



JANUARY 28, 2020

Supersize PV

How bigger blocks with advanced power conversion topology can improve plant economics

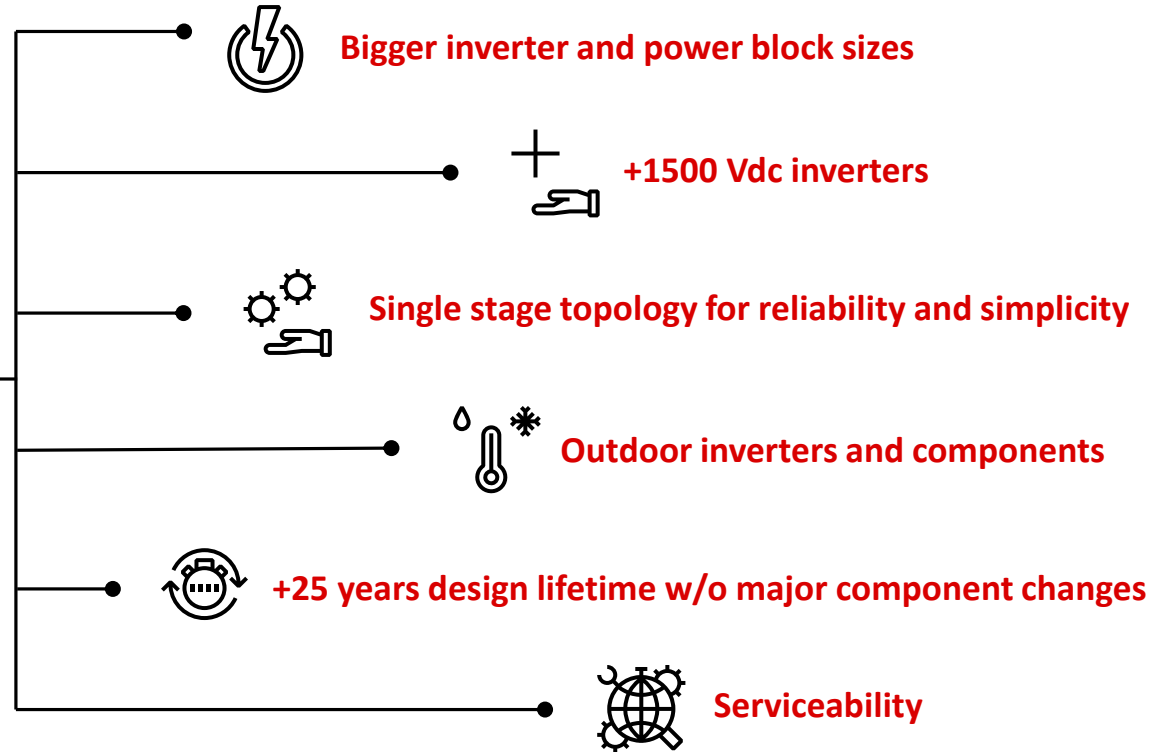
Jyrki Leppänen & Marko Harju



Supersize PV

Major trends to reach the reduced LCOE targets

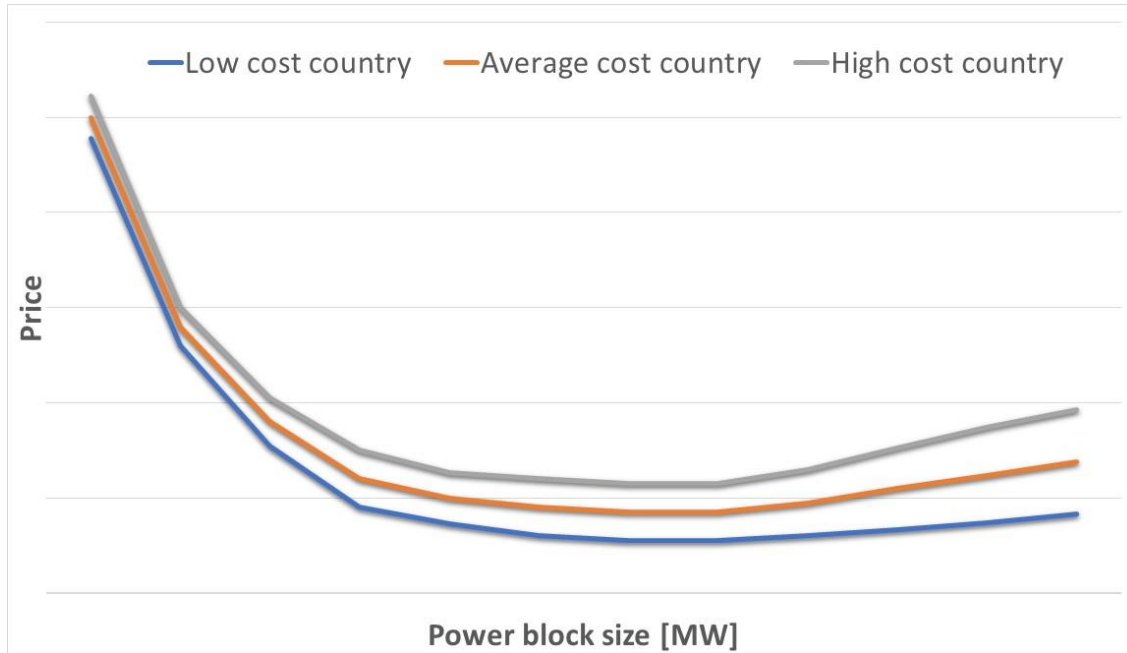
Reliability, efficiency and low maintenance for reduced Levelized Cost of Energy (LCOE)



