ATS
Leading of Integration

@IRIS™

Integrated Renewable Energy Inversion System

Applied Technical Systems Joint Stock Company

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A. Product Overview

@IRIS is the Integrated Renewable Energy Inversion System which is designed and provided by ATS including hardware as well as software modules.

Currently, fossil energy types such as coal, oil, etc. are running out, and the problem of environmental pollution caused by CO2 emission is getting worse. Modern society need to find clean, environmentally friendly energy sources, in which renewable energy sources such as solar and wind energy are one of the alternative choises of energy in the future.

The renewable energy inversion systems are increasing strongly, along with the continuous improvement in manufacture technology and the redution of investment costs, have been increasing market share, as well as increasing the importance in electricity system of each country to meet the energy demand.

An overview of inversion process of PV solar energy to electrical energy is shown in the Figure 1.

Photovoltaic modules will convert solar radiation energy into DC electricity by photoelectric effect. This DC power will be converted into AC power with reference frequency according to the frequency of the grid through the DC/AC energy converter (Inverter). The step-up voltage transformers and transmission lines will connect and synchronize energy to the national grid.

Connection structure, data acquisition for supervisory control of @IRIS system is shown in the Figure 2.

MAIN COMPONENTS

- Supervisory Control And Data Acquisition system (SCADA) plays an extremely important role in ensuring stable operation of the system, optimizing plant performance, minimizing risks and highest reliability. The main functions of software system include:
  - Communicate with devices in the system to collect data (electrical data, weather data, hardware device status data);
  - Monitoring plant status in real-time;
  - Monitoring operation status, event and alarm, support tool for maintenance;
  - Provides intuitive tools for displaying working data;
  - Directly control the power generation of the system when receiving commands from the central control room on the basis of online feedback signals (active power control, reactive power control, frequency and voltage stability control, ramp rate control, reactive power compensation (if any), start, shutdown sequence control);
  - Connect with SCADA/EMS system in the dispatch centers for the operation of the power grid;
  - Plant generation prediction;
  - Plant analysis and failure detection;
  - Support services to remote repair and operation.
- Hardware devices supporting power invertion: including power electronic devices with the function of converting DC current into AC current to connect to the power grid.

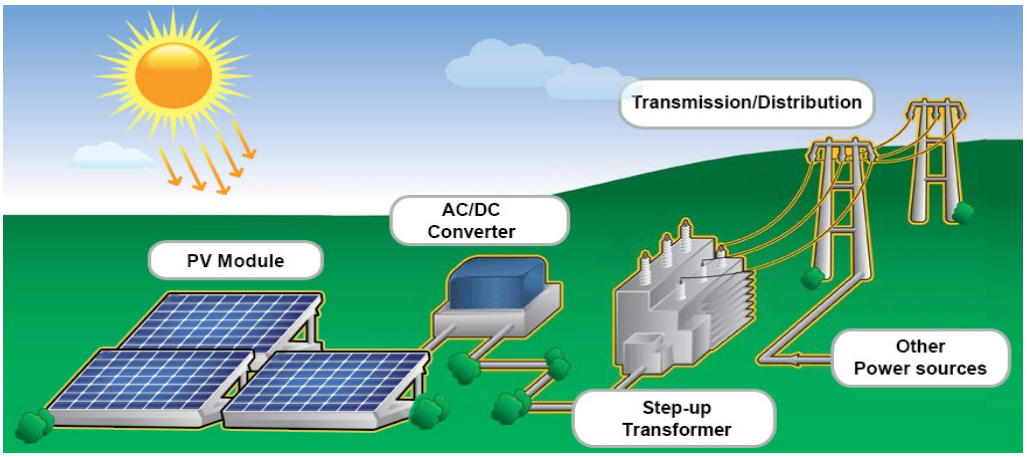

Figure 1. Process of transforming renewable energy into electricity

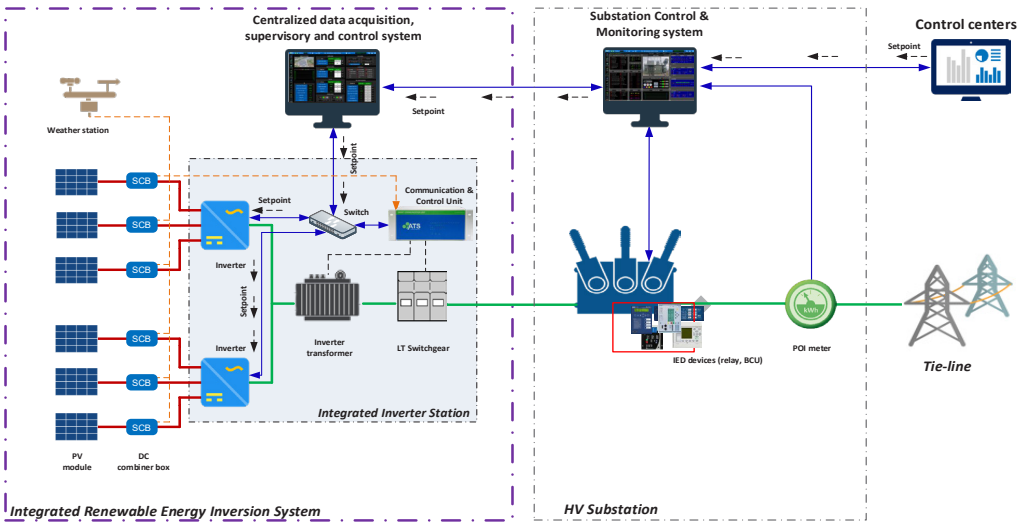

Figure 2. Principle of Integrated Renewable Energy Inversion System

1. APPLICABLE STANDARDS

@IRIS system is designed to ensure compliance with Vietnamese and international technical standards such as IS/IEC/IEEE with the latest version; policies, regulations and orientations for renewable power development in Vietnam; construction standards and national grid code.

