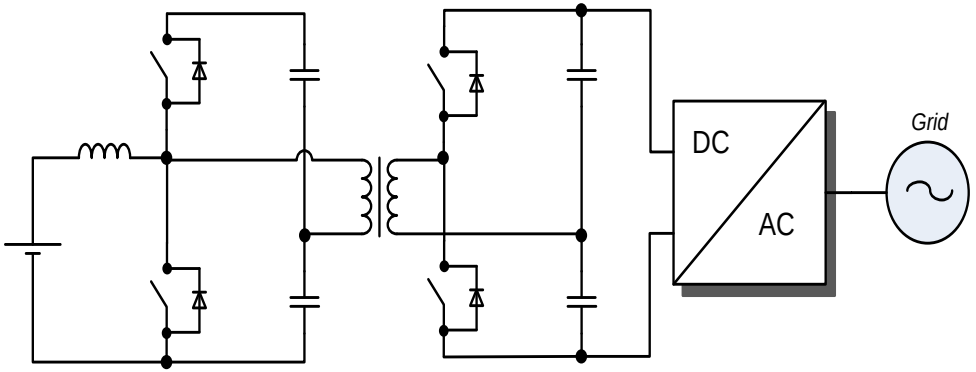
Step-up DC/DC converter (bidirectional half-bridge)



