PowerTrack™ EMS Solution

Stem's Edge-to-Cloud Energy Management System for Solar, Energy Storage, and Hybrid Assets

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Complete Edge-to-Cloud Technical Monitoring and Energy Management

The energy sector faces increasing complexity in integrating renewable energy resources, including solar generation and battery energy storage systems (BESS). Organizations must simultaneously ensure grid stability while meeting evolving regulatory requirements. Modern utility-scale installations must coordinate diverse equipment from multiple OEMs while delivering complex multi-mode control for frequency, voltage, and power management with sub-second response times. Traditional energy management systems often lack the technical capabilities to efficiently monitor and manage distributed resources across varying communication protocols. This results in extended commissioning cycles, limited operational visibility, and integration complexity that hampers both performance optimization and regulatory compliance.

Stem's PowerTrack Energy Management System (EMS) solution provides comprehensive technical monitoring and energy management of utility-scale solar, storage, and hybrid energy assets. The system architecture connects on-site controllers, supervisory control and data acquisition (SCADA) systems, and cloud infrastructure to enable:

- **Real-time system configuration and parameter adjustment**
- **Precise command execution with sub-second response times**
- **Data collection and analysis for operational optimization**
- **Standardized communication across multiple protocols**
- **Centralized management of distributed assets**

This integrated approach enables operators to monitor performance metrics, manage control parameters, and optimize operational efficiency across both individual sites and entire energy portfolios. The system supports multiple asset types including standalone BESS, standalone PV, and hybrid installations, with standardized interfaces that reduce integration complexity while enabling seamless scaling and hybrid expansion.

The architecture implements a layered design with distinct edge (on-site) and cloud components, leveraging Stem's industry-leading PowerTrack software, connected through secure communication channels and utilizing industry-standard protocols to ensure compatibility with existing infrastructure and regulatory requirements. On-premise hardware and software combine industry-proven platforms such as Advantech and SEL with transparent, non-proprietary software, providing customers with full visibility and control over their clean energy infrastructure without black-box limitations.

Stem's PowerTrack EMS solution delivers measurable value to developers, utilities, and IPPs to:

Accelerate Deployment

Reduce engineering hours by

32%

Scale with Confidence

Rely on Stem's proven expertise managing

800+

BESS assets

Maintain Reliable Operations

Ensure continuity with

99.99%

controller uptime

Advanced Capabilities

PowerTrack EMS solution is designed for reliability, scalability, and ease of use.

Real-Time Data Monitoring

Achieve 99.99% controller uptime, ensuring reliable system performance

Intuitive User Interfaces

Easy-to-use edge and cloud interfaces simplify operations

Standardized Data Model

Supports IEEE 1815.2 scheduling with multi-protocol compatibility, including DNP3, Modbus, OPC-UA, IEC 61850, and IEC 60870

Configurable SCADA Interfaces

Includes a Human-Machine Interface (HMI) for streamlined control

Centralized Portfolio Management

Manage your entire asset portfolio through a unified cloud platform, extending the capabilities of Stem's industry-leading software

Scalability

Scale from individual assets to enterprise portfolios while seamlessly upgrading standalone PV or BESS installations to hybrid configurations

Project Lifetime Data Storage

Securely store and access data for the operating life of your assets

Industry Compliance and Certifications

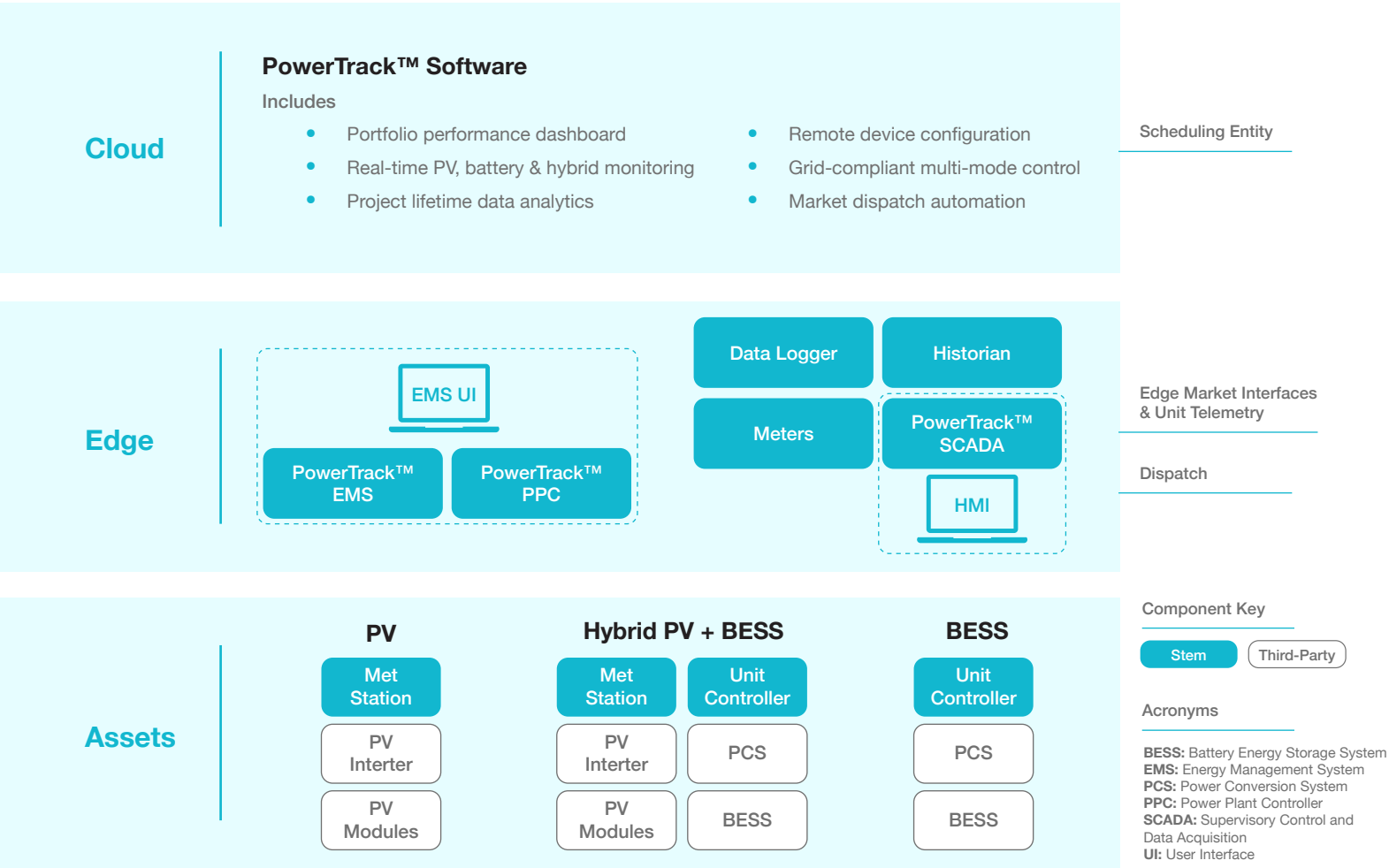
Ensure global regulatory compliance across operational environments with certifications for NA, LATAM, EMEA standards