@IRIS system are based on the design with high tolerance, redundancy configuration of critical devices in the system, to providing an optimal, safe and stable power inversion system with long-term economic efficiency.

With a solution based on computerized platform and logic software architecture complying with IEC 61131-3 standard, our central control and monitoring system can meet requirements according to technical agreements, requirements grid connection techniques, as well as regulations and rules of the Vietnamese government and authorities.

2. SCOPE OF WORKS

@IRIS will assist operators to perform all supervisory and control functions. All important information about the operation of the plant including system characteristics, measurement data, status of integrated controllers, sequence control functions, alarm functions ... will be collected and displayed immediately on the control operating interface.

We propose completed implementation range including design, production, construction and installation, testing, commissioning and adjustment of Integrated Renewable Energy Inversion System, provision of COD-Ready services to ensure to meet, comply with technical requirements and specialized standards and energizing successful system into national power grid.

Basic scope includes:

- Designing an integrated renewable energy inversion system.
- Provision and installation of Hardware equipment system at power plant: Inverter, Weather station, LAN equipment, port and I/O converter, computerized system, peripheral equipment and other auxiliary systems.
- Provision and installation of Integrated Software System to supervisory and control the energy inversion system.
- Testting, commissioning and related agreements and approvals (COD-ready services) to energize the system into national power grid successfully.
- Training, operating instructions and maintenance services.
- All provided equipment and software are warranted within 24 months from the date of installation with 24/7 technical support and troubleshooting within 24- 48 hours.

3. HARDWARE SOLUTION

The system is built with the following main hardware components:

- Inverter: perform the function of converting DC energy from photovoltaic panels into AC energy and equipped with monitoring and control capabilities through industrial protocols.
- Communication and Controller Unit at each integrated inverter station with digital and analog inputs/outputs and support protocol converter function (Modbus RTU/TCP) to collect all monitoring and control data of PV solar energy inversion system such as DC combiner box, inverter, multi-function meter, MV transformers, MV switchgear and other auxiliary systems (AC/DC distribution system, fire alarm system, etc). All collected data will be connected to the centralized monitoring and control system through high-speed fiber optic ring network.

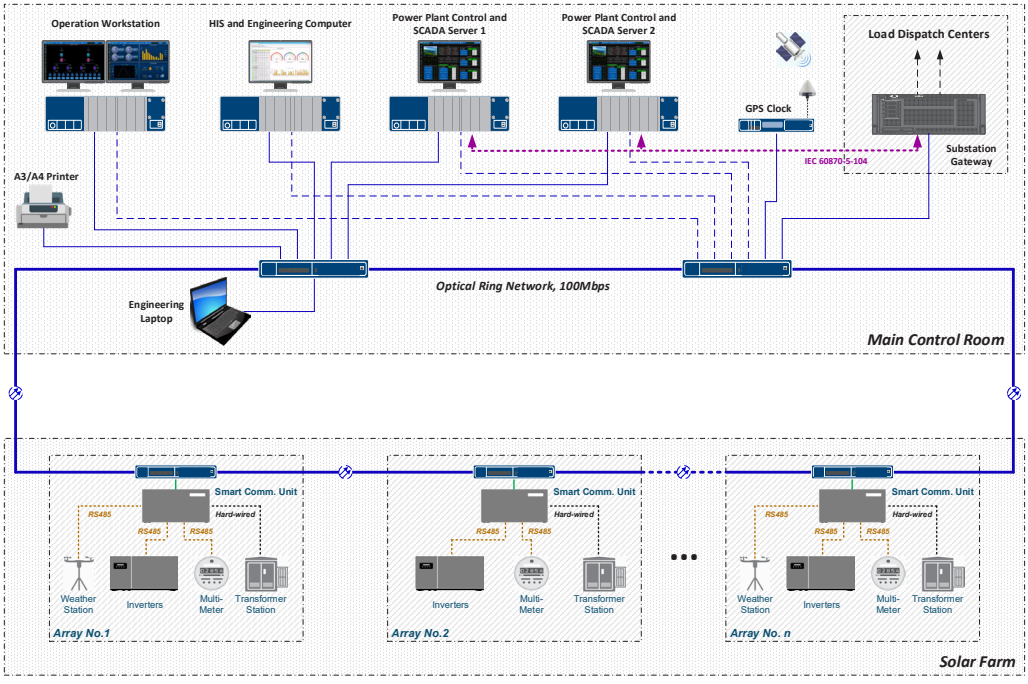

Figure 3. Hardware architecture of @IRIS

B. Technical Highlights

- Weather station at the central locations of the generation area will measure solar radiation intensity, ambient temperature, PV panel temperature, wind speed and direction, humidity, pressure, for analyzing the power generation efficiency of the plant as well as planning the operation.
- Equipment at the central control room:
  * Power Plant Control and @IRIS Server: operate in redundant mode, to collecting all data, processing, calculation and displaying on user interface, and perform monitoring, control functions of the energy inversion system. These server are designed based on industry standards, with open architecture, providing network connectivity and compatibility with widely used industrial protocols, ensuring any damage to the device does not affect the process of monitoring and operating the PV plant. This servers also act as Gateway, to connecting and exchanging SCADA data with Control Centers through Gateway computer at integrated substation control system.
  * Operation Workstation: provides Human-Machine Interface (HMI), allow operator to interactive and implement monitoring and control of the system.
  * HIS and Engineering computer: for long term data storage and historical data mining applications for analysis, review and report, engineering applications for database configuration, building interfaces, and maintaining SCADA systems.
  * Network Switch devices: establish and manage optical cable ring network that assures the continuous operation of the system in case of any single failures of LAN parts. All data for monitoring and control of energy inversion system will be connected, collected and shared on the central control and monitoring system based on the High-speed fiber optic ring network.
  * GPS-Synchronized network clock to device time synchronization in the system..