Voltage fed – Dual half bridge

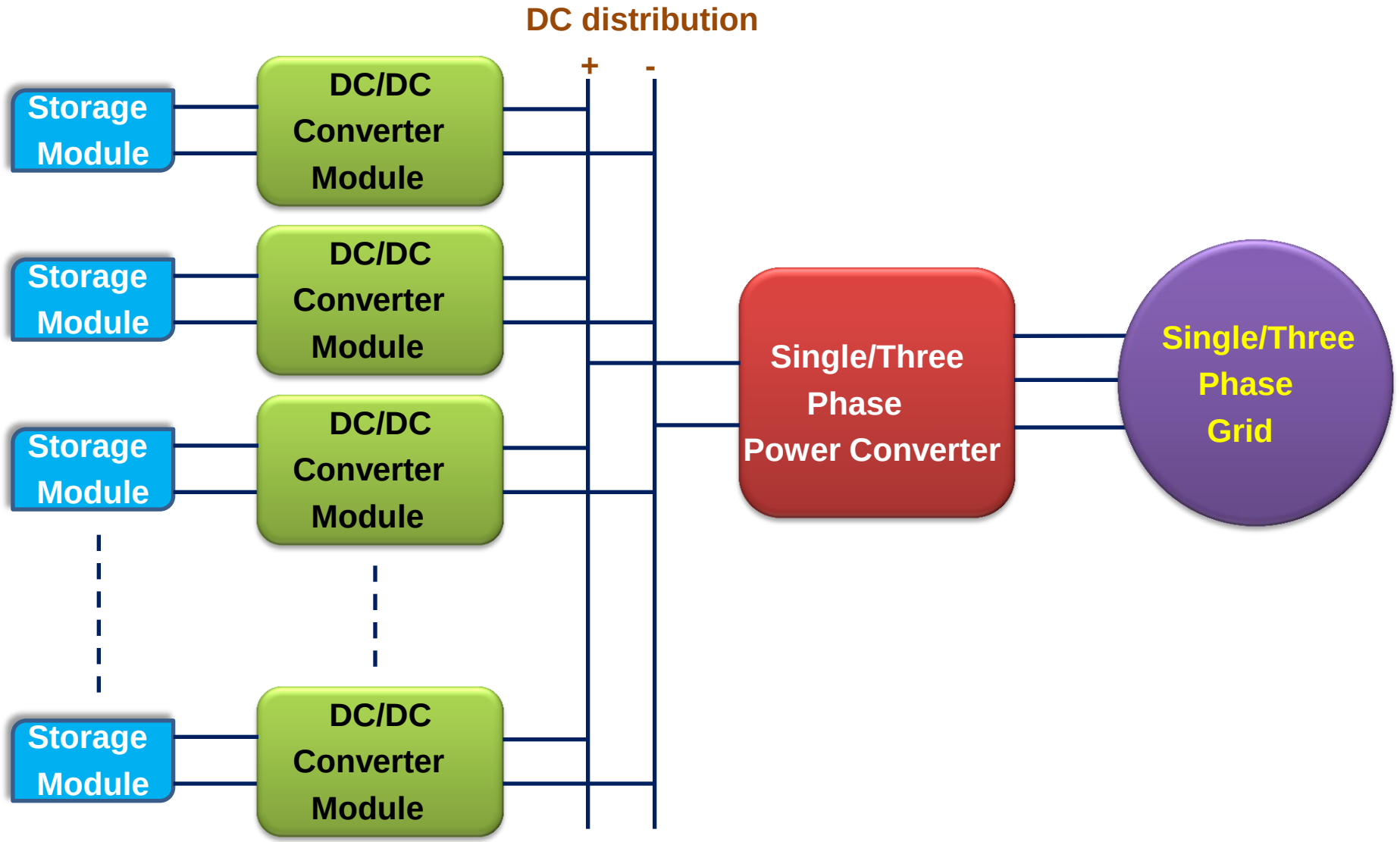


Current fed – Dual half bridge



Standard Topologies – Double Stage

DC distribution configuration of Storage Modules



Standard Topologies – Double Stage

The advantages of DC distribution are:

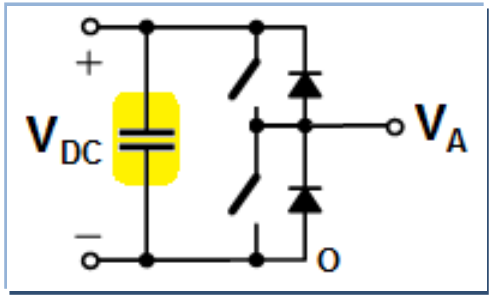
- Each storage unit can be controlled independently with the dc-dc converter module.
- The storage modules can be disconnected from the system for maintenance or replacement and the rest of the system would continue the operation
