Fulcrum3D
WIND SOLAR FUTURES

CloudCAM

General Information: Real-time onsite solar forecasting

Introduction

The Fulcrum3D CloudCAM system is a robust, turn-key cloud detection and solar forecasting system, targeted at optimal management of solar power fluctuations due to cloud impacts. It can be used for general monitoring / alarm applications or integrated directly into plant control systems. CloudCAM can also provide cloud detection and solar irradiation through the Fulcrum3D proprietary data interface called FlightDECK.

The main advantages of CloudCAM are short-term forecasting for electricity market operations, grid stability via pre-emptive ramping of solar and in island grid applications, fuel savings via spinning reserve management.

Figure 1: CloudCAM installed at Epuron's Kalkarindji high penetration solar power station in central Australia

CloudCAM consists of an on-site all-sky camera and processing unit. High-resolution all-sky images are captured every few seconds and processed on-site using Fulcrum3D's proprietary algorithms to detect and track clouds. Site specific models of the solar power station allow for accurate power forecasts.

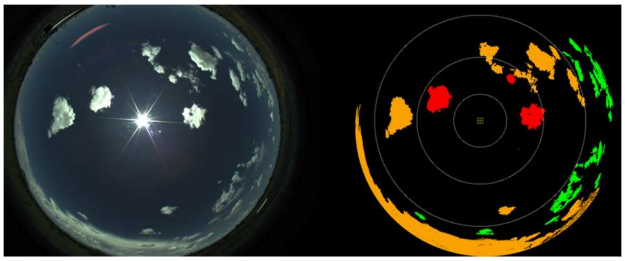


Figure 2: CloudCAM image (left) and cloud identification (right)

Real-time data is presented via Modbus TCP/IP and all high-resolution all-sky images can be archived onsite for post analysis. CloudCAM can perform high-volume synchronous logging of local SCADA parameters for system monitoring and performance analysis. Fulcrum3D can provide data retrieval, secure warehousing and automatic data forwarding via its FlightDECK web portal. As with all Fulcrum3D monitoring platforms, CloudCAM logs pyranometer and sensor data at 1Hz. All individual 1Hz samples can be downloaded via FlightDECK with all-sky thumbnails updated every few minutes.

The logging capabilities of CloudCAM and optional ramp-rate controller can eliminate the need for a separate SCADA or PLC on small to medium centralised solar power stations.

CloudCAM Base Package & Add-on Software Modules

CloudCAM is supplied with a Base Package that has three add-on Module options to satisfy specific applications. Each system is integrated by Fulcrum3D prior to delivery. The add-on modules are:

- *Irradiance Forecasting Module*
- *Power modelling Module*
- *Ramp-rate Module*

Base Package

*CloudCAM **Base Package** provides all software and hardware for on-site cloud detection. The **Base Package** does not provide solar or power forecasting however can be used in 'now-casting' control systems which only require the current status of cloud cover / cloud detection. It can measure and estimate irradiance over a local solar power plant or an area of distributed roof-top solar power generation, e.g. a small township or suburb, or distribution feeder.*

It includes:

- *the CloudCAM camera system - external camera and internal processing unit (an FDL2 Logger)*
- *Kipp & Zonen SMP11 pyranometer*
- *silicon reference cell*
- *mounting pad and boom*
- *10m umbilical cabling.*

*The **Base Package** software:*

- *detects clouds*
- *measures cloud cover*
- *provides cloud shadow maps*
- *Uses irradiance measurements to broadly estimate current solar power production by applying a scaling factor against "full sun" production estimates, or to broadly quantify the percentage drop for spinning reserve control applications.*

System configuration is performed by an on-board web interface which also allows real-time monitoring of the system. The system can interface with local SCADA via Modbus TCP/IP, archive high-resolution images and upload relevant data to Fulcrum3D servers for system monitoring with client access to data via FlightDECK.

Irradiance Forecasting Module

*The **Irradiance Forecasting Module** is a software upgrade that uses the **Base Package** to forecast irradiance.*

Forecast performance is dependent on local conditions, with reliable forecasts typically available out to 15 minutes. Real-time forecasts are performed onsite and can be presented to the local control system via Modbus TCP/IP.