Supersize PV

Optimum powerblock size – does it exist?

Comparison power block size versus system cost



System cost does not include: PV modules, racking systems, PV Installations, PV string wires, string wire laying and connections

Matters affecting to analysis - sensitivity

- Raw material cost (AL, Cu) – cable price
- Local labour cost – installation and civil works
- DC to AC ratio – DC cable length
- Local regulations – distance between components, protections
- Site layout – internal MV network layout, cable lengths
- MV network (voltage, SC current) - component cost
- Site location – logistics cost

- No universal optimum size
- Optimum depends on the case in question
- Inverter size affects to the optimum meaningfully



Central inverter topologies

With 1500 Vdc system

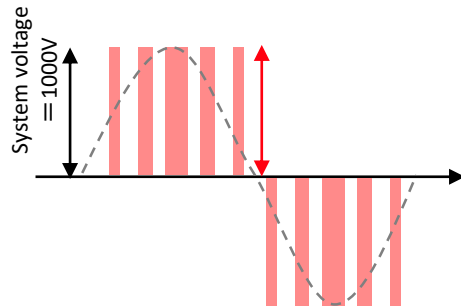
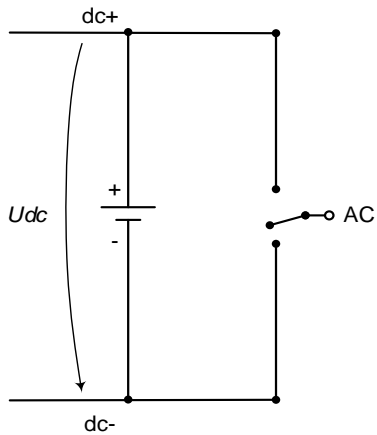
Central inverter topologies 2- and 3-level

Main topologies for central inverters

2-level inverters

Phase output is connected to positive or negative DC bus (dc+, dc-).

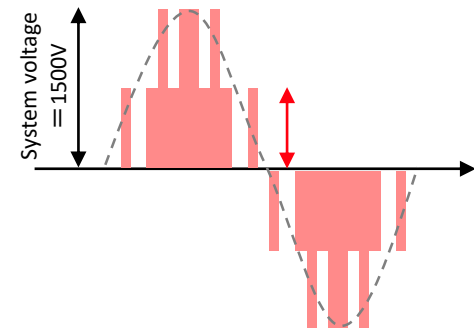
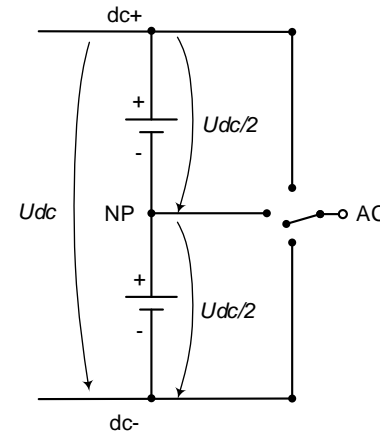
Fundamental phase output voltage is formed by varying the dc+ and dc- times.