- Increased reliability and fault tolerant operation can be achieved by adding redundant storage modules together with dc-dc converter modules
- Each subsystem can be designed as an individual module and combined together as needed

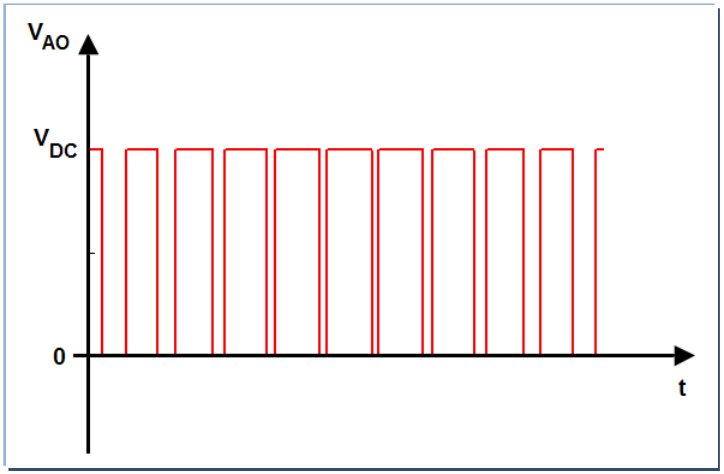
The disadvantages of DC distribution are:

- When the instantaneous voltages at the outputs of the dc-dc converters are not equal, circulating currents will occur. These will interfere with the operation of the system so they have to be prevented
- This configuration requires higher device count than the series configuration because of the dc-dc converters
- Higher cost and reduced efficiency

