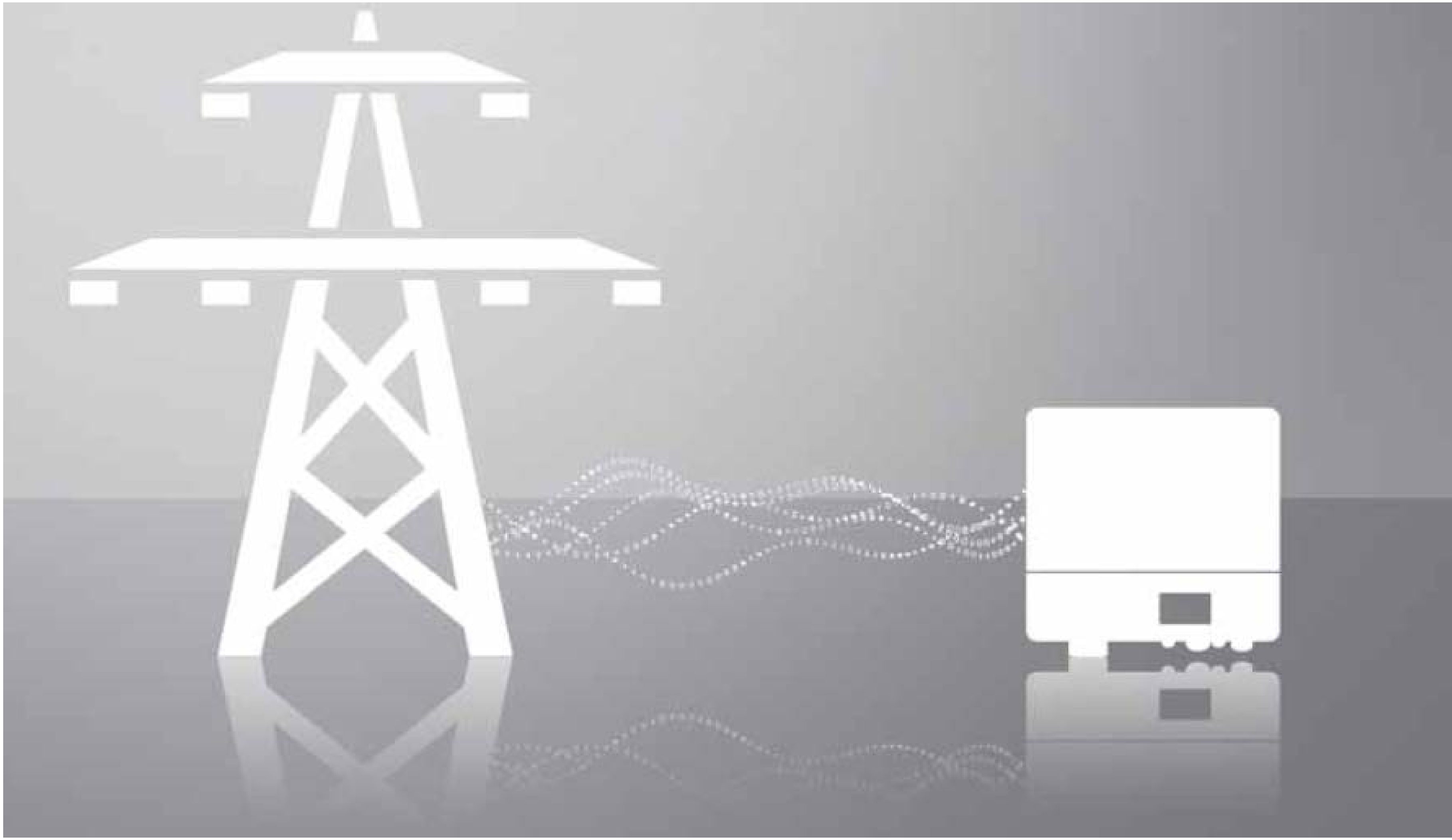
SMA Smart Inverter/ Grid Support Capabilities



April 2014

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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

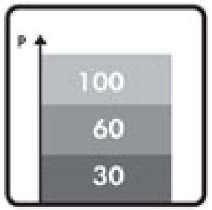
Inverters with ‘Smart’ features available in the U.S.