4. SOFTWARE SOLUTION

4.1. Support protocol

The system provides support for standards-based protocols widely used in industry such as:

- Modbus Serial/TCP (combiner box, Inverter, weather station, data concentrator, multi-meter, protection relay...).
- IEC61850, SEL FastMessage, DNP3,... (Protection relays, power quality monitoring equipment,...)
- IEC 62056/IEC61107 (Tariff meter)
- And other protocols are widely used in industries...

4.2. System sizing

@IRIS system provided by ATS ensures ensures that the performance met all requirements of current system and extended in the future without having to upgrade any of the control system components.

The @IRIS system can support sizing capacity for over 2,000 IEDs, controller and monitor, and 256,000 data points.

4.3. Software structure

@IRIS software system is designed with modular-architecture to easily manage, maintain, upgrade, ensure security and stability.

The main software modules of the @IRIS system include:

- Data Acquisition module (DA)
- Real-time Database (RTDB)
- PV Power Plant Control
- Historical Information System (HIS)
- Human – Machine Interface module (HMI)
- PV power plant generation predicting module
- PV power plant analysis and failure detection module

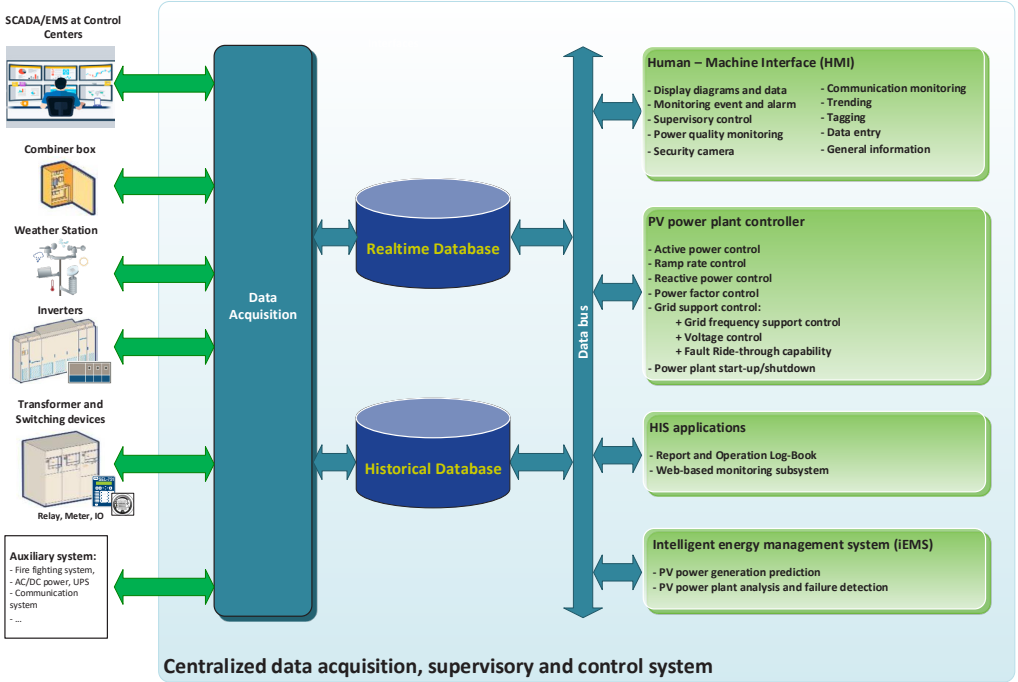

Figure 4. Software Architecture of @IRIS

4.4. Software Functions

4.4.1. Data Acquisition (DA)

The Data Acquisition module will perform initializing, managing real-time information channels and communicating data with monitoring and control devices and other systems. This is an integral part of any data acquisition, data processing and control system.

The Data Acquisition module will acquire all available analog data, status data and perform control signal from PV energy inversion system through DC string combiner boxes, Inverter controllers, Inverter station comunication and controller units, relays, Common IO devices, Weather station, Multi-function meters, MV switchgear.

DA module process following data types:

- Analog data
- Status indications and alarm signal
- Time stamped status and SOE
- Manually entered data
- Oscillograph information
- Disturbance and Power Quality Information
- Control command…

Data acquisition from main PV power plant devices:

- DC string combiner boxes
  - Current, voltage, power of each input PV string;
  - Output current, voltage and power of DC combiner box;
  - Status, alarm signal of output MCB of DC combiner box;
  - Protection signal;
  - Box temperature (if any).
- Inverters:
  - Analog Signals:
    - DC current, voltage, power of each input;
    - Output AC phase-phase, phase-earth voltage, current, active power, reactive power, apparent power, power factor, frequency;
    - Inverter efficiency;
    - Harmonic distortion;
    - Daily power yields, total power yields;
    - Total daily operation time;
    - Internal temperature;
    - …
  - Status signals:
    - Operation Status: Run, Stop, Initial Standby, Emergency Stop…
    - Alarm state signal: Communication fault, Low Insulation resistance, Insulation plate abnormal, fault, derating run, alarm run
    - Fault state: DC under-voltage, DC over-voltage, AC under-voltage, AC over-voltage, Under-frequency, Island protection, Over-temperature, Overload protection, Earth Fault protection, AC switch abnormal, DC switch abnormal…
    - Device status signal: AC switch state, DC switch state, DC fuse state…
- MV transformer:
  - Protection Signals.
    - Oil/Winding temperature alarm
    - Oil/Winding temperature trip
    - Pressure relief trip (if any)
    - Low oil level signal (if any)
    - Gas relay alarm (if any)
    - Gas relay trip (if any)
  - Supervision Signals:
    - Tap changer position (if any)
    - Operation temperature (winding, oil)
- MV Switchgear:
  - Voltage, current, active power, reactive power, frequency, power factor…
  - Status and alarm signal of circuit breaker, load break switch.
  - Relay protection signals
- Meteorological station:
  - Global horizontal irradiance (GHI);
  - Plane of the array irradiance (POA);
  - Ambient temperature;
  - PV Panel temperature;
  - Wind direction and wind speed;
  - Humidity
  - Atmospheric pressure…