3-level inverters

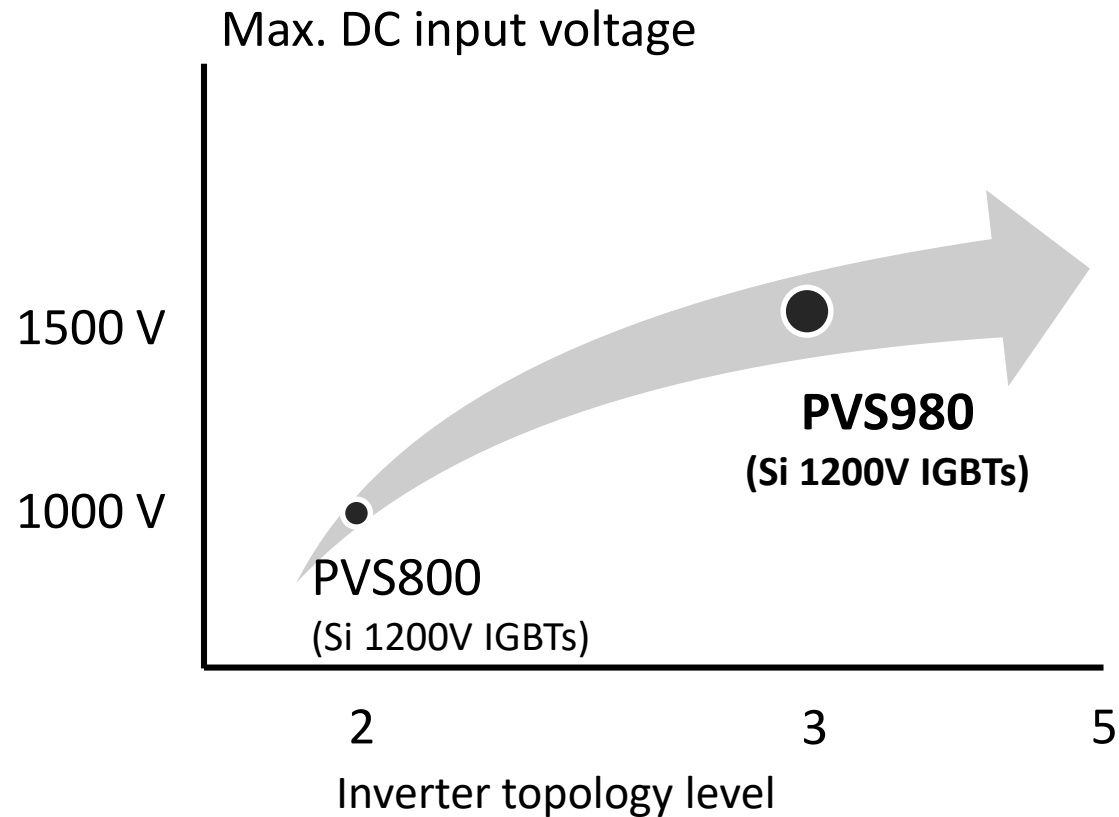
Phase output is connected to positive, neutral or negative DC bus (dc+, NP, dc-)

Fundamental phase output voltage is formed by varying the dc+, NP and dc- times



Central inverter topologies 2- and 3-level topology

Main advantages and disadvantages



3-level inverter

- + Can support high DC voltage (1500V) with same IGBT as 1000V with 2-level
- + Miniaturization: More sinusoidal waveform
→ Smaller line filter (AC side)
- + Higher efficiency: Switching loss reduces by half

2-level inverter

- + Simplicity: less components
- Less IGBT supplier at 1500Vdc due to 1700V IGBT need
- Smaller DC voltage operation range

Central inverter 3-level inverter topologies

Main topologies for 1500Vdc central inverters

Characteristics

Active Neutral Point Clamped, ANPC

- Symmetrical voltage stress on all devices ($U_{dc}/2$)
- Balanced power loss distribution for all power factors