Power Modelling Module

*The **Power Modelling Module** is a further software upgrade supported with the inclusion of a Vaisala HMP60 temperature and humidity sensor. It adds to the **Base Package** by:*

- *taking in the plant parameters of a centralized or distributed solar power system, as well as local weather parameters*
- *providing an accurate current power output estimate.*

*For centralized power stations, the **Power Modelling Module** can:*

- *take into consideration plant parameters including module types, mounting arrangements, tracking configurations, and plant location*
- *use plant feedback to correct power output estimates based on system status (e.g. inverter failures), PV module temperatures and total system output measurements where SCADA connections are available and suitable metering is in place.*

*The **Power Modelling Module** can use PV panel temperature from the local SCADA network or Fulcrum3D can supply back of panel temperature sensors.*

Ramp-rate Control Module

*Fulcrum3D's **Ramp-rate control** system can pre-emptively ramp up or down the output of solar power inverters to maintain power output within acceptable ramp rate limits. The system can work in either a nowcasting or forecasting mode.*

In now-casting mode, clouds detected within a reasonable window of the sun location trigger a ramp-down signal to a pre-determined 'safe' level. Once the clouds have cleared the output is ramped back up to the maximum available output.

In forecasting mode, a more optimal ramp-rate control is applied which follows the expected solar production based on best available data (cloud event forecast; solar irradiance forecast or solar power forecast), reducing the amount of energy spilled.

In each case, the control module sends a signal to the local control system to meet ramp rate requiremen

Module Selection Guidance

Application		Package/Module Required				Usage Example
		Base Package	Irradiance Forecasting Module	Power Modelling Module	Ramp-Rate Module	
NOW-CASTING	Cloud detection, cloud cover measurement and cloud shadow maps.	✓				Cloud cover measurements
	Solar irradiance "now-casting" at solar plant location	✓				Estimating irradiance / solar power output over a regional township
	Ramp rate control using "now-casting"	✓			✓	Ramp rate control using "now-casting"
	Solar power output "now-casting" at solar plant location	✓		✓		Estimating solar power output using accurate power model.
FORECASTING	Solar irradiance forecasting	✓	✓			Predicting irradiance input into existing power calculation tools
	Solar power forecasting	✓	✓	✓		Predicting solar power output to optimise energy storage management
	Ramp rate control based on forecast solar power forecasts	✓	✓	✓	✓	Optimised ramp rate control based on predicted solar power output

A tick indicates this package/ module is required for the application to function.

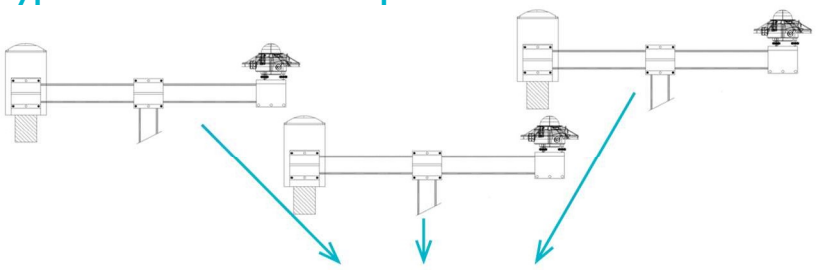
CloudCAM Set-up

On-site CloudCAM sky-cameras will provide good coverage of the array and output high-accuracy short-term forecasts on the scale out to approximately 15 minutes.

The exact number and locations of CloudCAMs will depend on site layout. The on-site CloudCAMs will forecast irradiance variations ***across the arrays*** *on the time scales of minutes. The central processor (an additional FDL2 Logger in the case of multiple CloudCAMs) will perform the forecast irradiance to power conversion including calibration from power meters.*

The parameters from the forecasting system will be available by local SCADA via Modbus TCP/IP (or other interface on request), and a local http web interface for local monitoring. Data will also be pushed to Fulcrum3D's FlightDECK platform for analysis, feedback to the forecasting system and dissemination as required (by email, or automatic FTP uploads for example).