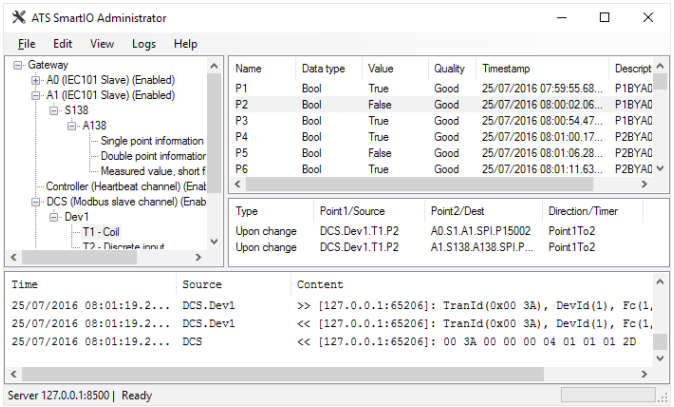

Figure 5. Data Acquisition interface

B. Technical Highlights

4.4.2. Real-time Database (RTDB) Processing

The Real-time Database module is a central component in the system. RTDB is a data bridge between the Data Acquisition module and other application modules (HMI, HIS, etc.), which manages and processes all real-time data of the system.

Real-time database management with ability to process unlimited data points, collecting data from operation level or processing level, commonly from IEDs such as relays, BCUs, IO device, inverter controller, sensor... Data will be processed and converted to archiving form and allow to covert depend on user requirements.

Technical specifications of RTDB:

- Designed with Client/Server model.
- Other application can access each data point in real-time database.
- Support multi session access to real-time database at the same time.
- Process and convert to appropriate data format as requirement of other applications.
- Ensure the integrity and reliability of the electrical system data.
- Automatically send and receive data as requirement of other application.
- Support import/export function to facilitate of data management processing.
- Support mathematic and logic functions used to calculate.

RTDB supports the following types of data processing:

- Quality Data
- Analog Data
- Status Data
- Calculated Data
- Sequence Of Event Data
- Manual input data
- Command Data, etc

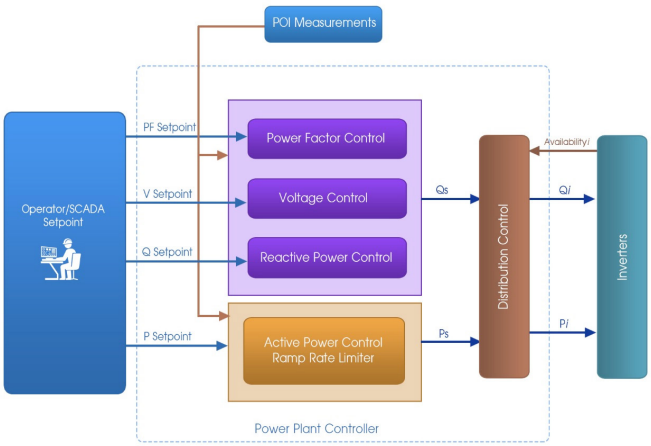

Figure 6. Power plant control function block diagram

4.4.3. PV power plant control (PPC)

PV Power Plant Controller (PPC) is an intelligent vendor-independent system for dynamic PV power plant control and grid code compliance, customizable to satisfy any grid requirement while ensuring interoperability with plant SCADA systems.

Our solution is suitable for controlling PV Power Plant with different Inverter vendors (such as ABB, SMA, Huawei, TMEIC, Sungrow, etc.). The PV plant controller will be implemented at plant-level logic and utilized closed-loop control schemes. Real-time commands will be sent to each inverter via industrial protocols such as Modbus RTU, DNP3, IEC 61850, IEC 60870-5-104, etc... to achieve fast and reliable regulation of PV power plant generation.

The main PV power plant control functions:

- Active Power Control: Hold the output at fixed commanded Setpoint or react to curtailment commands by operator and the Load dispatching center. Ensure that output of PV power plant does not exceed specified limit.
- Ramp rate control: Limit a smooth active power ramp rate must be followed in the output to the grid, ensure not to cause to the system instability at the grid connection point.
- Reactive Power Control: Used to hold the plant at a specific reactive power output.
- Power Factor Control: Allow the plant to maintain a desirable power factor at the point of connection.
- Grid support control:
  - AGC-Automatic Generation Control: Automatic regulate the active power delivered based on the instantaneous frequency deviation of the Grid.
  - AVR- Automatic Voltage Regulator: Allows the plant to dynamically provide reactive power support, based on system voltage.
  - Fault Ride-through capability: do not trip off during system disturbances such as specific low and high voltages or low- and high-frequency circumstances and continue to provide power when the grid needs it.
- Power plant start-up/shutdown:
  - If a planned outage is needed, operations should have a way to take the plant offline in a controlled manner by one click activity. Similarly, after the outage period; the plant needs to come up smoothly.
  - When a shutdown request is provided along with required confirmation, the active power of plant will ramp generation down all the way to 0MW. Inverters will then be stopped. Likewise, when a startup command is issued, each inverter will be started and ramped up to the plant level setpoint.
  - Operator can configure automatic start-up power plant at setting time or at the beginning of solar radiation intensity of shutdown power plant at the end of solar radiation intensity.
- MV switchgear control function:
  - Remote control of MV switchgear at each Inverter stations with Interlocking Logic via Relays and Bay Control Units in specific conditions such as maintenance and repair process or in fault isolating and recovering process.