Solution Components

Stem's PowerTrack EMS solution integrates a modular hardware and software architecture to create a comprehensive energy management system. The implementation utilizes industry-proven hardware platforms from leading vendors including Advantech and SEL. These are combined with standardized interfaces and communication protocols to ensure interoperability between components. The system architecture consists of the following core elements:

Architecture Overview:

- **Cloud** software components for centralized management and monitoring
- **Edge** (on-site) components for local control and data acquisition
- **Asset-specific** components for device integration and control
- **Communication** infrastructure for secure data transmission

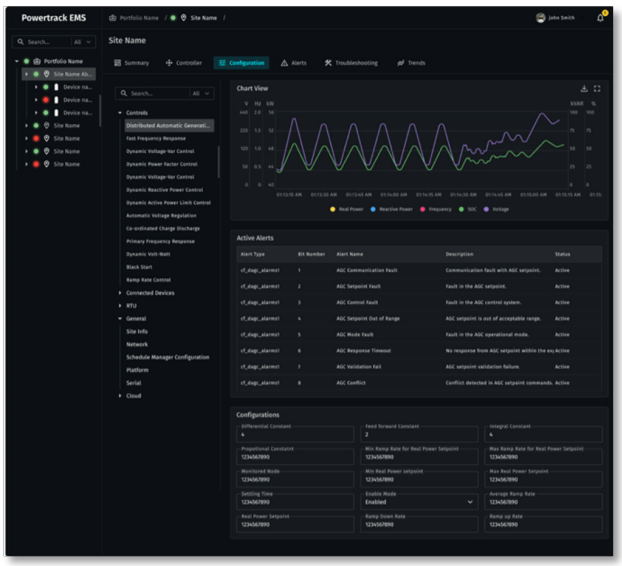


The solution implements a distributed processing model with redundant communication pathways to maintain operational reliability. Component selection can be configured based on specific project requirements, environmental conditions, and operational parameters.

The architectural design supports staged implementation, enabling system expansion from basic monitoring to comprehensive control functionality. All components utilize industry-standard communication protocols to facilitate integration with third-party systems and ensure compatibility with evolving regulatory requirements.

EMS User Interface

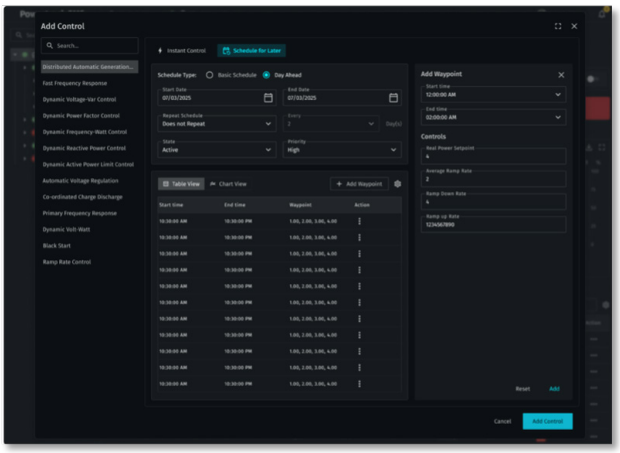
Stem's EMS User Interface (UI) provides an on-site operator interface for system configuration, monitoring, and control of solar, energy storage and hybrid assets. This interface serves as the primary interaction point for on-site or remote technical management, offering equivalent functionality to standalone SCADA systems while maintaining compatibility with existing SCADA infrastructure when required.



Real-time Adaptive Monitoring and Trends

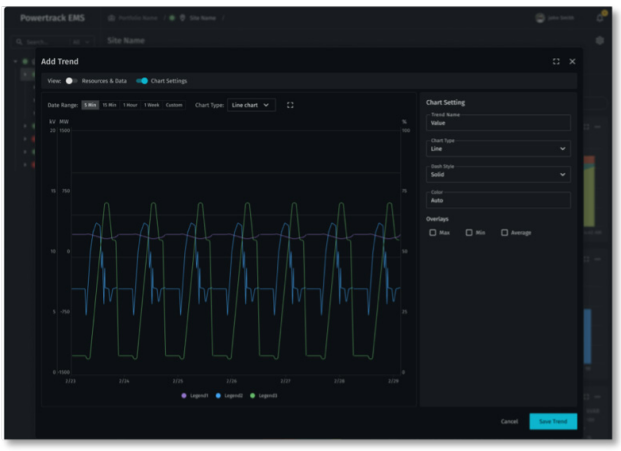
Monitoring point addition capability for immediate asset visualization without system interruption during commissioning.

Reduces commissioning cycles and diagnostic intervals while maintaining operational continuity.



Advanced Scheduler

Implements temporal, priority, and mode-based scheduling with day-ahead SOC waypoint targeting. Enables deterministic energy management and optimized dispatch sequencing.



Advanced PID Tuning with Real-Time Visual Feedback

Graphical parameter adjustment interface with real-time response visualization for control optimization. Remote commissioning capability eliminates on-site tuning requirements.

Device-Level Site Configuration

Granular configuration architecture with device-specific parameter management. Provides parameter-level control resolution for diverse asset configurations.

Control Modes

PowerTrack PPC features 12 comprehensive control modes designed to optimize energy storage and grid integration, with ongoing development of additional modes to meet evolving market requirements. These modes are categorized into Frequency Management, Voltage Management, Power Management, and System Control, providing flexible and efficient operation for various grid scenarios.