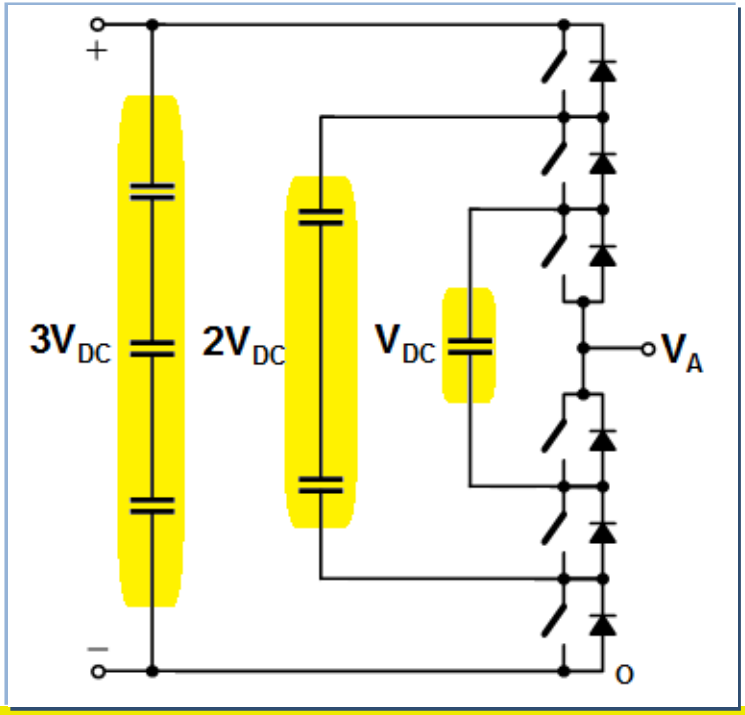
Multilevel Converters

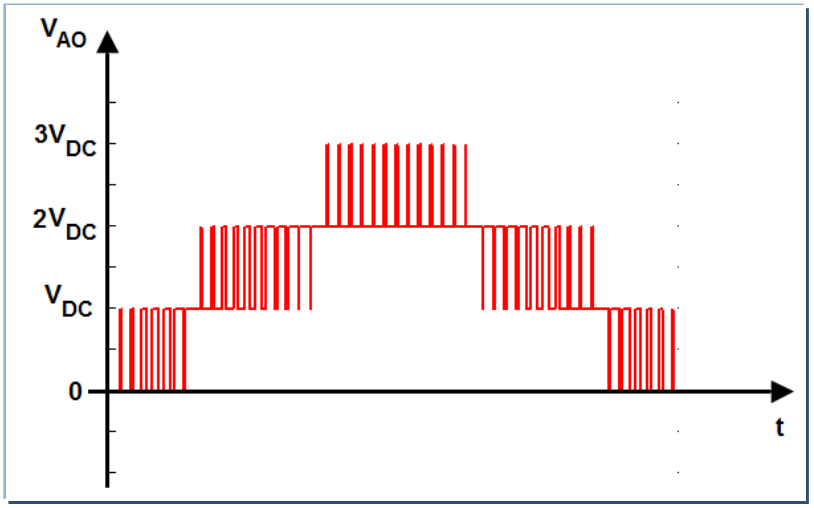
Two-Level





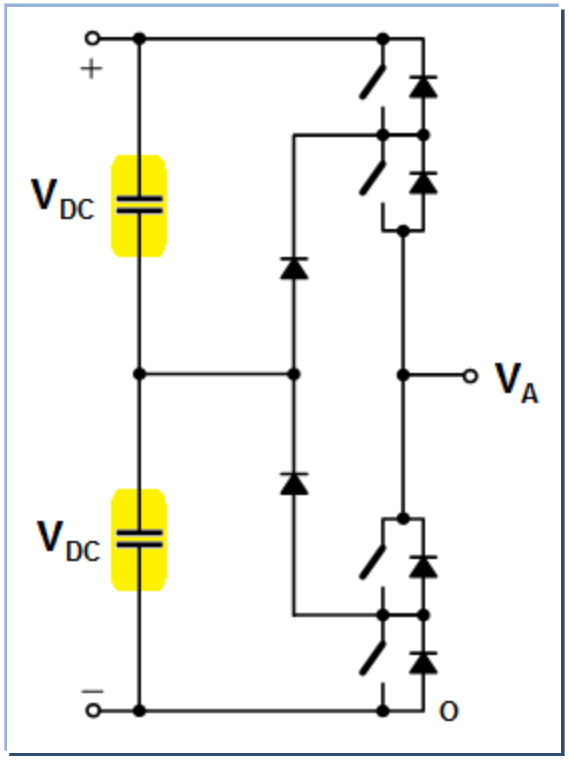
Flying capacitor converter



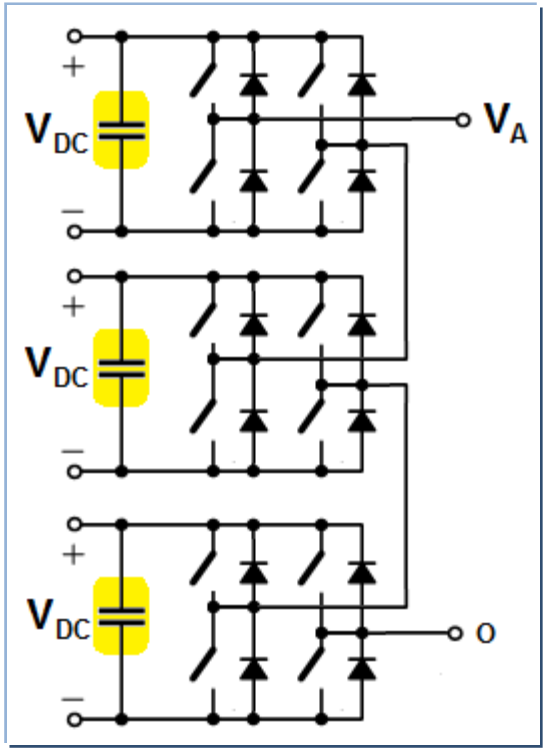


Multilevel Converters

Neutral-Point-Clamped (NPC)

