SMA Smart Inverter/ Grid Support Capabilities
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Global Leadership, Local Expertise

- $1.2+B in annual revenue
- 5,000 employees worldwide
- 1,000 professionals in research and development
- 15 GW total manufacturing capacity
- More than 35 GW installed worldwide
- 30+ Years of Experience
- Well-positioned in 21 markets across the globe
- North American production in Denver and Toronto
- Solutions for all power classes and applications
Inverters with ‘Smart’ features available in the U.S.

**Residential**
Sunny Boy 3/4/5000TL-US

**Commercial**
Sunny Tripower 12/15/20/24000TL-US

**Utility Scale**
Sunny Central CP-XT and CP-US
Future Proof – Advanced Grid Support Features

- On-demand Active Power reduction (curtailment)
- Frequency-dependent Active Power reduction
- Reactive Power supply
  - Fixed, on-demand or dynamic control
- Low Voltage Ride-Through (LVRT)
  - Limited or full dynamic grid support
Autonomous vs On-Demand Inverter Functions

**Autonomous Functions**

- No communications architecture required
- Pre-defined behaviors that can be ‘programmed’ through inverter operating parameters
- May be activated at system commissioning or later
- May be activated, de-activated or adjusted as needed via on-site or remote operator interfaces

**On-Demand Functions**

- Communications and control architecture required
- Direct, exception-based command control of inverter behavior
- Control initiated based on remote grid operator commands or PCC-based control loop
Autonomous Functions: Frequency-dependent Active Power Limitation

Reduce PV generation to alleviate over-supply conditions

- Inverter interprets increase in frequency as over-supply condition
- Inverter reduces active power output until frequency returns to normal
Autonomous Functions: Dynamic Reactive Power Control

- **Support EPS voltage stabilization**

  > Characteristic curve based on \( \cos \varphi(P) \) or \( Q(V) \)

- Based on conditions at inverter output terminals
- \( \cos \varphi(P) \): Dynamically adjust power factor based on power \( (P/P_{nom}) \)
- \( Q(V) \): Dynamic VAR injection based on grid voltage

![Characteristic curve based on \( \cos \varphi(P) \) or \( Q(V) \)](image)

- **Pythagoras' theorem:** \( S^2 = P^2 + Q^2 \)
- \( S = \frac{P}{\cos \varphi} \)
- \( P = S \cdot \cos \varphi \)
- \( Q = \sqrt{S^2 - P^2} \)
Autonomous Functions: Low-Voltage Ride-Through

> Grid Support during grid fault/disturbance
> Stay connected during High Voltage grid disturbances to avoid simultaneous shutdown
> During voltage dip to 0v, inverter injects reactive current for voltage support and to aid in protection devices.

![Diagram showing the requirements of dynamic grid support](image-url)
Autonomous Functions: Low-Voltage Ride-Through

Avoid loss of PV generation from system faults

> **Full Dynamic Grid Support**
  
  - Inverter remains connected through fault and supplies reactive current

> **Limited Dynamic Grid Support**
  
  - Inverter remains connected through fault but does not provide active or reactive power

![Image of graph showing dynamic grid support](image)

Figure 5: The requirements of dynamic grid support
Autonomous Functions: Additional Grid Interface Controls

> Voltage and Frequency trip points and times
  • Configurable to Area EPS conditions and requirements
    ▶ Avoid sudden loss of PV generation

> Reconnection time delay settings
  • Can be staggered or randomized across multiple inverters
    ▶ Avoid surges due to sudden reconnection of PV generation

> Ramp rate controls
  • Controllable active power ramp following grid disturbance or normal connection
    ▶ Avoid surges due to sudden reconnection of PV generation
On-Demand Functions: Active Power Reduction (Curtailment)

Reduce PV generation to alleviate over-supply conditions or grid backfeed

> Initiated by grid operator

• For severe over-supply conditions
• Requires defined standards for communications architectures and protocols

> Initiated by local control loop

• For systems where back fed power is prohibited or must be limited
• “Load serving” systems
• Communications architecture and protocol can be site-specific

> Remote OFF

• Can be effected by 0 kW command
On-Demand Functions: Reactive Power Setpoints (cos $\phi$ or $Q$)

- **Support EPS voltage stabilization**

> **Initiated by grid operator**

- Requires defined standards for communications architectures and protocols

> **Initiated by local control loop**

- Based on conditions at PCC
- Communications architecture and protocol can be site-specific

Figure 1: Pythagorean theorem: $S^2 = P^2 + Q^2$

\[
S = \sqrt{P^2 + Q^2} \quad S = \frac{P}{\cos \phi} \quad P = S \cdot \cos \phi \quad Q = \sqrt{S^2 - P^2}
\]
# SMA Smart Inverter Capabilities by Inverter

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<td>Reactive power supply: Fixed</td>
<td>cos $\varphi$</td>
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<tr>
<td>Reactive power supply: Dynamic</td>
<td>cos $\varphi$ (P)</td>
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<td>LVRT: Limited Dynamic Grid Support</td>
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<td>LVRT: Complete Dynamic Grid Support</td>
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<td>On-demand active power reduction</td>
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<td>On-demand reactive power supply</td>
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WEIL: Inverter Technical Standards Proposal

Western Electric Industry Leaders – recommended enhanced ‘smart’ inverter functions:

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<th>Recommended Functions</th>
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