4.4.4. Historical Information System (HIS)

The Smart Historical Information System (SmartHIS) is the historical repository of all the information related to the Microgrid system which is time-series generated under normal operating conditions and/or during disturbances. The SmartHIS implementation will be predicated on the client-server architecture to collect, process, store, manage and retrieve data.

With SmartHIS the operators can store and maintain real-time data from any system point. The data will be stored in its exact resolution for a long period of time.

Multiple access security levels will be provided with firewalls, users ID and passwords. It must come with proxy server and IP masking capability to prevent unauthorized IP access to the server. Security for data access and point configuration is defined for read only; write only, both or none.

(1). Benefit

- Massive scalability and performance: the database can be scaled to support millions of devices or time series data points in continuous flow and perform real-time analysis.
- Reduced downtime: In scenarios where downtime is unacceptable, the architecture of a database that is built for time series data ensures that data is always available even in the event of network partitions or hardware failures.
- Lower costs: High resiliency translates into fewer resources needed to manage outages. Fast and easy scaling using commodity hardware reduces the operational and hardware costs of scaling up or down.
- Improved business decisions: customers can analyze data in real time and make faster and more accurate adjustments for energy consumption, device maintenance, infrastructure changes, or other important decisions that impact the business

(2). HIS applications

a)Report

Reports can be built using Data Link tool (an add-in for Microsoft Excel). This add-in can allow data to be retrieved directly from within the spreadsheet program. User can create complex reports and graphs using current or historical data from the HIS.

b) Web-based monitoring subsystem

The Microgrid control system supports to display data at utility office for remote monitoring. It is able to display in web service or mobile application with integration open source web server.