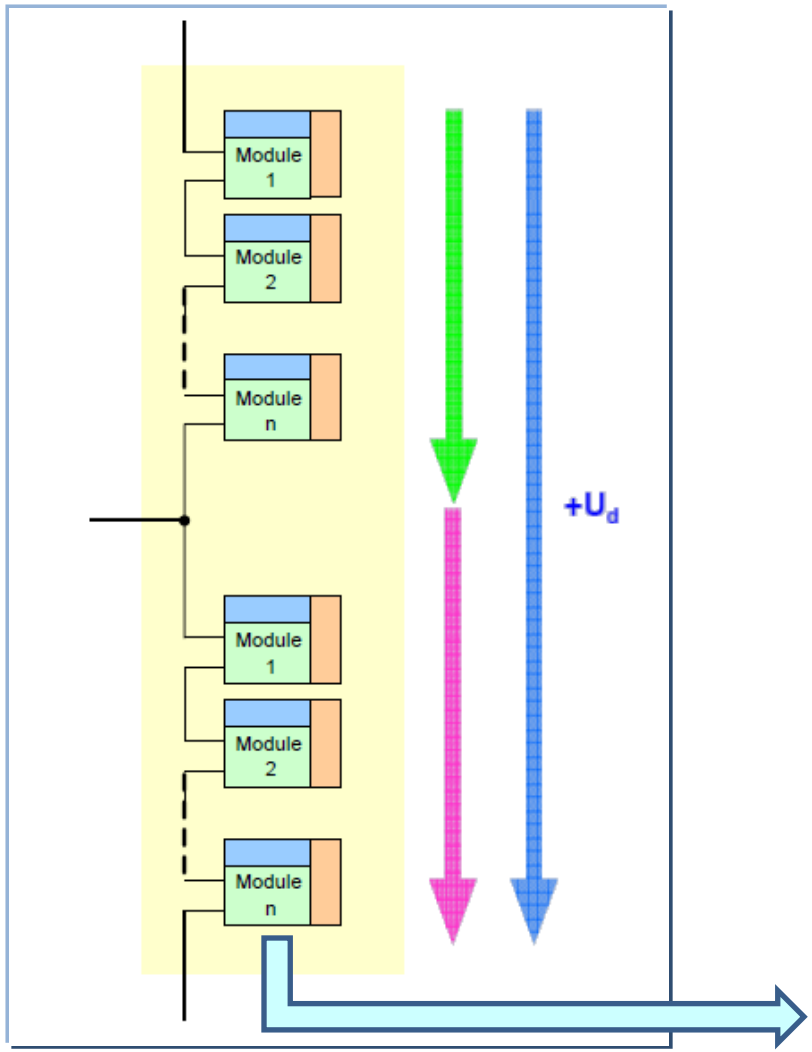


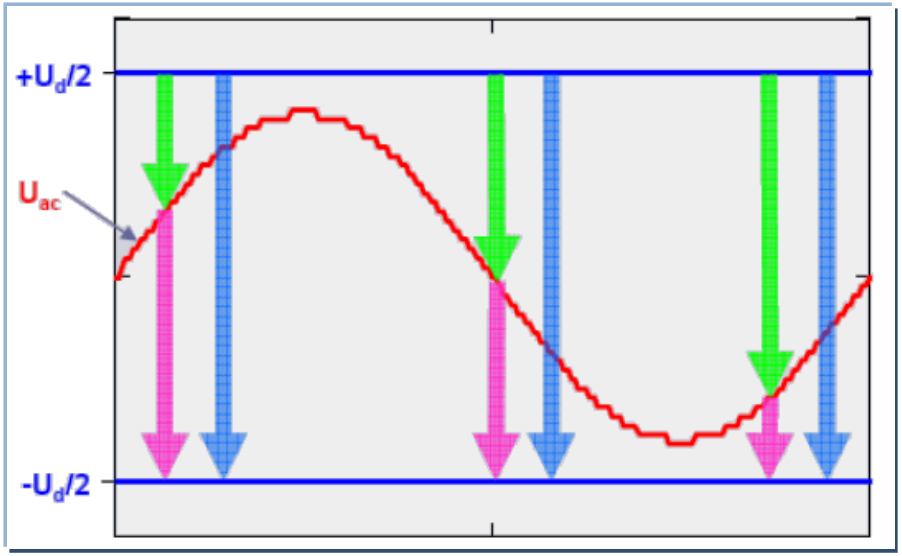
H Bridge cascaded

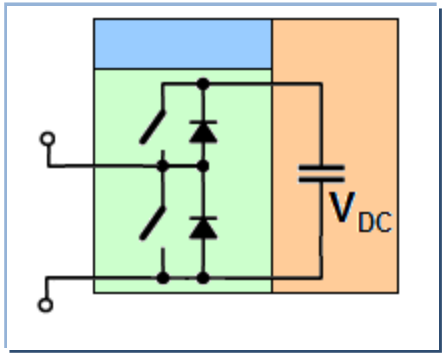


Multilevel Converters

Modular Multilevel Converter (MMC)