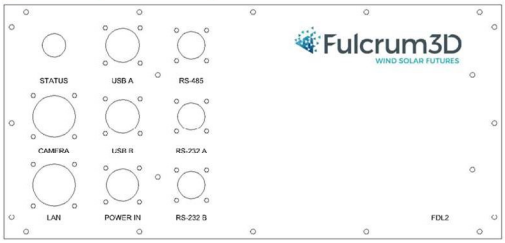
Typical CloudCAM Set-up:

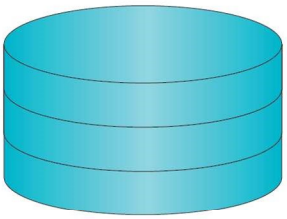


CloudCAM *(Base package includes FDL2 Data Logger with each CloudCAM)*

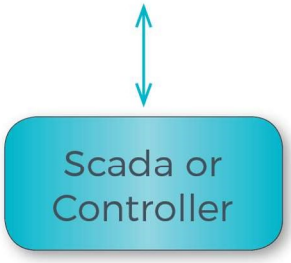
Multiple CloudCAMs *are required if forecasting over large arrays. (~1 Cloudcam per 250m radius area)*

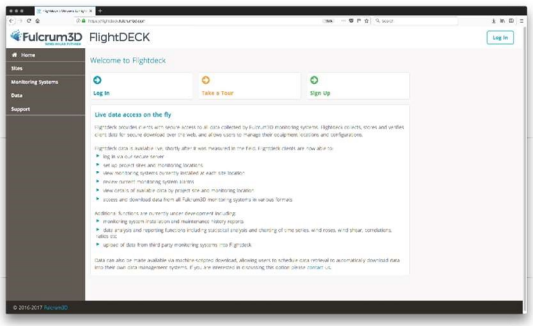
Central processor (FDL 2) *provides power forecasting and interface with F3D servers. Additional FDL2 required if >1 CloudCAM. CloudCAM base package FDL2 performs this role if only 1 CloudCAM.*





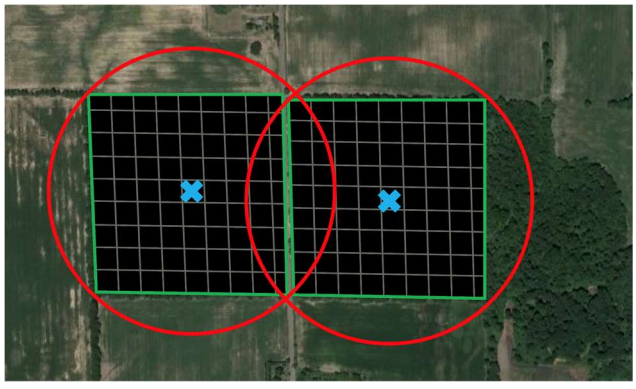
F3D Server *existing secure infrastructure for power model optimisation and data services*





Data warehousing, analysis and dissemination through ***FlightDECK***

CloudCAM Configuration Depends on Site layout:



Effective Radius of Each CloudCam (250m)

Position of Each CloudCAM

Block of Solar Panels

Each CloudCAM will generate a forecast for its discreet block of panels.