Residential
Sunny Boy 3/4/5000TL-US

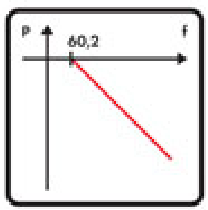
Commercial
Sunny Tripower 12/15/20/24000TL-US

Utility Scale
Sunny Central CP-XT and CP-US

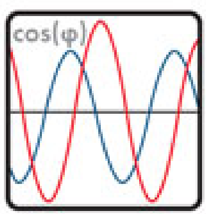
Future Proof – Advanced Grid Support Features



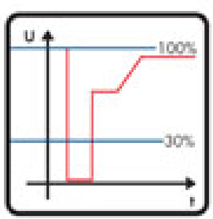
- On–demand Active Power reduction (curtailment)



- 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

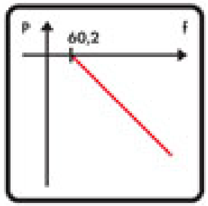
- No communications architecture required
- Pre-defined behaviors that can be ‘programmed’ through inverter operating parameters
- May be activated at system commissioning or later
- May be activated, de-activated or adjusted as needed via on-site or remote operator interfaces

> ## 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

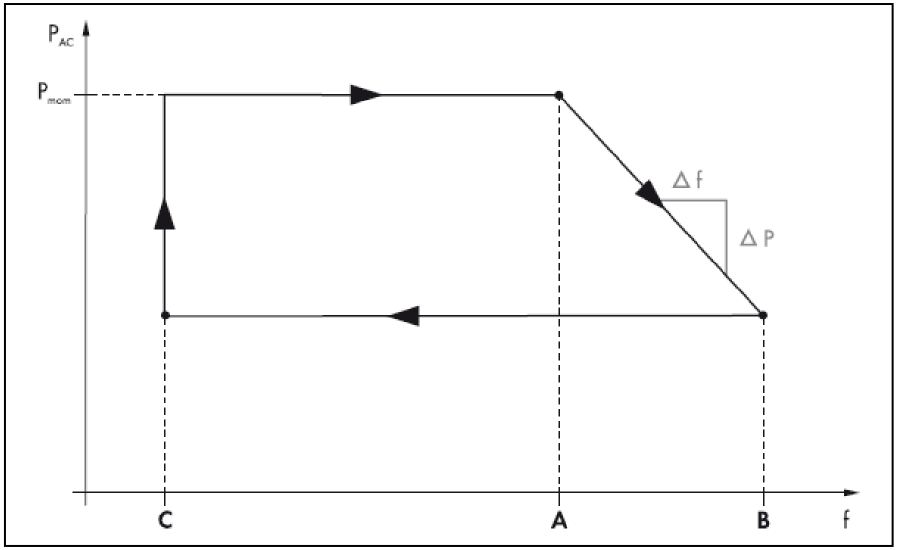
Autonomous Functions: Frequency-dependent Active Power Limitation

Reduce PV generation to alleviate over-supply conditions



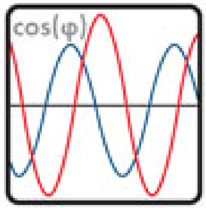
> Frequency-dependent Active Power Limitation

- Inverter interprets increase in frequency as over-supply condition
- Inverter reduces active power output until frequency returns to normal



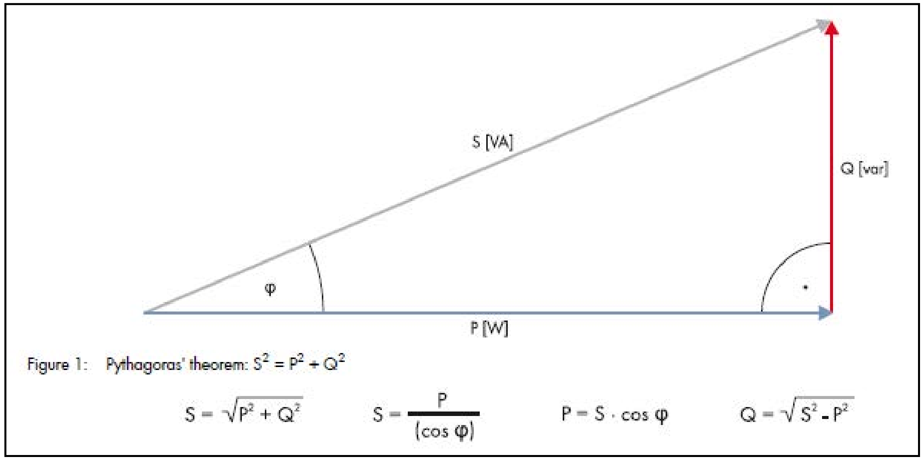
Autonomous Functions: Dynamic Reactive Power Control