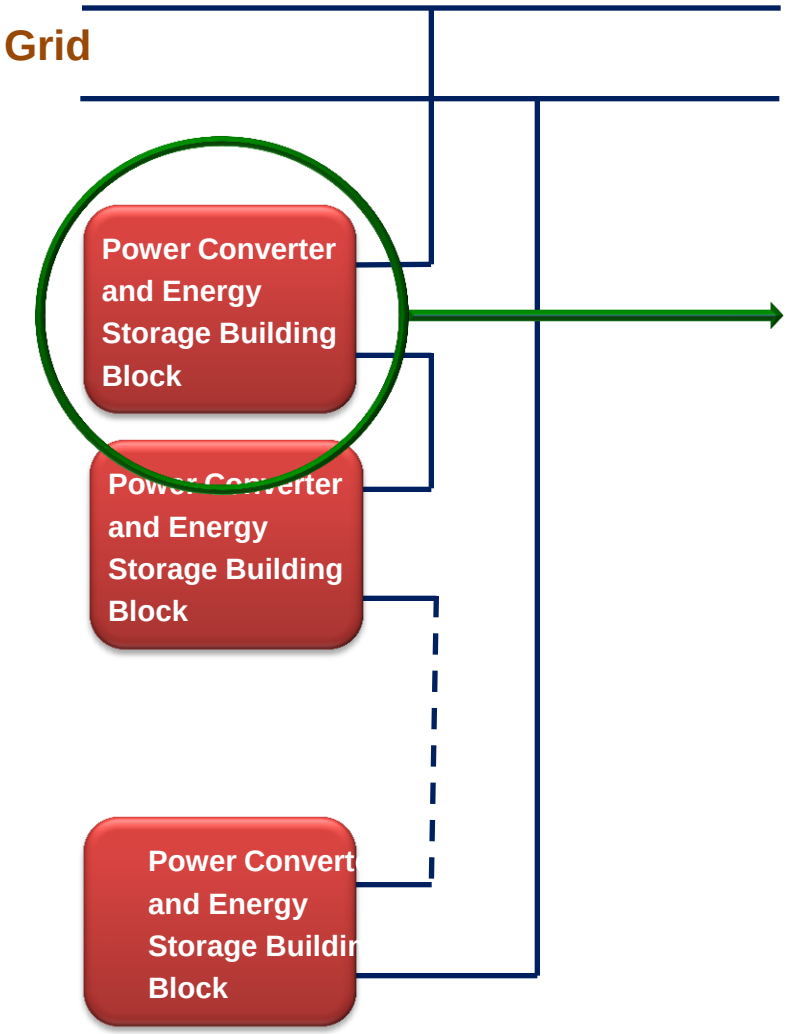




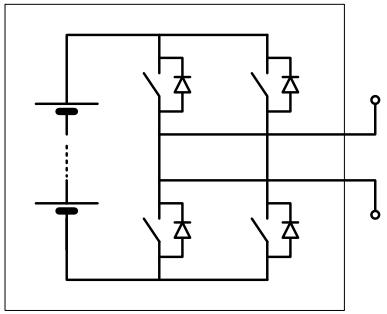


Multilevel Converters

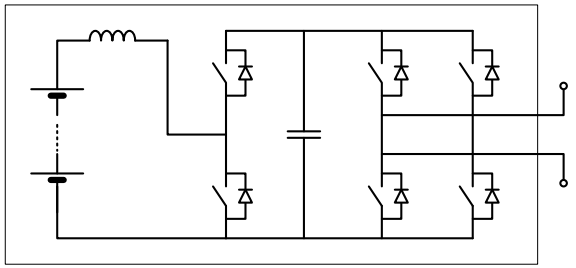
Block diagram of the multilevel configuration