	Control Mode	Description	Market Application & Revenue Opportunity
Category: Frequency Management			
	**Fast Frequency Response (FFR)** *Frequency Containment Reserve (FCR) - Primary Frequency Control*	Reacts within milliseconds to grid frequency deviations, injecting or absorbing power to rapidly stabilize the grid during sudden changes	Enhanced interconnection terms and capacity payments **North America (NA):** High-value FFR services and primary frequency response revenues **Europe (EU):** FCR market participation with premium pricing for fast response
	**Frequency Watt Control** *Primary Frequency Control or Frequency Response*	Automatically adjusts active power output based on grid frequency, modulating power to help restore balance and enhance grid resilience	Configurable response characteristics for optimal market participation **NA:** Frequency regulation and grid support service revenues **EU:** Primary frequency response markets and grid balancing service revenues
	**Power Oscillation Damping**	Detects and mitigates power system oscillations by dynamically adjusting power output, improving system reliability during transient events	Reduced curtailment risk through improved grid performance **NA:** Grid stability services and enhanced interconnection value **EU:** Grid stability compensation and service premiums
Category: Voltage Management			
	**Automatic Voltage Regulation (AVR)**	Maintains voltage levels within specified limits through continuous monitoring and reactive power adjustment at point of interconnection	Enhanced grid interconnection terms and capacity benefits **NA:** Voltage support services and reactive power compensation **EU:** Voltage control services and reactive power markets
	**Volt-VAR Control** *Reactive Power-Voltage Control or Q(U) Control*	Dynamically compensates for reactive power based on voltage levels, following predefined curves to maintain optimal voltage profiles	Improved power factor and reduced demand charges **NA:** Enhanced voltage support services and distribution compensation **EU:** Dynamic reactive power services and voltage quality premiums
	**VAR Control** *Reactive Power Control or Q Control*	Provides constant reactive power support to the grid, addressing known reactive power deficiencies at specific network locations	Long-term service agreements and predictable revenue streams **NA:** Steady reactive power compensation and grid support revenues **EU:** Reactive power market participation and grid service contracts

	Control Mode	Description	Market Application & Revenue Opportunity
Category: Power Management			
	**Active Power Limiting** *Active Power Curtailment*	Caps active power output at specified levels, managing grid constraints and complying with interconnection agreements	Optimized interconnection capacity and reduced upgrade costs **NA:** Higher capacity factors through intelligent curtailment management **EU:** Constraint management services and congestion relief compensation
	**Fixed Power Factor** *Constant Cos ϕ Control*	Maintains constant power factor by balancing active and reactive power output to meet grid requirements and operational needs	Reduced penalties and improved operational efficiency **NA:** Power quality compliance and enhanced interconnection terms **EU:** Power quality services and grid code compliance benefits
	**Dispatch Regulation Reserve** *automatic Frequency Restoration Reserve (aFRR) - Secondary Frequency Control*	Participates in regulation services by following external dispatch signals, providing automatic frequency restoration capabilities	High-frequency trading opportunities and margin capture **NA:** Regulation market participation and real-time energy market access **EU:** aFRR market revenues through automated dispatch response
Category: System Control			
	**Dynamic SOC Control**	Optimizes battery state of charge based on forecasted grid conditions, energy prices, and system constraints for upcoming events	Maximized asset utilization and revenue stacking opportunities **NA:** Multi-market revenue optimization across energy and ancillary services **EU:** Coordinated day-ahead, intraday, and ancillary service participation
	**Automatic Generation Control (AGC)** *manual Frequency Restoration Reserve (mFRR) - Tertiary Frequency Control*	Integrates with grid control systems by responding to AGC signals from system operators for grid balancing support	Grid operator preferred status and enhanced dispatch priority **NA:** AGC market participation and regulation service revenues **EU:** mFRR market access and tertiary control revenues
	**SOC Waypoint** *SOC Scheduling*	Enables operators to set specific SOC targets at future times with automatic charge/ discharge management to meet scheduled requirements	Reduced market penalties and improved bidding accuracy **NA:** Optimized positioning for scheduled energy delivery and commitments **EU:** Precise Day-Ahead commitments and scheduled grid services

The system supports running multiple control modes simultaneously using priority-based algorithms and configurable overrides. Mode transitions implement bumpless transfer techniques, switching from one control mode to another without causing sudden jumps or disruptions, to maintain system stability during operational changes.

Components and Specifications

Edge

On-Site Hardware and Software: PowerTrack EMS implements an integrated hardware and software architecture for comprehensive management of solar, storage, and hybrid assets. The system architecture utilizes standardized interfaces for component interoperability while supporting customized configurations based on project-specific technical requirements.

PowerTrack EMS and PPC

Stem integrates EMS and power plant controller (PPC) functionalities within a unified computing platform. This architectural integration reduces signal latency and eliminates inter-device communication dependencies. It also minimizes potential points of failure across the control chain. The implementation standardizes equipment specifications across PV, hybrid, and standalone BESS deployments. The hardware configuration includes industrial-grade power supplies, uninterruptible power backup, managed network infrastructure, and redundant communication paths. All components are integrated within environmentally rated enclosures configured to meet installation site specifications.

Key Features

- Intuitive on-board user interface for rapid configuration
- Real-time monitoring with adaptive point additions
- Advanced PID tuning with visual feedback
- Powerful scheduler with priority-based applications
- Device-level site configuration capabilities
- Integrated PPC for closed loop controls

Hardware Options

Available on industry-leading platforms

See technical specifications on page 10

- Intuitive on-board user interface for rapid configuration
- Real-time monitoring with adaptive point additions
- Advanced PID tuning with visual feedback
- Powerful scheduler with priority-based applications
- Device-level site configuration capabilities
- Integrated PPC for closed loop controls

Stem provides standard and built-to-order panels to meet customer-specific needs

- Firewall
- GPS clock
- Camera
- RTAC
- Modem
- Inverter gateway

Technical Capabilities

Multi-Mode Control Implementation

High-performance control execution in complex, concurrent operating modes

Asset Type Compatibility

Protocol support for BESS, PV, and hybrid system integration with staged deployment capability

Response Performance

Optimized execution cycles for stringent grid interconnection requirements in Hawaii, ERCOT, and EU jurisdictions

Control Architecture

Codesys runtime environment and native PPC algorithms for standardized control implementation

Closed-Loop Control Functions

Simultaneous management of voltage regulation, power output, ramp rate limiting, frequency response functions, auxiliary device control, and inverter coordination

Communication Protocol Support

Implementation of Modbus TCP/RTU, DNP3, OPC-UA, IEC60870 and IEC61850 for heterogeneous system integration

Grid Operator Interface

Direct communication with transmission system operators with comprehensive control event logging for operational verification

Integration Details: The PowerTrack EMS and PPC are available in outdoor panel, indoor rack, and outdoor rack configurations with appropriate environmental enclosures.

Functional Components

The PowerTrack EMS and PPC platform incorporates two primary functional components, the EMS and PPC:

PowerTrack EMS

Stem's EMS handles system monitoring, optimization, and high-level control functions.

