pv magazine Webinar: From innovative inverter to disruptive system design
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With
• Marco Trova, Global Product Manager, ABB
• Moderation: Emiliano Bellini, pv magazine

Content
• Cost breakdown trends in the utility-scale market
• Inverter evolution: Inverter + transformer Station
• Modular construction with detachable wiring box
• Power electronics and system-level cost savings outside of the inverter
• 1500Vdc and 800Vac combined to enable higher power density and cluster capacity
• Advantages of multi-MPPT technology

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There’s a new power in Solar

1500V ultra-high power string inverters for utility-scale PV applications

Andrea Genovesi, Gianluca Marri, Marco Trova
Utility-scale PV market trends
Technology is fast moving to 1500Vdc

WW Utility scale market by DC voltage

Utility scale projects are moving to 1500Vdc!
Utility-scale PV market trends
Outlook on CAPEX and OPEX evolution in the next years

CAPEX repartition trend

2015 Capex repartition

- 58.0%
- 34.0%
- 8.0%

2025 hypothetical scenario

- 50.0%
- 39.5%
- 10.5%

Cost trend over next coming years
- PV Module: -32% in 2025
- Inverter: -25% in 2025
- Other: -50% in 2025

Major cost savings will come from “other costs” (Soft Costs, Installation, Hardware)

CAPEX reduction will increase the share of the OPEX in the LCOE

Estimated OPEX and CAPEX share in the LCOE

2015 repartition

- 19% Capex
- 8% Opex

Expected situation in 2025

- 33% Capex
- 15% Opex

In 2025 the Opex can reach the Total LCOE!

Inverter design targeting Total System Cost reduction is required!

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Source: IRENA analysis and Photon consulting, 2016
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Setting a new trend in the solar inverter technology

System cost breakdown evolving towards an higher share of BoS and O&M
Identifying other areas for cost optimization while preserving the yield

How inverters can support the solar industry to tackle these challenges?

- Evolving from component to a complete «all-in-one» solution
- Modular construction with detachable wiring box
- Power electronics enabling further system-level cost savings
  - 1500Vdc/ 800Vac = highest power density and cluster capacity
- Multi-MPPT Technology, offering maximum energy yield
  - Fuse & DC combiner free design, minimizing EBoS and O&M

\[
\text{LCOE} = \frac{\text{CAPEX} + \text{OPEX}}{\text{YIELD}}
\]
ABSTRACT

Evolving from component to a complete «all-in-one» solution

Virtual Central Inverter

String Inverter

“All-In-One” String Inverter

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ABB – PVS-175-TL
Evolving from component to a complete «all-in-one» solution

ABB’s PVS-175 the «all in one solution» – BoS benefit

Virtual Central inverter

-1,4€/ Wac cost saving > 63%

String inverter

-0,5€/ Wac cost saving >45%

PVS-175 additional cost savings

Logistic: Up to 65% less component to store onsite

MW Station: Enabling bigger cluster size

Civil works: Reduced basements and mechanical structures with respect to Virtual central solution

ABB’s PVS-175 Virtual Central

DC cables feeder
DC Recombiner
DC Installation
DC cables string

Virtual Central

DC-Bos

ABB’s PVS-175

Virtual Central

DC-Bos

ABB’s PVS-175 String Inverter

AC Recombiner
AC Installation
AC cables
ABBB – PVS-175-TL

Evolving from component to a complete «all-in-one» solution

ABB’s PVS-175 the «all in one solution» – O&M benefit

Modular construction with detachable wiring box reducing installation and maintenance effort.

- Two box structure (power module ~76kg, wiring box ~77kg)

Benefits:
- Two person can manage the mounting of boxes
- Power module can be easily replaced without removing the wiring box.

Cost saving on logistics:
- Wiring box/ inverter box can be stocked separately
- Future local variants of wiring box possible
ABB – PVS-175-TL
Evolving from component to a complete «all-in-one» solution

ABB’s PVS-175 the «all in one solution»

Reducing time spent on site: Commissioning, FW Upgrade, parameter’s setting and troubleshooting may be performed either remotely via cloud or locally through a mobile App.