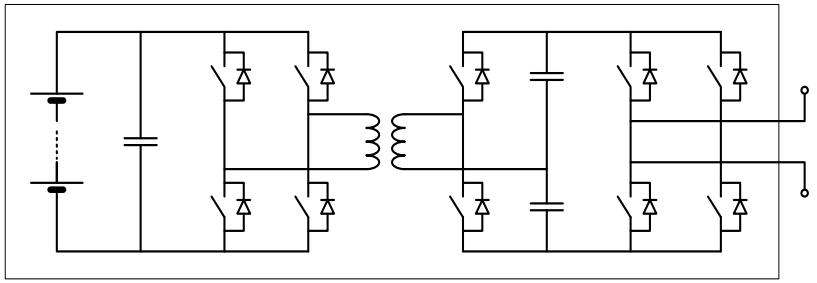
Single stage



Double stage



Double stage with isolation



Multilevel Converters

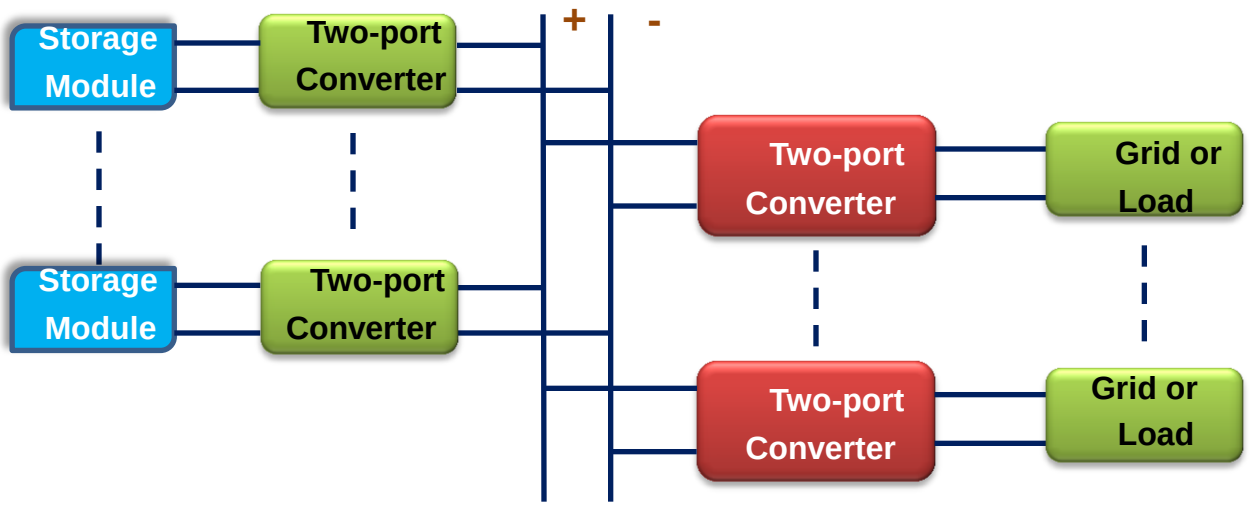
The advantages of multilevel configuration are:

- Less harmonics of the AC voltage.
- The storage modules can be disconnected from the system for maintenance or replacement and the rest of the system would continue the operation
- Increased reliability and fault tolerant operation can be achieved by adding redundant storage modules together with dc-dc converter modules
- Reduced voltage ration of the devices

The disadvantages of multilevel configuration are:

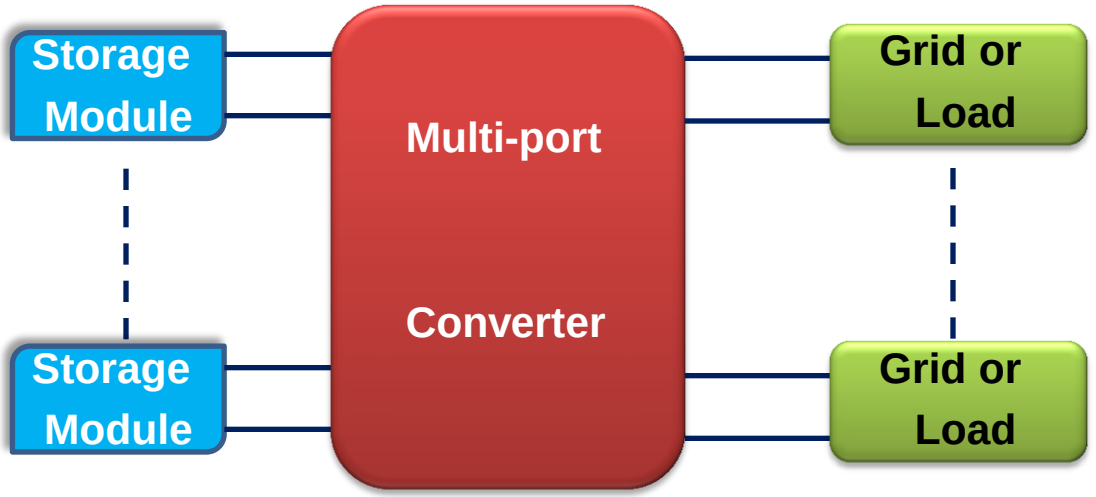
- Higher number of devices
- Overall system more expensive and complex