Key Features

- Advanced scheduler with priority-based energy applications
- Real-time performance monitoring with instant system insights
- Seamless edge-to-cloud telemetry for remote visibility and control
- Historical data logging for long-term analysis and compliance reporting
- Visual PID tuning and flexible control parameter configuration
- Remote commissioning for efficient off-site setup and updates
- Multi-protocol support including Modbus, DNP3, OPC-UA, IEC 61850, and IEC 60870

Technical Capabilities

Computational Architecture

Implements distributed processing model with configurable resource allocation

Data Management

Utilizes time-series databases with configurable retention policies and compression algorithms

Integration Framework

Protocol implementation supporting heterogeneous device integration across vendor platforms

Visualization System

Web-based interface with responsive design supporting both operational and analytical functions

Commissioning Tools

Configuration validation with parameter verification and automated consistency checking

PowerTrack PPC

PowerTrack PPC implements active and reactive power control algorithms across multiple operating modes, coordinating command distribution to Power Conversion Systems (PCS) and/or PV inverters. This control module is integrated within the EMS solution architecture, providing comprehensive power management at grid interconnection points.

Advanced high-speed control options ensure compliance with complex interconnect standards globally, delivering rapid response for services such as automatic Frequency Restoration Reserve, Frequency Containment Reserve, Power Oscillation Damping, Fast-Frequency Response, and more.

Key Features

- High reliability for complex multi-mode control applications
- Simultaneous closed-loop control across all 12 control modes
- Independent inverter control for challenging site topologies

Technical Capabilities

Control Execution Framework

Implements deterministic processing cycles with configurable priority for critical control functions

Concurrent Mode Operation

Architecture supports simultaneous execution of multiple control algorithms with conflict resolution

Response Performance

Sub-cycle execution for high-speed grid requirements with configurable response characteristics

Device Management

Independent control parameter management for distributed inverter topologies with heterogeneous characteristics

PowerTrack EMS & PPC Technical Specifications

Hardware	Advantech UNO-137	SEL 3355
Type	Industrial PC	Industrial PC
General		
Certification	CE, FCC, UL 61010-2-201, CCC, BSMI	CE, FCC, 47 CFR 15 B Class A, UKCA, UL
Dimensions	35 x 105 x 150 mm	133 x 288 x 465 mm 19” 3U
Mounting	DIN-rail	Rack Mount
Power Requirements	10 – 36 Vdc	38 – 58 Vdc (LV) HV PS Available
Power Consumption	21 W Typical 47 W Peak	49 W Typical 69 W Peak
System Hardware		
Processor	1.6 – 1.8 GHz	2.5 GHz
Memory	8 GB DDR3, 1600 MHz	4 - 16 GB DDR3, 1333 MHz
Storage	1 x 2.5” SSD/HDD 1 x M.2 B key 2242 SSD	4 x Industrial SATA or 2 x Consumer SATA
I/O		
Serial Ports	2 x RS-232/422/485	2 x EIA – 232 Ports
LAN	2 x 10/100/1000 Mbps IEEE 802.3u (RJ45)	2 RJ45
USB	3 x USB 3.2 gen 1, 1 x USB 2.0	4 x Rear Panel USB 2.0 2 Front Panel USB 2.0
Isolated DI/O	8 x Digital Input Channels 8 x Digital Output Channels	
Displays	2 x DP 1.2, up to 4K @ 60 Hz	1 x DVI-I 1 x DVI-D 1 x DP 1.1, up to 1920x1200
Power Connector	1 x 2-pin terminal block	120/240 V Terminal Block
Environment		
Operating Temperature	-40 to 70 °C / -40 to 158 °F	-40 to 75 °C / -40 to 167 °F
Storage Temperature	-40 to 85 °C / -40 to 185 °F	-40 to 85 °C / -40 to 185 °F
Relative Humidity	95% RH @ 40 °C/104 °F Non-condensing	5% to 95% Non-condensing
Shock Protection	Operating, IEC 60068-2-27, 60G	IEC 60255-21-2:1988 Bump Class 1 Response Class 2
Ingress Protection	IP40	IP30

Unit Controller

The Unit Controller is a dedicated hardware device installed at the PCS level within separate electrical enclosures, functioning as an intermediary control system within Stem's EMS architecture. Specifically designed for coordinating DC battery block and PCS operations at the unit level, it establishes bidirectional communication between the PPC and individual Power Conversion System (PCS) and DC battery block components. The Unit Controller receives control commands from the PPC, executes these commands at the PCS level, and collects telemetry data from both PCS and DC blocks for transmission to the EMS.

Why Unit Controllers Are Essential

Vendor Flexibility

- Enables independent procurement of DC battery blocks and PCS from different vendors
- Critical for projects with split hardware procurement due to supply chain constraints
- Supports local vendor preferences and price-performance optimization requirements

Project Benefits

- Maintains seamless integration and full-stack EMS control across multi-vendor environments
- Bridges field devices with comprehensive EMS functionality for EPCs and asset owners
- Preserves centralized control without sacrificing hardware selection flexibility

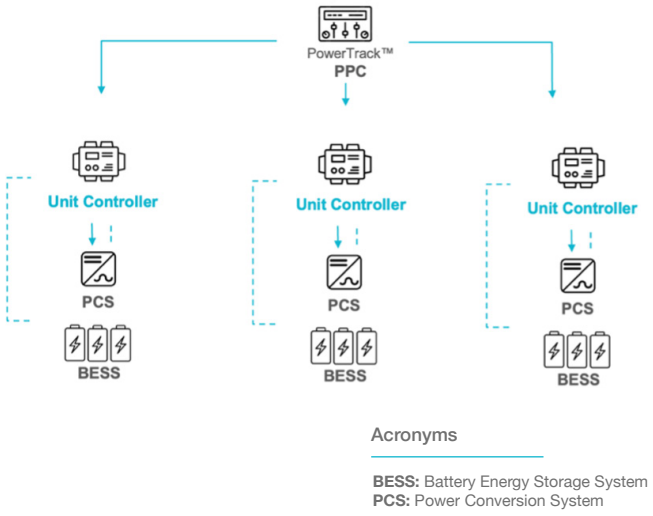
Technical Architecture

Hardware-Agnostic Design

- Defined abstraction layers for inverter/PCS communication
- Integrated EMS system communication framework

Standardized Integration

- Standardized interfaces for upstream and downstream communication
- Consistent control methodology across heterogeneous hardware deployments
- Seamless interoperability with diverse vendor platforms



Acronyms

BESS: Battery Energy Storage System
PCS: Power Conversion System

Key Features

- Scalable from 125 kW to 400 MW+ installations
- Independent monitoring and control of DC and PCS blocks
- Validated with real-time hardware-in-the-loop simulation
- Pre-configured for rapid deployment and reduced commissioning time

Use Cases

- Multi-vendor BESS projects requiring independent battery and PCS procurement
- Hybrid and standalone BESS applications where DC block is paired with PCS
- Projects with specific vendor requirements or regional supply chain constraints
- Only deployable with Stem PowerTrack EMS and PPC systems

Technical Capabilites

- Complete vertical integration from edge to cloud monitoring
- Bring-your-own-hardware capability supporting diverse vendor combinations of BESS and PCS

Historian

The historian component provides long-term data storage capabilities for deployments where the EMS UI should replace traditional SCADA systems. This module maintains a comprehensive record of system performance and operational metrics throughout the project lifecycle, ensuring data integrity and availability for analysis and compliance purposes. Integration typically requires environmentally controlled conditions to preserve data integrity.