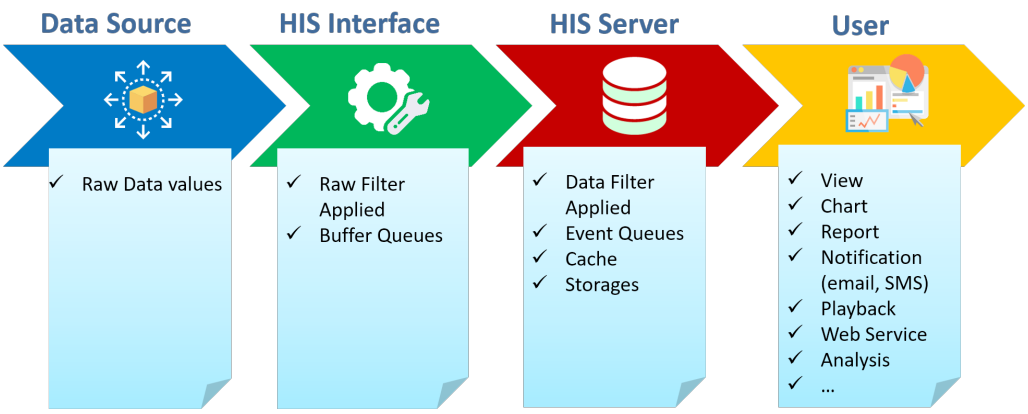

Figure 7. SmartHIS system overview

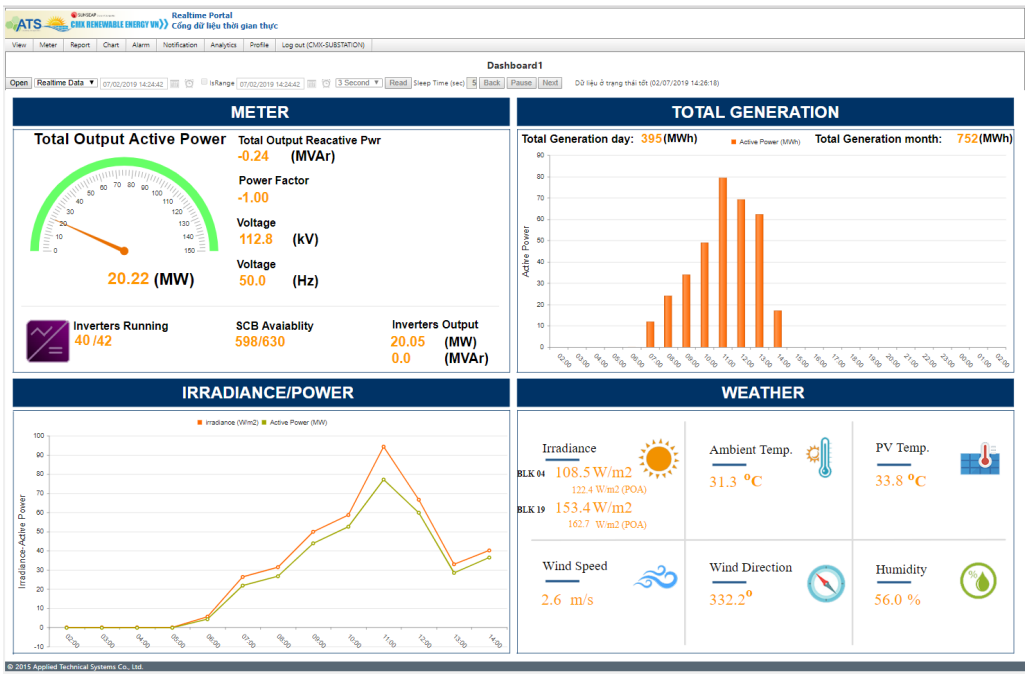

Figure 8. Real-time and Historical Data presented on Web

B. Technical Highlights

4.4.5. Human-Machine Interface (HMI)

- The HMI is connection interface between the user and the monitoring, controlling program of the central control system, as well as other applications. HMI allow to monitoring, controlling all primary device in power plan, access to storage data simply and friendly.
- The design of Screen can be simply modified and reused.
- User Interface can immediately reflect by light and sound indication corresponding with happening event of operator or primary devices.
- The operator can implement every controlling action exclude automatic controlling functions. All message or warning signals will be unlimited follow time sequence. All signals of operation process will be collected and continuously warn to operator at Alarm screen.

At the central control room, the HMI interface system will be built integrated and unified, support the operator to be able to perform all monitoring and control operations of the solar inversion system.

The main functions include:

(1). Manage system access

- Manage Username and password with an unlimited number of access accounts.
- Manage access levels corresponding to each Username.
- Assign Username for all operations after access.
- Add new users, edit or delete existing users with system administrator level.

(2). Monitoring

The HMI function is designed with multi-layer architect, more lower layer more detail information:

Figure 9. Power Plant Dashboard

Display plant dashboard with current generation parameters (3 phase currents, voltage, active power, reactive power, power factor and frequency); total plant daily, weekly and monthly yield; current weather parameters...

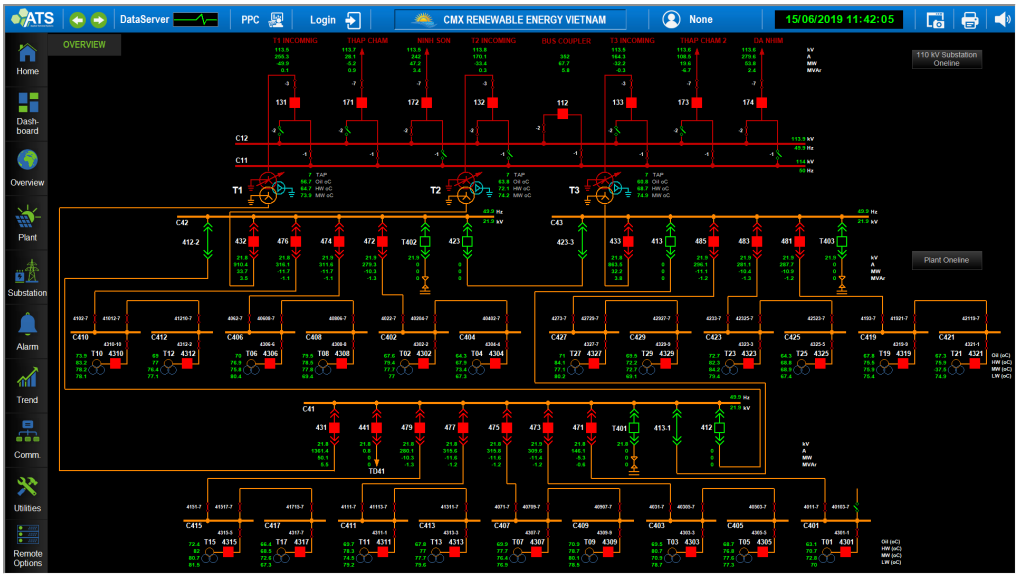

Figure 10. PV power plant Single Line Diagram

Display solar energy inversion system oneline diagram with main devices and operation parameters include DC SCBs, Inverters, MV transformers, MV switchgear,...

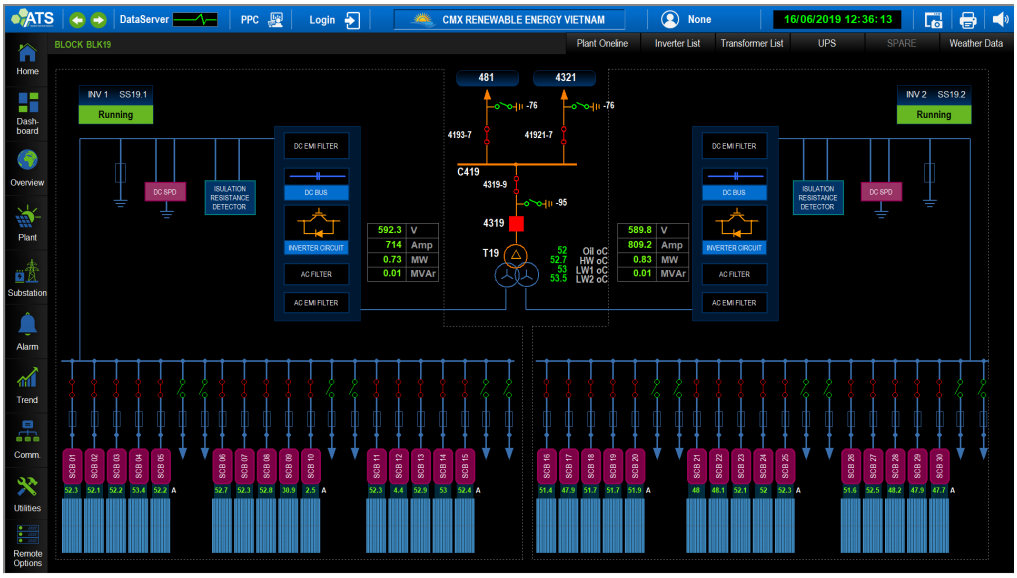

Figure 11. Inverter Station Screen

Display operation parameters, status signal, alarm and protection signal of each Inverter station.