Multiport Technology



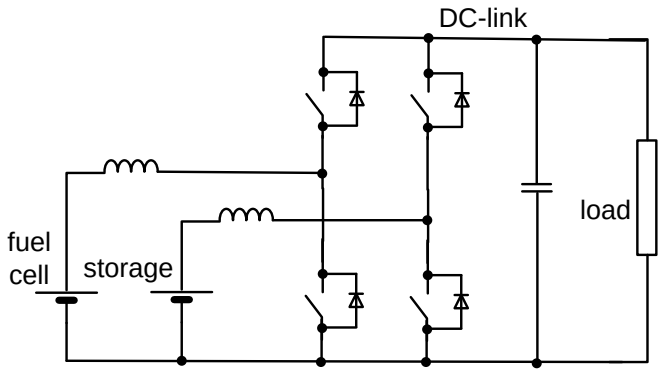
Multiple two-port Converters

Multi-port System Structure

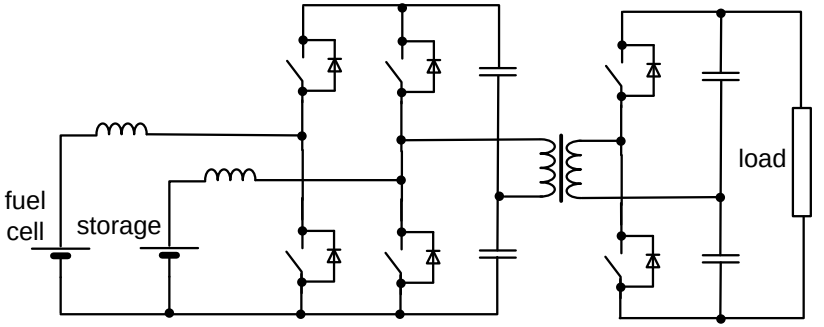


Multiport Technology

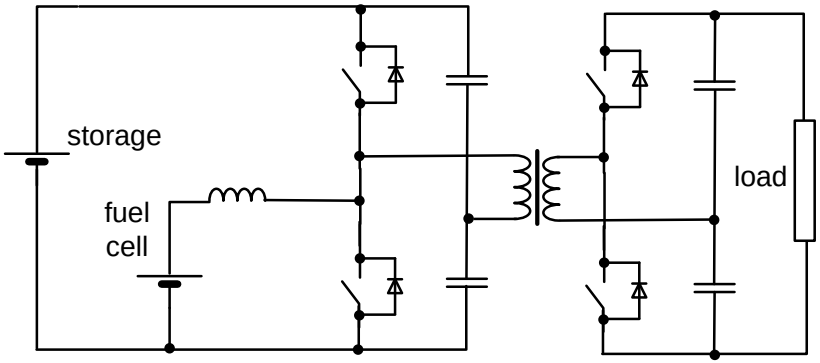
Three-port converter with a DC-link



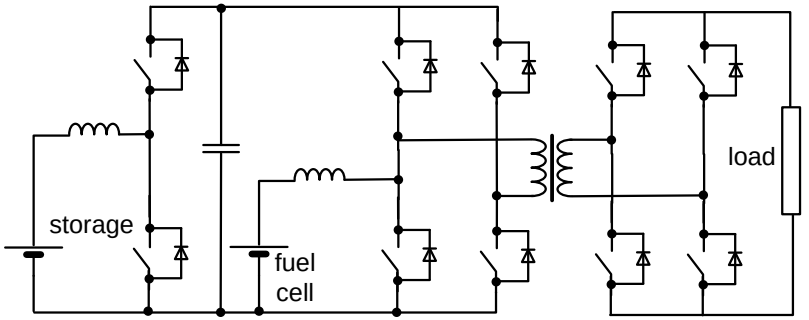
Three-port converter combining DC-link and magnetic coupling



Three-port converter where the storage connects directly to the DC bus



Three-port converter with full bridges combining DC-link and magnetic coupling



Multiport Technology

The advantages of multi-port configuration are:

- Does not need a DC bus, thus the conversion steps are minimized.
- Low cost and size
- Uses centralized control

The disadvantages of multi-port configuration are:

- Complexity of the control system
- Limitation for High power applications

Conclusions

The choice of the power converter topology depends of several issues, such as :

- **Type of the used storage unit**
- **Reliability**
- **Cost**
- **Efficiency**
- **Power of the aplication**