Key Features

- Configurable and adaptable to meet project-specific requirements
- Scalable storage capacity for varying project needs, supporting 5 years of site data retention
- Project lifetime storage options available when required
- Robust data backup and recovery mechanisms
- Secure access controls for data protection
- Compatible with Stem's PowerTrack EMS solution

Use Cases

- Remote sites with limited connectivity requiring local data storage
- Projects with regulatory compliance requiring extended data retention
- Operations requiring detailed historical performance analysis
- Sites using EMS UI as primary monitoring interface
- Applications requiring comprehensive operational records for warranty validation

Integration Details

- Seamless integration with PowerTrack EMS and PPC
- Compatible with standard data export formats
- Available in outdoor rated or indoor rack-mounted configurations
- Deployable alongside other Stem control components

Benefits

- Ensures continuous access to historical operational data
- Reduces reliance on cloud connectivity for historical analysis
- Supports detailed performance evaluation and troubleshooting
- Facilitates compliance with data retention requirements
- Enhances operational decision-making with comprehensive historical context

Technical Capabilities

- Storage capacity customized based on project requirements
- Flexible hardware configurations based on deployment environment
- Multiple redundancy options available
- Data compression capabilities to optimize storage efficiency
- Query tools for efficient data retrieval and analysis

Peripheral and Auxiliary Components

The PowerTrack EMS solution integrates with peripheral measurement and communication devices to provide comprehensive site monitoring capabilities. These components enhance data collection accuracy and system reliability through standardized interfaces and protocols.

Integrated Components

The following sensors and equipment can be integrated with the PowerTrack EMS solution:

Meters: Power Quality Meter (PQM), Revenue Grade Meter (RGM)

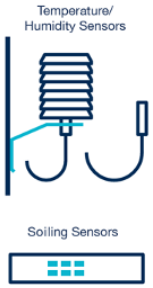
- Provides high-accuracy measurement for settlement and regulatory requirements
- Hardware: SEL-735, Janitza, Elkor, Accuvim
- Monitors power quality parameters for grid compliance

Network Infrastructure

- Industrial-grade network switches for reliable data transmission
- Advanced firewall protection for cybersecurity compliance
- Cellular modems for redundant connectivity options

Meteorological Equipment

- Integrated met station for comprehensive environmental monitoring
- Temperature and humidity sensors for ambient condition tracking
- Wind and barometric pressure sensors for weather impact analysis
- Pyranometers for solar irradiance measurement
- Module temperature sensors for performance optimization
- Soiling sensors for maintenance scheduling and yield analysis



Benefits

- Enhanced data accuracy for performance verification and warranty compliance
- Comprehensive environmental monitoring for performance analysis
- Secure and reliable network infrastructure for mission-critical operations
- Simplified integration through pre-configured interfaces and standardized protocols

Integration Details

All peripheral components connect directly to the PowerTrack EMS and PPC through standardized interfaces, enabling plug-and-play deployment and reducing commissioning time. Data from all sensors is available through both the EMS UI and PowerTrack software interfaces for comprehensive monitoring and analysis.

Met Station Technical Specifications	
Hardware	
RS485 Bus Hub	4 x RS485, opto-isolated
RTD Measurement Module (optional)	6-channel temperature measurement (Pt100, Pt1000)
Power Supply Unit (optional)	85-264 Vac to 24 Vdc including an AC surge protector
Electrical Data	
Power Supply	24 Vdc 85-264 Vac
Power Consumption	max. 48 W at DC supply max. 80 W at AC supply
Interfaces	4 x RS485 Bus (HD), Modbus-RTU 3 x RS485 Bus (HD), Modbus-RTU, 6 x RTD measurement channels, Pt100 and Pt1000
Data Transfer	
Protocol	1.6 – 1.8 GHz Modbus-RTU
Data Rate	19.2 kBit/s standard; up to 115.2 kBit/s possible
Recommended Cable for Connection to EMS	Li2YCYv (TP) 4 x 2 x 0.5
Conformity	
Standards	EN 60950-1, EN 61000-6, UL 62368-1:2014 Ed.2, CSA C22.2#62368-1:2014 Ed.2
Mechanical Data	
Degree of protection	IP66 / NEMA 4X when mounted with mounting frames
Dimensions, H X W X D	647 x 436 x 250 mm
Weight	14 kg
Cabinet	UV-resistant glass-reinforced polyester, lockable
Mounting Options	Wall mounting, pole mounting
Ambient Conditions	
Operation Temperature	-20 to 50 °C / -13 to 140 °F
Storage Temperature	-30 to 70 °C / -22 to 158 °F
Relative Humidity	Up to 95%, non-condensing

PowerTrack Supervisory Control and Data Acquisition (SCADA)

The PowerTrack EMS solution provides an optional SCADA system that features real-time monitoring, control, and analysis capabilities for power plant equipment. The architecture integrates at both edge and cloud levels, providing comprehensive operational visibility across all connected assets. Built on the Ignition platform, the system features real-time human-machine interface with configurable polling rates, OPC-UA connectivity for PLC integration, and SQL database functionality.

The EMS UI delivers standard SCADA capabilities, with additional functionality available through Induction Ignition systems for projects requiring specialized configurations.

Key Features

- Real-time updates (<1 second data)
- At-a-glance view of site operations, device alarms, trending tools, and flexible data export
- OPC-UA server native capability for third parties
- Tiered polling rates
- Hot standby redundancy
- Standard and custom KPIs
- Automatic data recovery from data loggers after comms outage
- Alarm module (<1 second activation time) with user-designated hierarchy

Technical Capabilities

Data Acquisition Framework

Implements sub-second data collection with configurable polling frequencies for critical parameters.

Interface Architecture

Web-based visualization system with responsive design for operational monitoring and control.

Redundancy Implementation

Supports hot standby configurations with automatic failover for mission-critical applications.

Data Management

SQL and time-series database integration with configurable retention policies and query optimization.

Alarm Processing

Hierarchical alarm management with configurable priority structures and notification pathways.

Control Integration

Direct communication with transmission system operators for grid control functions.

Integration Details

PowerTrack SCADA is available as a standalone system for specialized applications. It supports deployment in various environmental configurations including control room installations and remote site implementations.