<table>
<thead>
<tr>
<th>Minimum costs (both OPEX and CAPEX)</th>
</tr>
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<tbody>
<tr>
<td>– Multi-inverter plant commissioning via Installer App</td>
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Minimum costs (both OPEX and CAPEX) - Multi-inverter plant commissioning via Installer App - Intelligent, remote monitoring and control

Protecting customer’s investment - TCP/IP as proven standard technology - Cyber Security managed data transfer

Reduced plant complexity, improved reliability - Integrated digitalization capabilities with ABB Ability™ - Direct transferring of telemetry data to cloud

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ABB Ability™

**ABB Ability™**

- **Improved user experience** in large scale installations (Installer App for plant commissioning)
- **Self-consistent**: advanced logging and control capabilities embedded into the inverter
- **Reduced time on site**: Life time free remote cloud services (FW upgrade, asset management)
- **Proven technology**: for better protecting customer’s investment (TCP/IP, Modbus Sunspec certified, IEC 61850 information model,...)
- **Future-proof**: meet current and future regulatory norms (like Rule 21- Step 2, EC61850, ...)

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**Protecting customer investment**

- **Off-the-Shelf TCP/IP components**
- **Standard technology**: no need to educate people
- **IP protocol** is the only one really suitable for IoT
- **Modbus TCP Sunspec**: trouble-free integration with third party devices

**Multiple data streams and services can run at the same time:**
- Remote monitoring
- Plant control (incl. dynamic feed-in)
- Remote FW update
- Remote parameter’s setting
1500VDC allows high AC voltage!

High AC voltage is enabled with DC/DC boosters and 1500Vdc input voltage

- Single stage inverter reasonable max AC voltage ~ 600VAC
- Dual stage inverter AC voltage can be increased to 800VAC

800VAC to reduce Balance of System cost (i.e. AC side cabling) and enabling higher power units with same current (less units per power block)

More power from the same enclosure
AC power vs AC voltage

- 400V: 80, 100, 130, 150, 175
- 600V: 80, 100, 130, 150, 175
- 690V: 150, 175
- 800V: 80

(140kVA/130kVA)
(185kVA/175kVA)

Less units and resources are needed
AC-BOS cost savings (LV distribution)

- 75% less Cu/Al components
- 75% less

Bigger PV clusters may be designed

- 3,7MVA
- 5MVA

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### ABB – PVS-175-TL

Enabling further cost savings with the world’s highest power inverter in the string category

#### 1500VDC allows high AC voltage!

High AC voltage is enabled with DC/DC boosters and 1500Vdc input voltage

**Main benefits**
- Bigger PV clusters can be designed, reducing MV & AUX system costs, as well as installation costs!

<table>
<thead>
<tr>
<th>100MWac project</th>
<th>Virtual Central (600Vac)</th>
<th>ABB’s PVS-175 (800Vac)</th>
<th>Cost saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>N° of Cluster</td>
<td>27</td>
<td>20</td>
<td>Installation and Civil works → 26%</td>
</tr>
<tr>
<td>N° of MV/LV transformer</td>
<td>27 x (3,7MVA)</td>
<td>20 x (5MVA)</td>
<td>Equipment → 6%</td>
</tr>
<tr>
<td>N° of MV switchgear</td>
<td>27</td>
<td>20</td>
<td>Equipment → 26%</td>
</tr>
<tr>
<td>N° of LV switchgear</td>
<td>27</td>
<td>20</td>
<td>Equipment → 19%</td>
</tr>
</tbody>
</table>

**Total cost saving for equipments**  
~ 0,3 €c/W

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ABB – PVS-175-TL
The ideal solution for decentralized utility-scale application

Integrated Solution overview

**MVCS (MV Compact Skid)**
- Fits within a 20ft container
- Dedicated protected feeder for each inverter
- All auxiliaries included
- Oil Transformer
- Up to 6.7MVA
- Most cost efficient

**MVS (MV Station)**
- Containerized 20ft solution
- Dedicated protected feeder for each inverter
- All auxiliaries included
- Dry Transformer
- Up to 6.7MVA
- Self-transportable solution