CloudCAM Specifications

Data Capture And Storage	
Sampling rate	Default 1s solar data and 3s for other data, configurable up to several hundred samples per second for high speed data (e.g. power quality).
Data averaging	Configurable, default 10 minutes for solar and met data and 1 minute for cloud and solar forecast data.
Data upload	End of each integration period (3G/4G/GSM systems). Every 2 hours on satellite. Standard configuration delivers ~100MB/month (excluding imagery).
Data storage	16GB on-board data storage, expandable to 64GB. Optional image storage via 2TB hot-swap USB2 HDD.
Data access	All data available via *Flightdeck* online data management system allows data download and operating status checks. Image thumbnails and/or sample high resolution image download available depending on data bandwidth. All data available via SCADA / Modbus.
Interfaces	
Serial	2x RS-232, 1x RS-485. Serial ports have switched battery power with current limit.
Ethernet	1x 10/100M Ethernet
USB	1x USB2 user; 1x USB2 for USB modem
Digital / analogue	Analogue and digital I/O available via Modbus modules
SCADA	Optional SCADA interface via Modbus RTU and TCP/IP (Modbus data specification available on request)
Telemetry And Controls	
On-board control	Individual instrument power, system power for remote power cycle/watchdog
On-board telemetry	System temperature, battery voltage, internal rail voltages, system current and individual device current
Power And Communications	
Average power consumption	15W (daytime) / 8W (night-time) average consumption with standard configuration.
Power supply	12/24V d.c. with optional industrial 110/230V a.c. *Solar option*: 1x 150W PV module, MPPT,2x 12V 80Ah battery (~5 days storage typical).
Communications	*Optional*: NextG/3G/GPRS with 6.5dBi antenna Satellite/Wi-Fi/Ethernet
Environmental Conditions	
Temperature	-20° to 60°C ambient
IP Rating	IP66 mounting enclosure, IP68 instruments
Lightning protection	Multi-strike lightning protection fitted to communications equipment. All instruments chassis grounded.
Physical (Standard Configuration)	
Dimensions (WxDxH)	FDL2 data logger: 340x110x200mm incl mounting flanges Enclosure: 470x300x530mm. excl. aerial, solar modules, mounting system, sensors etc
Weight	~18kg enclosure; ~7kg sensor head incl 800mm boom
Materials	Aluminium heat shields, powder coated steel box, sealed aluminium electronics box, aluminium brackets and booms

Standard configuration	
Standard inclusions	*Logger Box*: IP66 enclosure and wall/post mounting brackets including FDL2 datalogger; 12/24V d.c. power connection; GSM/3G/4G communications and antennae. *Sensor head*: Standard sensors and mounting brackets, 0.8m x 48.4mm boom and mounting bracket, cabling kit. Installation tool kit; material safety datasheets; instruction manual. *Mounting kit and local SIM not included.*
Standard Sensors	
CloudCAM™	*Fulcrum3D CloudCAM™ All-sky* cloud detection/forecast and solar forecasting system: • Forecast time 0 – 15 min (typical)[2] • Configurable update frequency Outputs include: • current and forecast % cloud cover • current and forecast solar irradiance • performance statistics • sensor head roll / tilt / orientation
Pyranometer	Kipp&Zonen SMP11 with mounting bracket
Temperature and Humidity[1]	Vaisala HMP60 with radiation shield, providing: • Temperature -40°C to +60°C range, ±0.6°C Humidity ±3% (10% to 90%), ±5% (0% to 100%)
Optional Sensors	
Weather station upgrade	Replace Vaisala HMP60 with Vaisala WXT520 providing: • Temperature -52°C to +60°C, ±0.3°C • Humidity 0% to 100%, ±3% in range 0-90% • Pressure 600 to 1100hPa, ±0.5hPa (0 to 30°C) • Rain accum. ±5% • Rain intensity 0 to 200mm/hr • Wind speed 0 to 60m/s, ±3% at 10m/s • Wind direction 0 to 360°, ±3°
Location	GPS altitude (m) and location (WGS 84) <5m RMS horizontal position accuracy
Other sensors	Additional or alternate sensors available including: • Kipp&Zonen CVF3 ventilation unit • Alternate pyranometers or silicon reference cells • Kipp&Zonen SHP1 pyrheliometer & SOLYS 2 tracker • Additional met sensors as required *(may need power supply upgrade depending on selection)*
Optional Mounting Kits	
Post mount	1.8m 48.4mm aluminium mounting post
Wall mount	Standard and custom wall mounting brackets available on request for both mounting post and logger boxes.
Tripod mount	Standalone un-guyed folding tripod with 48mm boom mounting pole to 2m above ground. Earth screws for soil or sand, masonry fasteners or weights all optional.

Notes:

1. *NIST traceable and NATA calibrated sensors available on request.*
2. *Actual performance of instrument depends on local atmospheric conditions.*
3. *These specifications may change without notice.*

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