Cloud

PowerTrack Software

The PowerTrack EMS solution extends the capabilities of Stem's industry-leading PowerTrack software platform, providing remote monitoring for standalone battery and hybrid systems. These features enable centralized management of distributed assets while maintaining detailed visibility into individual site performance. Key metrics include state of charge (SOC), available power, state of health (SOH), and number of devices online, all within the unified PowerTrack software environment. The system implements enterprise-grade infrastructure with standardized interfaces for edge system integration and third-party data exchange.

PowerTrack Software Standalone BESS Dashboard

Key Features

- Portfolio overview dashboard providing unified visibility across solar, standalone BESS and hybrid projects with critical site metrics for efficient multi-site monitoring
- Enhanced site-level monitoring providing comprehensive real-time performance data
- Real-time alert monitoring system for 24/7 fault detection and notification
- Cloud historian for secure lifetime project data storage and retrieval
- Remote site and device configuration capabilities for battery management systems, inverters and hybrid components, eliminating the need for physical presence
- Remote dispatch functionality allowing power commands, SOC targets, and operational schedules to be sent from cloud to edge
- Intuitive visualization tools for performance analysis and reporting across all technology types and configurations
- Role-based access controls for secure, appropriate system access

Technical Capabilities

Data Acquisition Framework

Implements redundant architecture with 99.99% uptime and regional failover capabilities.

Security Implementation

Utilizes encrypted communications with multi-factor authentication and role-based access controls.

Scalability Architecture

Supports thousands of connected assets with configurable data retention and processing capabilities.

Data Management

Automated backup procedures with configurable retention policies and recovery mechanisms.

Interface Compatibility

Web-based platform supporting standard browsers and mobile device access with responsive design.

Communication Framework

Configurable data transmission frequencies with store-and-forward capability during connectivity interruptions.

Integration Details

The cloud platform implements standardized APIs for integration with PowerTrack EMS and PPC deployments, Stem's SCADA and historian solutions, and third-party analytics systems. The architecture supports configurable data export to external platforms through standard protocols and formats.

Reference Architectures

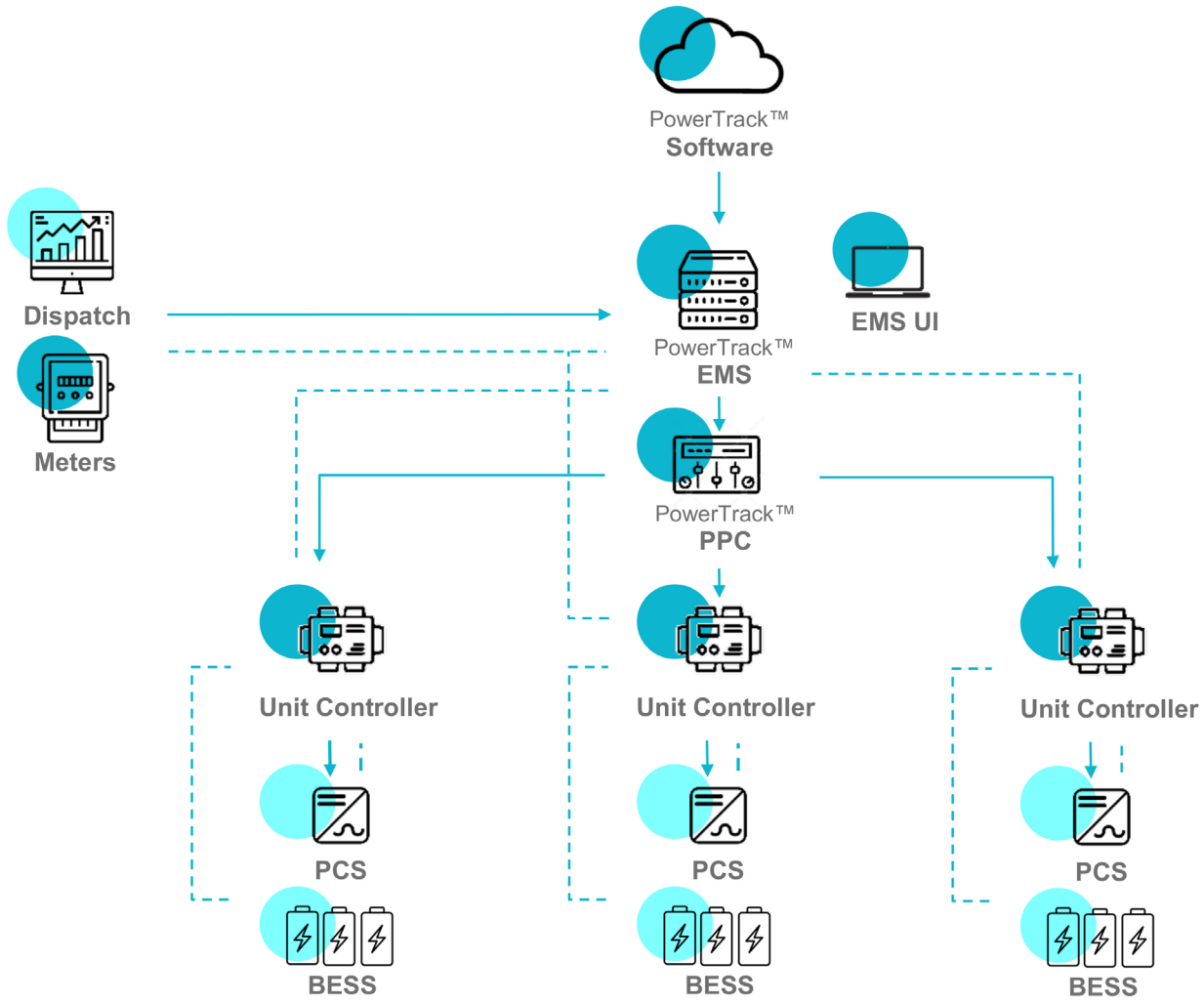
Stem's PowerTrack EMS solution supports multiple architecture configurations to meet your project's specific requirements. Our reference designs provide proven, field-tested templates that accommodate diverse deployment scenarios while ensuring optimal performance, reliability, and scalability.

Standardized Communication

Each reference architecture incorporates standardized communication protocols and industrial-grade network infrastructure. Stem's PowerTrack EMS solution supports **Modbus TCP/RTU, DNP3, OPC-UA, IEC61850**, and **IEC60870**, ensuring compatibility with a wide range of equipment manufacturers, optional SCADA systems, and utility interfaces.

Standalone BESS

PowerTrack EMS solution delivers comprehensive technical monitoring and management for standalone BESS, with flexible integration options that adapt to various battery systems and power conversion systems. The architecture includes intelligent site control, high-speed communication networks, and seamless cloud connectivity. This configuration optimizes performance across multiple operating modes and market applications while ensuring compliance with interconnection requirements.