All in one integrated string combiner

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# ABB – PVS-175-TL

The ideal solution for decentralized utility-scale application

## MVS main characteristics

### Data-sheet

<table>
<thead>
<tr>
<th>Item.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MV Switchgear</td>
</tr>
<tr>
<td>2</td>
<td>MV Transformer</td>
</tr>
<tr>
<td>3</td>
<td>AC cabinet</td>
</tr>
<tr>
<td>4</td>
<td>Inverter outputs</td>
</tr>
<tr>
<td>5</td>
<td>Auxiliary transformer</td>
</tr>
</tbody>
</table>

### Auxiliary Services

<table>
<thead>
<tr>
<th>Item.</th>
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</tr>
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<tbody>
<tr>
<td>6</td>
<td>AC cabinet heating</td>
</tr>
<tr>
<td>7</td>
<td>Transformers external fan1</td>
</tr>
<tr>
<td>8</td>
<td>Transformers external fan 2</td>
</tr>
<tr>
<td>9</td>
<td>External power socket</td>
</tr>
<tr>
<td>10</td>
<td>Lighting</td>
</tr>
<tr>
<td>11</td>
<td>Communication cabinet</td>
</tr>
<tr>
<td>12</td>
<td>MVS control equipment</td>
</tr>
<tr>
<td>13</td>
<td>AC cabinet control system</td>
</tr>
<tr>
<td>14</td>
<td>Spare</td>
</tr>
<tr>
<td>15</td>
<td>Spare</td>
</tr>
</tbody>
</table>

### String-MVS 5180

<table>
<thead>
<tr>
<th>Output (AC)</th>
<th>PVS-175</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compatible String Inverter type</td>
<td>PVS-175</td>
</tr>
<tr>
<td>Maximum AC output power ($S_{max}$ @ 30C)</td>
<td>5180 kVA</td>
</tr>
<tr>
<td>Maximum Inverters Inputs</td>
<td>28</td>
</tr>
<tr>
<td>Medium voltage range ($U_{MAX}$)</td>
<td>12 kV to 36 kV</td>
</tr>
<tr>
<td>Output frequency</td>
<td>50/60 Hz</td>
</tr>
</tbody>
</table>

### Power factor compensation (cosΦ)

| Transformer type | ABB Vacuum cast coil dry type |
| Medium voltage switchgear type | ABB Safelinq, SIF6 insulated (CV, CCV, CCVV) |

### Power consumption

| Maximum Own consumption in operation | Maximum 5900 W/ 3800 W |
| Auxiliary voltage for customer use | 3 - 400 V/50 Hz, up to 40kVA |

### Dimensions and weight

| Width/Height/Depth | 2438 mm/6058 mm/2438 mm (20' HC container dimensions) |
| Weight approx. | < 20 t |

### Environmental limits

| Degree of protection | IP54 |
| Ambient temperature range (nominal ratings) | -20°C to +50°C |
| Maximum altitude (above sea level) | 1000 m |

### Electrical
c

| Coefficient/standard | Eurocode: Roof/wind/seismic 200kg/47/m/s/0,3g |

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The ideal solution for decentralized utility-scale application

MVS lay-out

- Customizable aux booth
- Communication board
- UPS
- MW switchgear
- Extra compartment
- Fans
- MV switchgear compartment
- MV transformer compartment
- Aux transformer
- Exhaust air hood
- MV transformer
- AC panel compartment
Preserving maximum energy yield while reducing CAPEX and OPEX of the system

Fully exploit the benefits of string inverters with Multi-MPPT and fuseless technology

High YIELD and CAPEX
Preserving maximum energy yield while reducing CAPEX and OPEX of the system

Fully exploit the benefits of string inverters with Multi-MPPT and fuseless technology

### String level Inverter

- CAPEX
- OPEX

### Virtual Central Inverter (Single MPPT)

- CAPEX reduction penalizing YIELD

<table>
<thead>
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<th>CAPEX</th>
<th>OPEX</th>
<th>LCOE</th>
<th>YIELD</th>
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Fully exploit the benefits of string inverters with Multi-MPPT and fuseless technology

Maximizing YIELD while reducing OPEX
Preserving maximum energy yield while reducing CAPEX and OPEX of the system

Fully exploit the benefits of string inverters with Multi-MPPT and fuseless technology
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Preserving maximum energy yield while reducing CAPEX and OPEX of the system