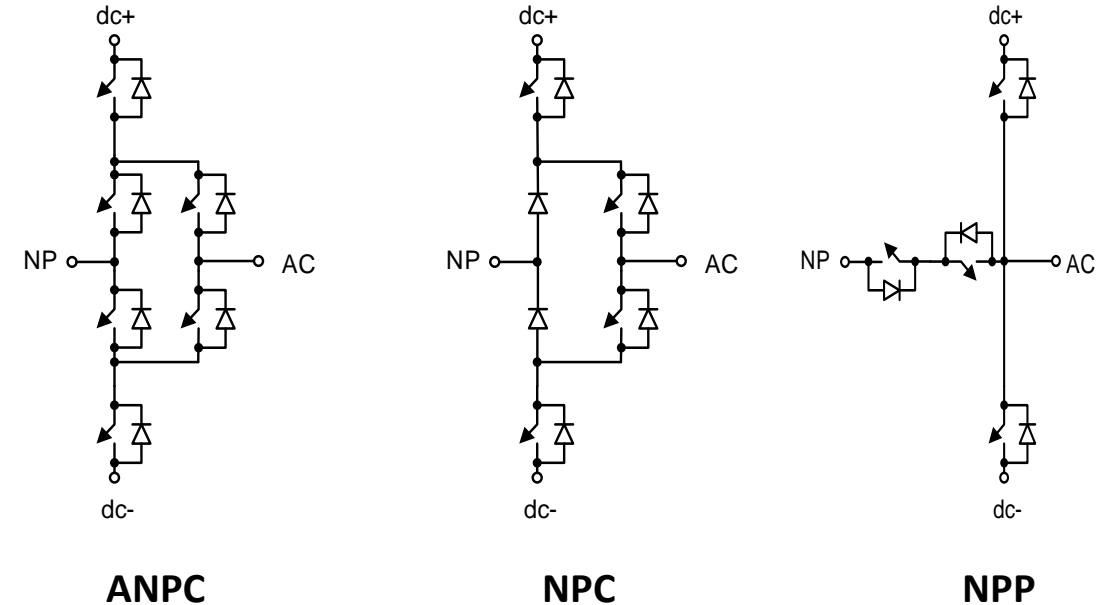
Neutral Point Clamped, NPC

- Symmetrical voltage stress on all devices ($U_{dc}/2$)
- Good for unity power factor

Neutral Point Piloted, NPP

- Different voltage stresses (upper and lower U_{dc} , middle $U_{dc}/2$)
- Mainly for lower power levels
- Limited DC-voltage range

Phase leg configurations



Central inverter 3-level inverter topologies

IGBT configuration directly affects system limitations and properties

Different topology summary

3-level topology in **NPP type** (1700 V IGBT)



- Small **voltage safety reserve** to 1500 Vdc
- Can not modulate up to 1500 Vdc
- Limited performance with high DC/AC ratio

2-level topology (1700 V IGBT)



3-level NPP topology drawbacks plus higher harmonics

3-level topology in ANPC type (1200 V IGBT)



- Neutral point = IGBTs see only 750 V
- Higher voltage safety reserve
 - Modulation up to 1500 Vdc with very low power derating from max MPPT rate voltage

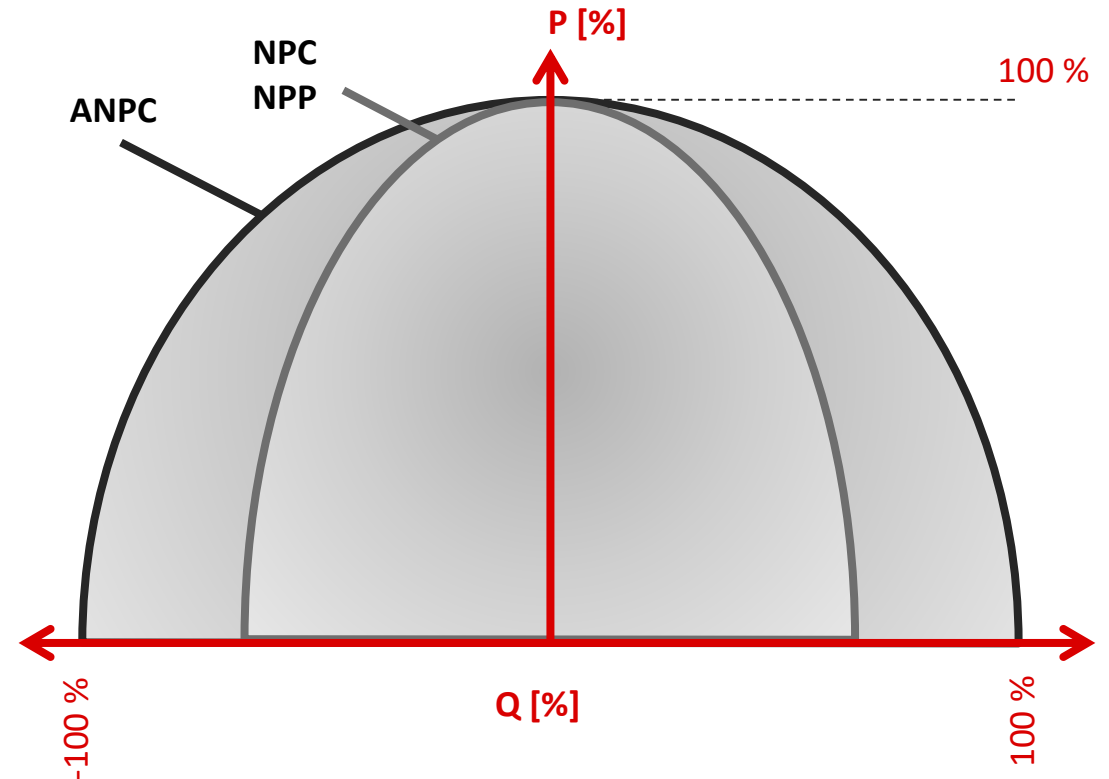
Central inverter 3-level inverter topologies