Standalone BESS Architecture Features

- Unified site-level control with precision command distribution
- Real-time battery management system integration
- Advanced power quality and grid support functionality
- Comprehensive monitoring of all system components
- Highly reliable communication infrastructure

Component Key

Stem | Third-Party

Data

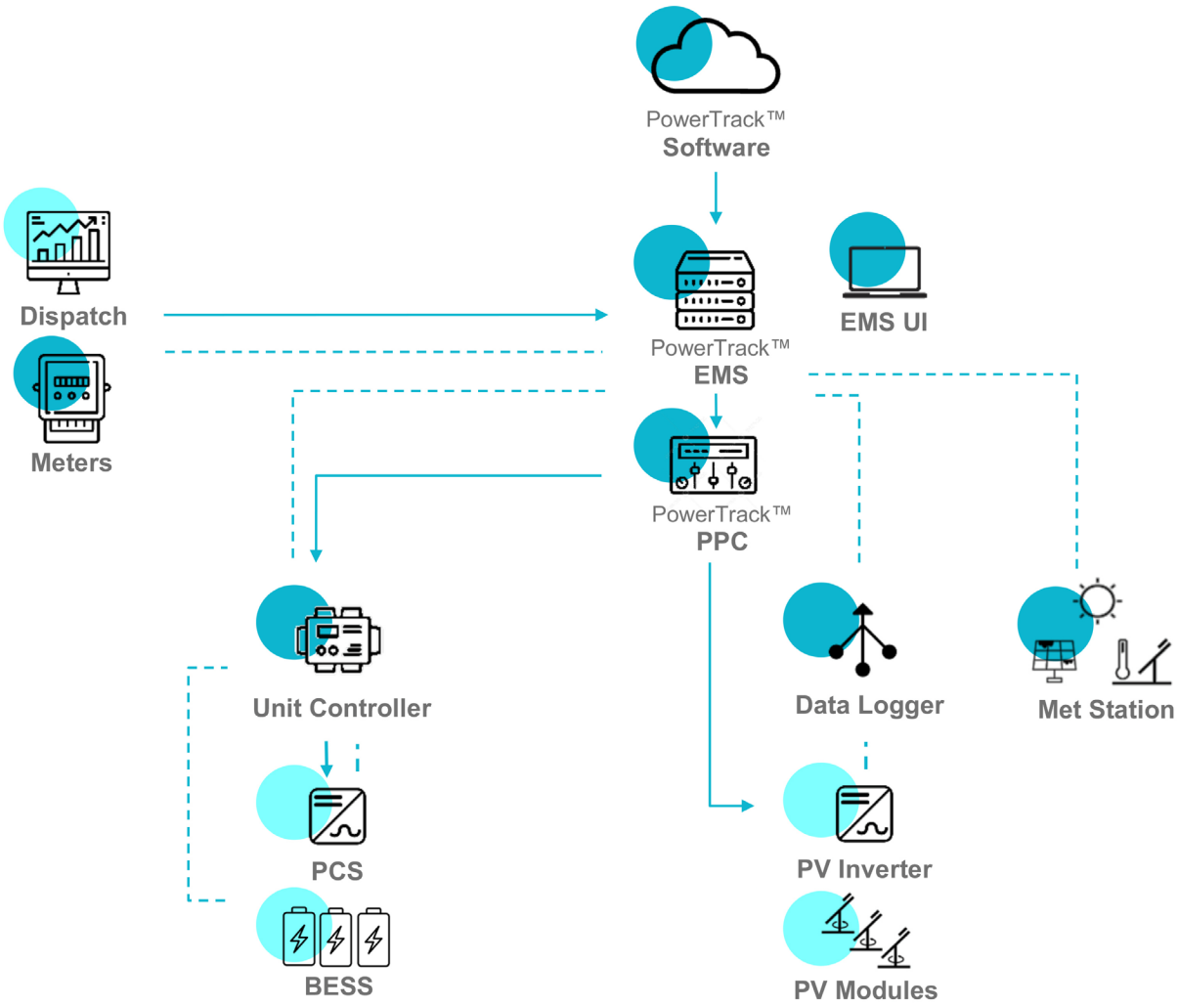
Controls

Acronyms

BESS: Battery Energy Storage System
EMS: Energy Management System
PCS: Power Conversion System
PPC: Power Plant Controller
UI: User Interface

PV Hybrid

PowerTrack EMS solution seamlessly orchestrates solar and storage assets in hybrid configurations. PowerTrack PPC coordinates operations between PV and BESS components to maximize energy yield, optimize dispatch, and ensure grid compliance. This architecture enables sophisticated functionalities including solar shifting, smoothing, firming, and clipping recapture while maintaining precise control over energy flows.



PV Hybrid Architecture

- Configurable operating priorities based on market conditions
- Enhanced revenue capture through multi-application stacking
- Coordinated response to grid events and interconnection requirements