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<table>
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<th>Virtual Central Inverter (Single MPPT)</th>
<th>More power generation by</th>
<th>Multi-MPPT vs Virtual Central</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mismatch &amp; Shading Losses (12 MPPT)</td>
<td>+0.3% ÷ +0.7%</td>
</tr>
<tr>
<td></td>
<td>Higher system availability (fuseless technology)</td>
<td>+0.1%</td>
</tr>
<tr>
<td></td>
<td>Overall Benefit using ABB's PVS-175</td>
<td>+0.4% ÷ +0.8%</td>
</tr>
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</table>

Assumptions
- 2200 equivalent hours
- PPA @ 3€c/kWh
- (100MWac/20y)

Up to €1.1 Million additional income over 20 years!
Preserving maximum energy yield while reducing CAPEX and OPEX of the system

**Fuseless technology benefit**

The PV panels must be protected by reverse current according to manufacturer data-sheet. Generally, if 3 or more strings are connected in parallel, a reverse current protection must be used.

Fuses are prone to nuisance tripping over the years and this increase:
- O&M cost → Site inspections are needed to check and replace fuses
- Energy yield losses

ABB’s PVS-175 with 12 MPPTs and only 2 strings into each MPPT no need fuses:
- Simplify O&M → Cost Saving
- Avoid energy yield losses
ABB – PVS-175-TL

Overview

PVS-175 1500Vdc/800Vac a unique, six-in-one product

- **185kVA @30°C/ 175kVA @40°C**: The World’s **Highest Power Inverter** in the String Category
- **Modular Construction**: with detachable wiring box
- **Remote Fw update & parameters setting**
- **Fuse-free design**: Minimize EBoS and O&M
- **12 independent MPPTs** for the highest yield and configurability in all ground conditions
- **Installer App**: 70% faster wireless plant commissioning
ABB – PVS-175-TL

Data-sheet

Inverter key parameters
- 185kW@30°C, 175kW @40°C
- Max Input Voltage 1500Vdc
- Vac = 800Vrms 3-ph/ 3 wire, 50/ 60Hz
- 12 Independent MPP/ 24 strings
- Fuseless DC combiner design
- VMPPT = 850 – 1350 Vdc, full power

User Interface
- Standard LEDs
- Integrated Web User Interface for managing inverter
- iOS and Android installation app for multiple inverter commissioning
- Standard level access to Aurora Vision remote monitoring service

Construction, weight, volume
- IP65
- Forced Air cooling
- Two box construction
- Overall weight ≈ 153kg (76kg + 77kg)

Efficiency
- Max. Efficiency: 98,7%
- EU Efficiency: 98,4%
- CEC Efficiency: 98,4%

Communication
- 2 x Ethernet;
- Wi-Fi Channel
- 1 x RS485;
- Modbus RTU/ TCP (Sunspec compliant);
- Integrated datalogger and direct connection to Aurora Vision remote portal

In/ Out protections
- Type 2 Surge arrester (both DC and AC)
- Insulation monitoring control per IEC 62109-2
- DC Series Arc Fault Circuit Interrupter (optional)
### ABB – PVS-175-TL
Evolving from component to a complete «all-in-one» solution

<table>
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<th>Lower CapEx</th>
<th>Better OpEx</th>
<th>Maximum Yield</th>
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<tr>
<td>• &gt; 63% saving on DC-BoS compared to Virtual Central</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• &gt; 45% saving on AC-BoS compared to conventional String Solution</td>
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<td></td>
</tr>
<tr>
<td>• Up to 65% less components to install</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 20% to 40% saving on AC cables and components versus 600Vac string inverters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 28% to 43% less inverter to manage versus all other string proposals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• up to 65% less components to commission onsite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Multi inverter commissioning thanks to installer app</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 30-50% less field interventions for fuses replacement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 0,3-0,7% lower losses on the harvesting versus to Virtual Central solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 0,1% increase on availability thanks to fuse free design</td>
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Discussion and Q&A

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8am to 9am (CET)

From innovative inverter to disruptive system design – challenges and advantages in the APAC region
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Tuesday, December 18
5pm – 6pm (CET)

From innovative inverter to disruptive system design - challenges and advantages in the LATAM region
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(in Spanish)

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