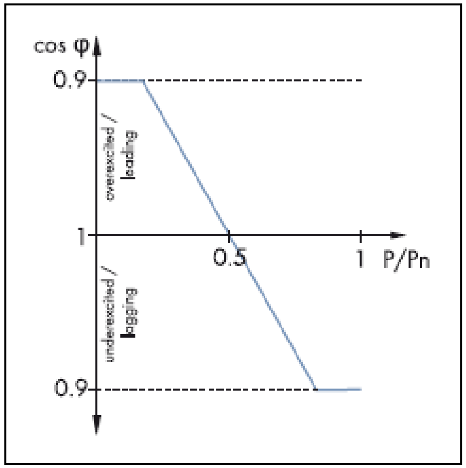
Support EPS voltage stabilization



> **Characteristic curve based on cos ϕ(P) or Q(V)**

- Based on conditions at inverter output terminals
- cos ϕ(P): Dynamically adjust power factor based on power (P/Pnom)
- Q(V): Dynamic VAR injection based on grid voltage





Autonomous Functions: Low-Voltage Ride-Through

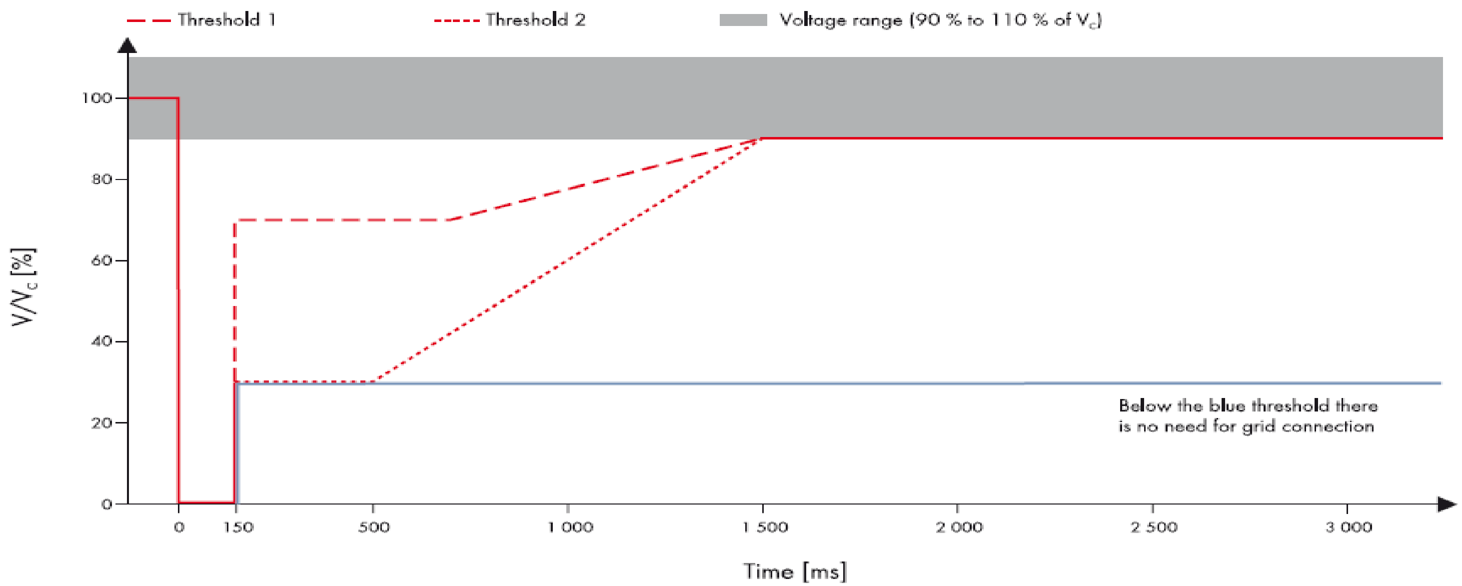
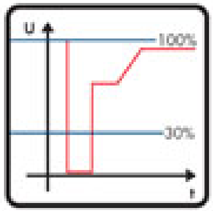
- Grid Support during grid fault/disturbance
- Stay connected during High Voltage grid disturbances to avoid simultaneous shutdown
- During voltage dip to 0v, inverter injects reactive current for voltage support and to aid in protection devices.
- 