Component Key

Stem | Third-Party

Data

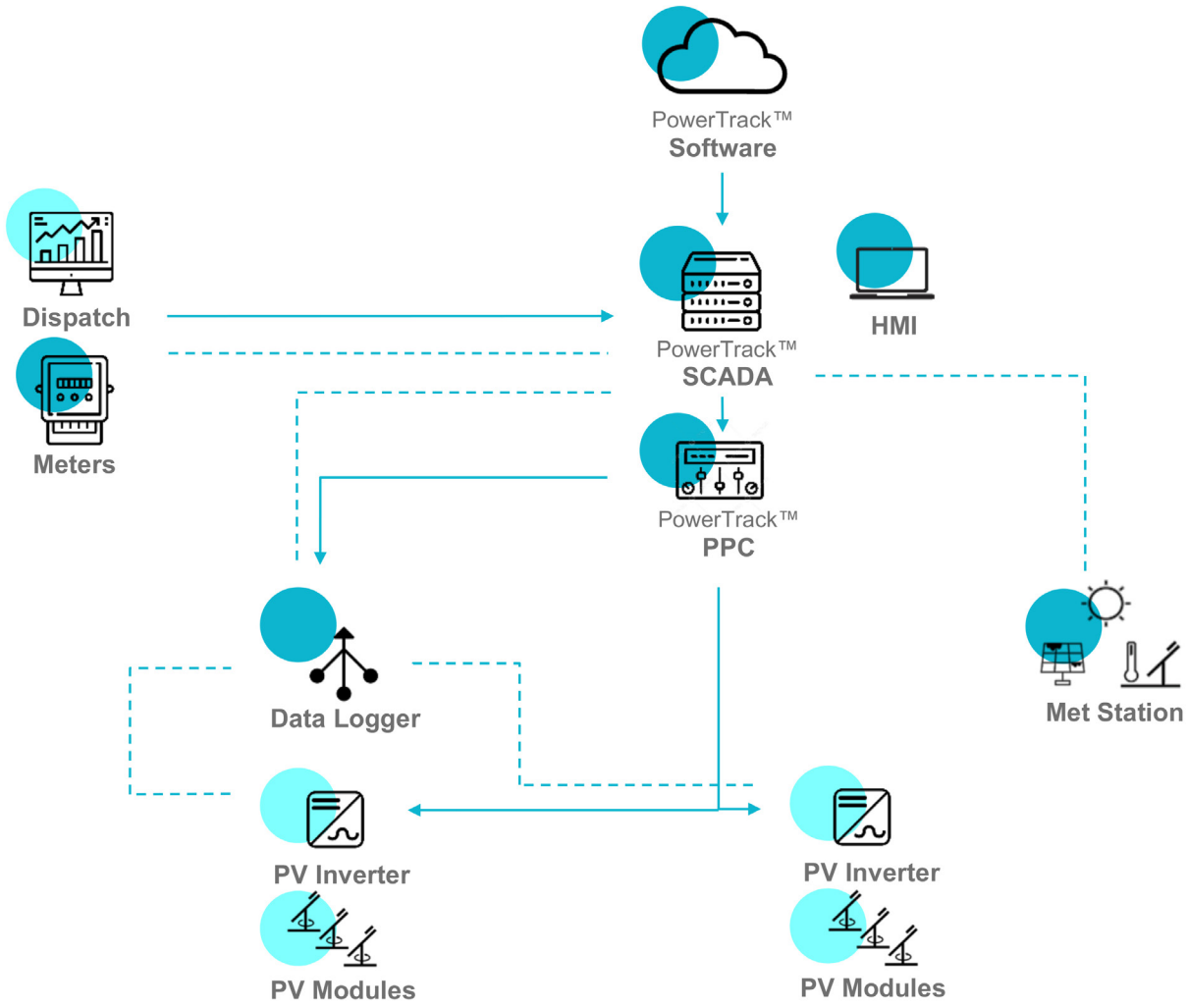
Controls

Acronyms

BESS: Battery Energy Storage System
EMS: Energy Management System
PCS: Power Conversion System
PPC: Power Plant Controller
UI: User Interface

Standalone PV

PowerTrack SCADA offers sophisticated control capabilities for standalone solar installations, providing advanced power plant control and grid integration functionality. This architecture leverages intelligent inverter management, meteorological data integration, and grid monitoring to ensure optimal performance and compliance with evolving interconnection requirements.



Standalone PV Architecture

- Precise active and reactive power control at the point of interconnection
- Ramp rate control for smooth power transitions
- Dynamic voltage regulation and frequency response
- Curtailment management based on grid conditions or market signals
- Comprehensive monitoring and performance analysis
- Seamless expansion capability for future storage addition

Component Key

Stem | Third-Party

Data

Controls

Acronyms

HMI: Human Machine Interface
PPC: Power Plant Controller
PV: Photovoltaic
SCADA: Supervisory Control and Data Acquisition
UI: User Interface

Deployment and Commissioning

Project Delivery
Stem provides comprehensive deployment and commissioning support throughout your project lifecycle, from initial development through commercial operations. Our experienced team ensures successful implementation while maximizing system performance and reliability.

Project Management Excellence
Each project receives a dedicated Project Manager who serves as your single point of contact. This ensures seamless coordination, proactive issue resolution, and efficient communication throughout all phases. Our structured approach maintains schedule adherence and optimal cost management.

Project Engineering
Each Project Manager is supported by a team of expert engineers to support design, configuration, and commissioning of the EMS and auxiliary components.

Our Team Delivers

- EMS, PPC, and SCADA solution support in addition to consulting and standardization services
- Comprehensive IFC design packages including panel assemblies, network communication, and control diagrams
- Complete configuration, testing, and commissioning by a team of electrical, networking, and control system engineers
- Factory Acceptance Testing (FAT) of controllers, cybersecurity equipment, and SCADA equipment
- Remote and onsite commissioning
- Customer Site Acceptance Tests (SAT) and Utility Witness tests

Production
All hardware is procured and assembled in Stem's UL-Listed production facility located in Longmont, Colorado. Stem prioritizes in-assembly configuration and testing, reducing commissioning timelines and improving time-to-data for customers.

Our Team Delivers

- Procurement and assembly of control panels
- Hardware testing and verification, including pull tests and fuse checks
- Electrical testing, including wire continuity tests and High Potential testing (Hipot)
- Network configuration and IP checks
- Edge-to-cloud configuration and testing, including controllers, firewalls, and cellular devices

From initial design to final commissioning, Stem's experienced professionals ensure your PowerTrack EMS solution is properly configured, thoroughly tested, and optimized for long-term performance.

Our structured methodology and extensive experience minimize risk while accelerating your project's path to successful operation.

Experience

Stem remains the leader in the management of solar, hybrid, and storage assets and portfolios. Together with our customers, we are leading the clean energy transition towards a more resilient energy future.

Industry Expertise
With over 30 GW of solar assets and 800+ operational battery energy storage system (BESS) sites across more than 50 countries, Stem delivers unparalleled expertise in complex hybrid energy systems. Our global presence spans multiple continents with deep market knowledge in diverse regulatory environments and utility interconnection requirements.

Dedicated Support

Our expert team brings specialized assistance in:

- Utility-scale operations and management
- Complex grid integration and compliance
- Regulatory navigation across diverse markets
- Remote commissioning and troubleshooting
- Performance optimization and revenue enhancement
- Comprehensive training and knowledge transfer

With nearly two decades of experience, our team provides unmatched support from project development through the entire operational lifecycle of your assets.

About Stem, Inc.

Stem (NYSE: STEM), is a global leader reimagining technology to support the energy transition. Turning complexity into clarity, and potential into performance.

Helping asset owners, operators and stakeholders benefit from the full value of their energy portfolio by enabling the intelligent development, deployment, and operation of clean energy assets. Stem's integrated software suite, PowerTrack, is the industry-standard and best-in-class for asset monitoring, supported by professional and managed services, under one roof. Meant to tackle challenges as seamlessly as possible, Stem shows you the information you need clearly and accurately and help you harness raw data to inform actionable insight. With global projects managed in over 55 countries, 16,000 customers have relied on Stem for nearly 20 years to maximize the value of their clean energy projects.

Driven by human intelligence, business intelligence, and artificial intelligence – Stem is unlocking energy intelligence. Learn more at stem.com.

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