Figure 12. PV Inverter data monitoring and control

Display analog parameter such as input current, input voltage, output current, output voltage, output power, power factor, frequency, operation time; status, alarm, protection signal of input and output switching devices of each Inverters...

Figure 13. MV transformer monitoring

Display operation signal of tie-transformer such as tap position, temperature, alarm and protection signal...

B. Technical Highlights

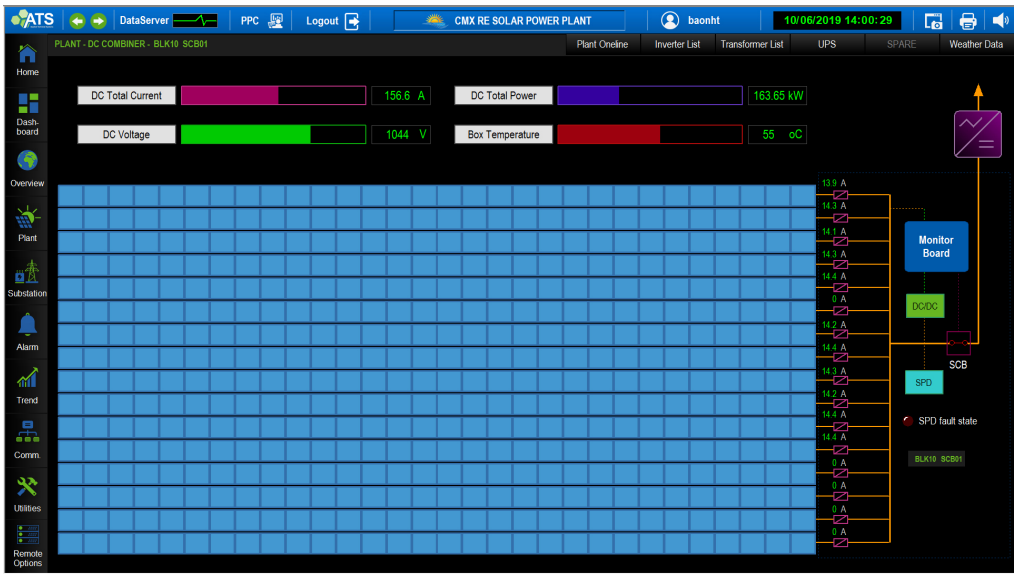

Figure 14. PV String Monitoring

Display all analog parameter such as: current, voltage and power of each solar string, surface temperature and evaluate efficiency and operation time of each PV string

Figure 15. Weather conditions Monitoring

Display current value of weather conditions such as solar radiation, ambient temperature, atmospheric pressure, wind direction and speed, humidity, ...

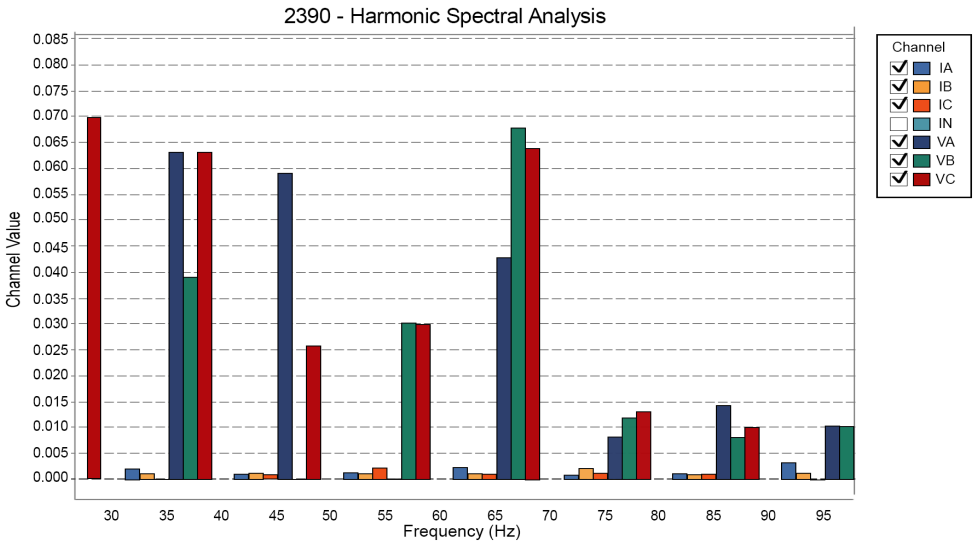

Figure 16. Power Quality Monitoring

Monitor VSSI – Voltage sag, well and interrupt, harmonic distortion, voltage fluctuation, frequency variation, power factor,...

(3). Supervisory control

The supervisory control commands shall be enterable at the Operator's request, via tabular and graphic displays, will be processed by the Power plant controller and sent to the Inverter controller, relay, BCU only after the command has been validated. The control sequence shall be predicated on the "select and check before operate (SBO)" philosophy in order to ensure the operation security.

The supervisory control step sequence is provided as follows:

- Display schematic diagram or tabular display on displays.
- Select the device for remote control by means of cursor positioning.
- Invalid requests shall result in a message showing the reason for rejection and the cancellation of the point selection – the ability shall be provided for the Operator to insist on the request in case of predefined non-critical situations.
- Change the color and blinking attribute of the affected device or function on the schematic diagram if the operation has been performed.

a) PV power plant control functions:

* Dynamic voltage and/or power factor, reactive power regulation of the solar plant at the point of interconnection (POI) to Grid support.
* Active power output control with fixed setpoint or curtailment command of the solar plant when required so that it does not exceed an operator specified limit.
* Frequency control to lower plant output in case of over-frequency situation or increase plant output (if possible) in case of under-frequency.
* Support incorporate fault ride-through capability is that they do not trip off during system disturbances such as over – under voltage, over – under frequency but continue to provide power when the grid needs it.
* Start-up and shut-down control of whole power plant.

a) MV switchgear control functions:

Device Control – The capability to control devices shall be enabled in accordance with the pre-defined areas of responsibility; control commands entered by non-authorized users shall be inhibited.