Figure 5: The requirements of dynamic grid support

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

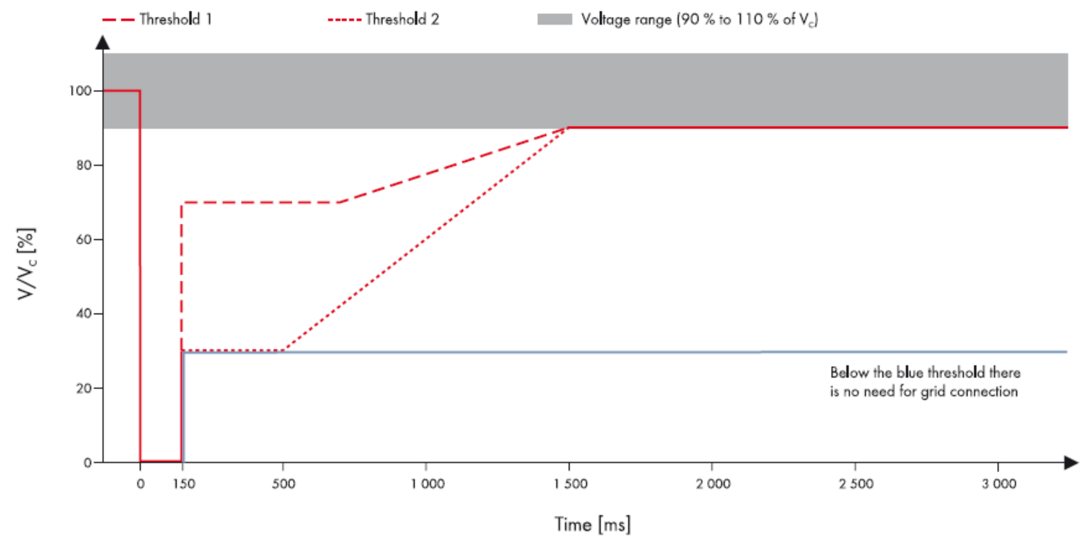


Figure 5: The requirements of dynamic grid support

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

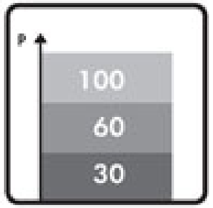
> **Ramp rate controls**

- 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

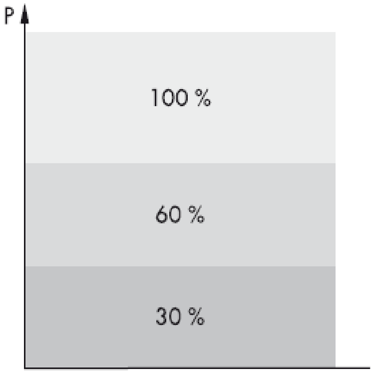


> **Initiated by grid operator**

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

> **Initiated by local control loop**

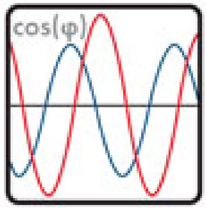
- For systems where back fed power is prohibited or must be limited
- "Load serving" systems
- Communications architecture and protocol can be site-specific



> **Remote OFF**

- Can be effected by 0 kW command

On-Demand Functions: Reactive Power Setpoints (cos ϕ 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

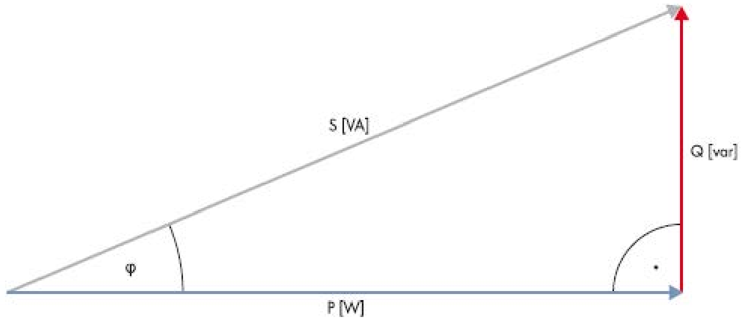


Figure 1: Pythagoras' theorem: $S^2 = P^2 + Q^2$

$S = \sqrt{P^2 + Q^2}$ $\quad S = \frac{P}{(\cos\varphi)}$ $\quad P = S \cdot \cos\varphi$ $\quad Q = \sqrt{S^2 - P^2}$

SMA Smart Inverter Capabilities by Inverter



Applications		Residential	Commercial	Utility
Inverters		**Sunny Boy TL-US**	**Sunny Tripower TL-US**	**Sunny Central CP-XT / CP-US**
Frequency-dependent power reduction	P(f)			
Reactive power supply: Fixed	cos φ			
	Q			
Reactive power supply: Dynamic	cos φ (P)			
	Q(V)			
LVRT: Limited Dynamic Grid Support				
LVRT: Complete Dynamic Grid Support				
On-demand active power reduction				
On-demand reactive power supply				

WEIL: Inverter Technical Standards Proprosal

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

Recommended Functions	Existing SMA Functionality
Communications capabilities	Requires identification/definition of standards
Real and reactive power support	✓
Dynamic VAR injection	✓
Expanded frequency trip point	✓
Low voltage ride through	✓
Randomization of timing for trip and reconnection	✓

Thank You