PQ performance of 3-level inverter topologies

PQ performance

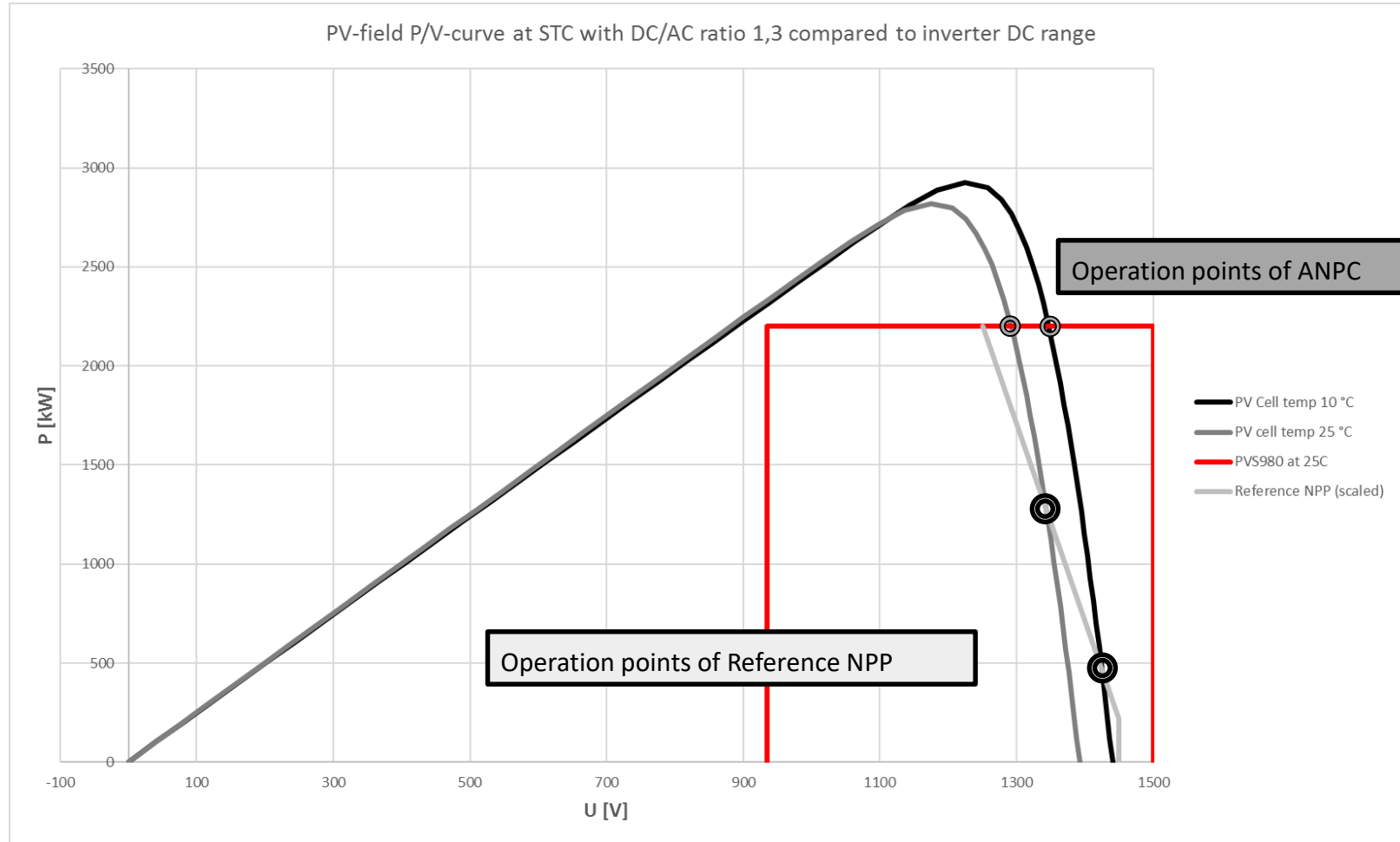
- Needed especially for grid support
- ANPC can easily reach 100% reactive power support without additional strain to the power semiconductors
- NPC and NPP performance is limited and depends on the components selection

Differences of PQ performance



Central inverter 3-level inverter

DC voltage range of 3-level inverter topologies





Cooling methods

Advantages and disadvantages to meet high power inverters' needs

Cooling methods

General advantages and disadvantages

Main cooling methods

Air cooling – heatsink

- + Simplicity
- + Low maintenance
- Lower efficiency

Liquid cooling

- + High efficiency
- + Higher IP rating structure
- High maintenance
- Reliability
- OPEX cost



Self-contained thermosyphon heat exchanger

Characteristics of two phase thermosiphon technology

Heat exchanged itself is totally passive

- Simplicity comparable to the traditional heat sink cooling

High performance with low pressure drop

- Efficiency comparable to liquid cooling
- Low auxiliary power consumption for superior overall efficiency

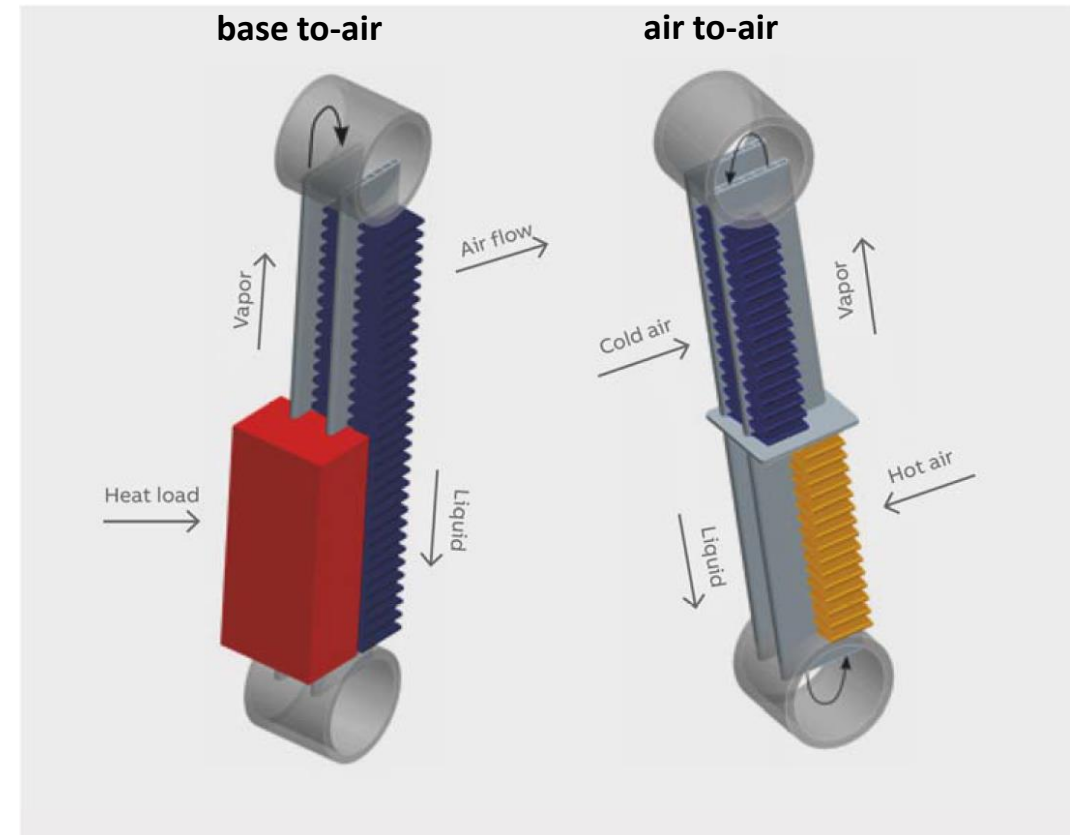
No commissioning or maintenance need

Long lifetime over 30 years

- Hermetically sealed
- Corrosion resistant aluminum

Extreme temperature tolerance from -60...+60 C

ABB patented

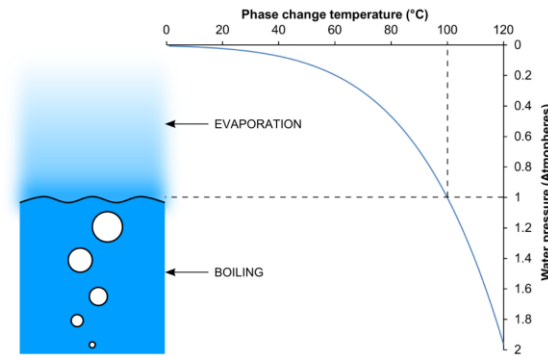
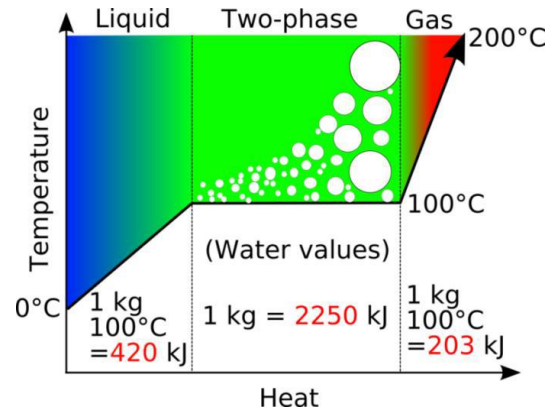


Self-contained thermosiphon heat exchanger

Principle of the two phase thermosiphon technology

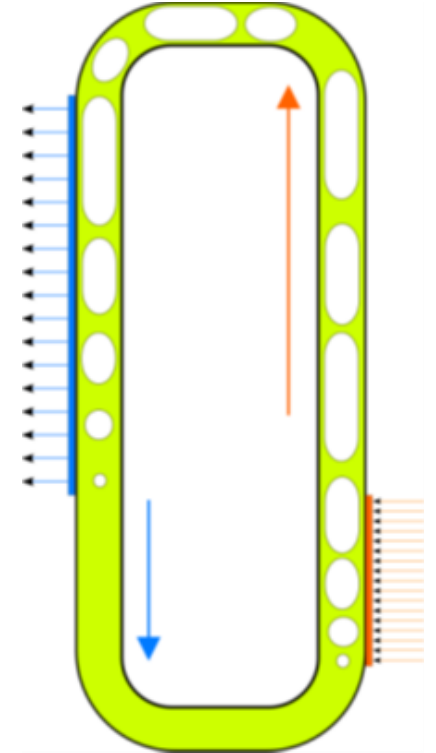
Phase change:

- A lot of energy is transferred
- High efficiency



Thermosiphon effect:

- Pumpless cooling
- Long lifetime
- No commissioning needed
- No maintenance



Self-contained thermosyphon heat exchanger

Manufacturability



Made from aluminum, which has:

- High corrosion tolerance
- High thermal conductivity
- Easy manufacturability

Less material than typical heat sink

Multiport extruded aluminum structure commonly used in automotive industry

- Huge global production capacity
- Cost efficient solution

Coolant medium in heat exchangers: R134a (1,1,1,2-tetrafluoroethane)

- Non-flammable and chemically very stable
- Used as a refrigerant also in industrial applications
- Only very small amount in sealed containers is required

Self-contained thermosyphon heat exchanger

Proven technology

Used in different applications

High IP rating dry-transformer

- First units running since 2011

Low harmonic frequency converter for outdoor use, ACS800-38

- First units running since 2012 in harsh environment

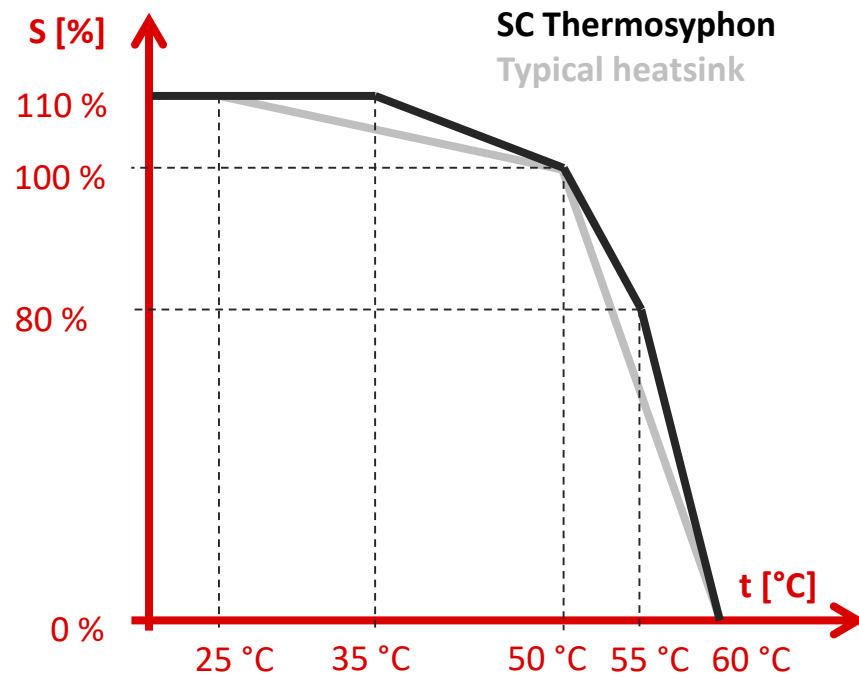
High power central inverter PVS980-58

- Released in 2017
- More than 4 GW delivered so far



Self-contained thermosyphon heat exchanger

Comparison to traditional methods



Thermal design of inverter is combination of:

- Cooling system performance
- Component selection and dimensioning
- Component temperature margins

→ Inverter lifetime design & reliability



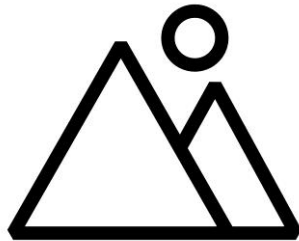
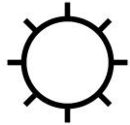
High altitude challenge

Attractive solar energy production conditions

High altitude challenge

Ways to resolve

High altitude challenge



Taking the challenge

- High heat, cold, corrosion and radiation tolerance
- Efficient in cosmic ray prevention
- Lower or no power derating at high altitude locations
- Max creepage and clearance distances (up to 4000m without voltage derating)

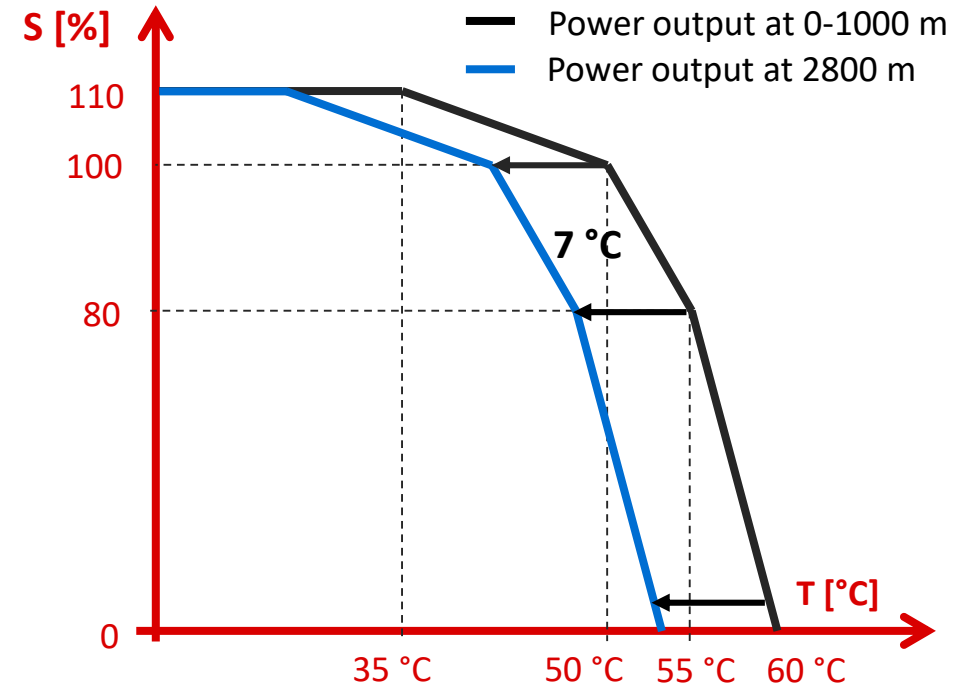
Answering to challenge

- High corrosion resistant outer material with dual layer enclosure
- Increasing voltage margin with 3-level ANPC topology
- Effective self-contained thermosyphon cooling

High altitude challenge

Advanced technologies enabling performance

- IGBT voltage reserve directly affecting to failure rates with cosmic rays.
- Cooling method directly affecting to power derating at high altitudes



Reduced Levelized Cost of Energy (LCOE)

Cost-effective solutions and enabling technologies

Value proposition - summary

PVS980-58, 5 MVA

Reduced LCOE



Low Capex

- High power rated inverter and power block
- Advanced power conversion topology
- Integrated protections and auxiliary power supply
- Double skin envelope and effective cooling method
- Easy and fast site AC connection by busbars



Low Opex

- Superior cooling system
- Simple preventive maintenance schedule
- Corrosion resistive dual layer enclosure
- +25 years design lifetime without scheduled major component changes
- Shared power conversion and control platform



High Yield

- High efficiency
- Low auxiliary power consumption
- Reliable and redundant design for high uptime



ABB