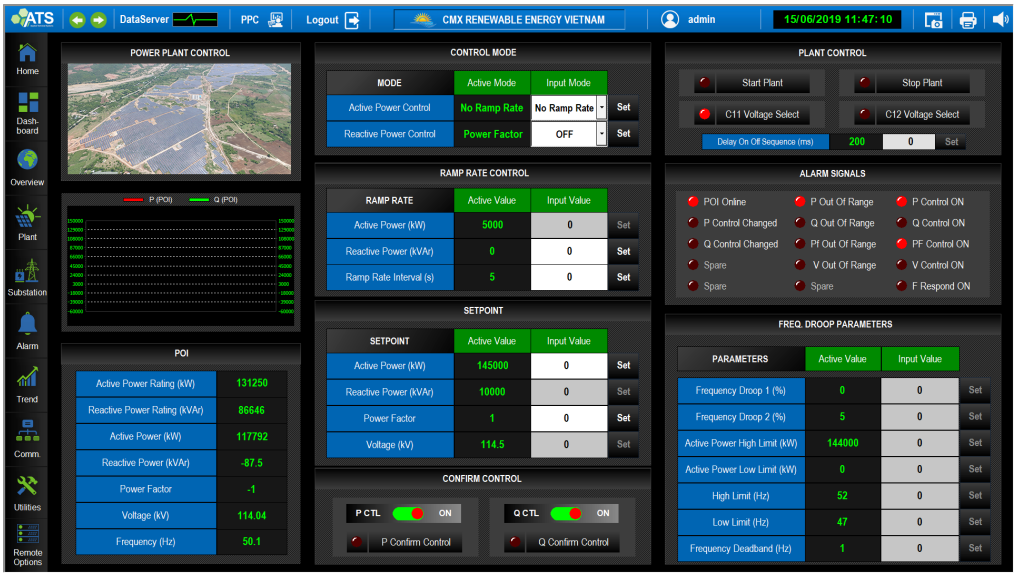

Figure 17. Power plant control user interface

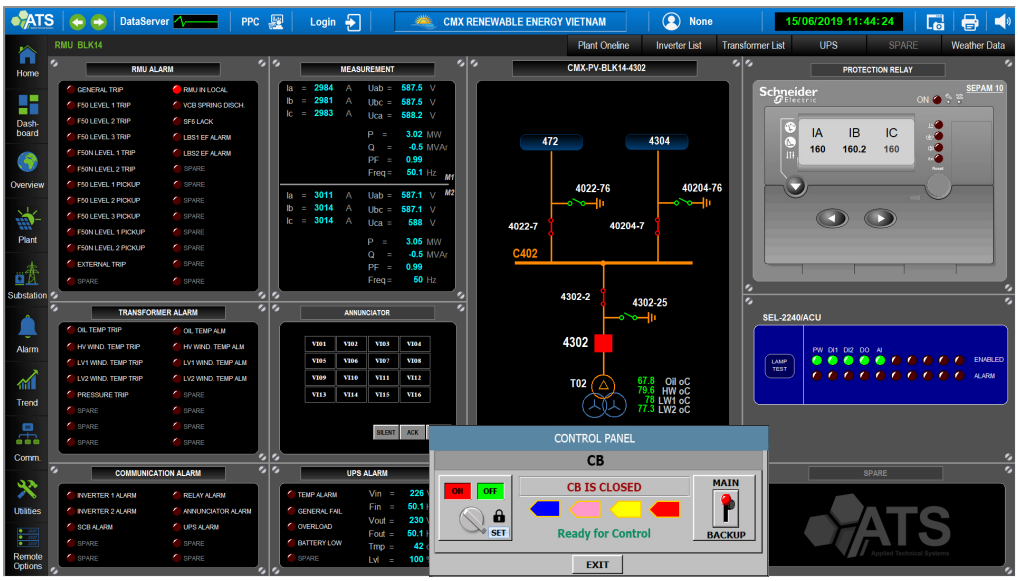

Figure 18. MV Switchgear Control

B. Technical Highlights

(4). Alarm processing

The monitoring of alarms coming from the equipment operation has a major importance in the power plant operation, especially during significant events such as total or partial system outages. An event is defined as any change in the power plant operation. An alarm is a subgroup of events. Any unsolicited status change or violation of any allowable limits of the power system variables shall initiate an alarm.

As a minimum, the following information shall be included for each alarm:

- Date and Time
- Substation Name
- Element Identifier
- A brief description of the alarm condition

(5). Trending

The PV plant mornitoring and control system shall incorporate trending functionality. It shall be possible to represent trends both from historical data, using the information stored in the HIS, and with real-time data.

There are some trend types the system can support:

- Electrical parameters trending (U, I, P, Q, Hz, PF...)
- Temperature trending (Ambient temperature, Room temperature, PV panel temperature, Inverter temperature, Tie transformer temperature...)
- Auxiliary parameters trending...

(6). Tagging

Tagging of the circuit breakers and disconnector switches, inverters... for maintenance, hot line work or automatic re-closing is an important part of the SCADA system design criteria. This will be accomplished by using as one input in interlock condition.

The Tagging function also allows the user to enter the following tag information:

- Job/Permit Number
- Date
- Purpose
- "Tagged by" and "Tagged for" Information

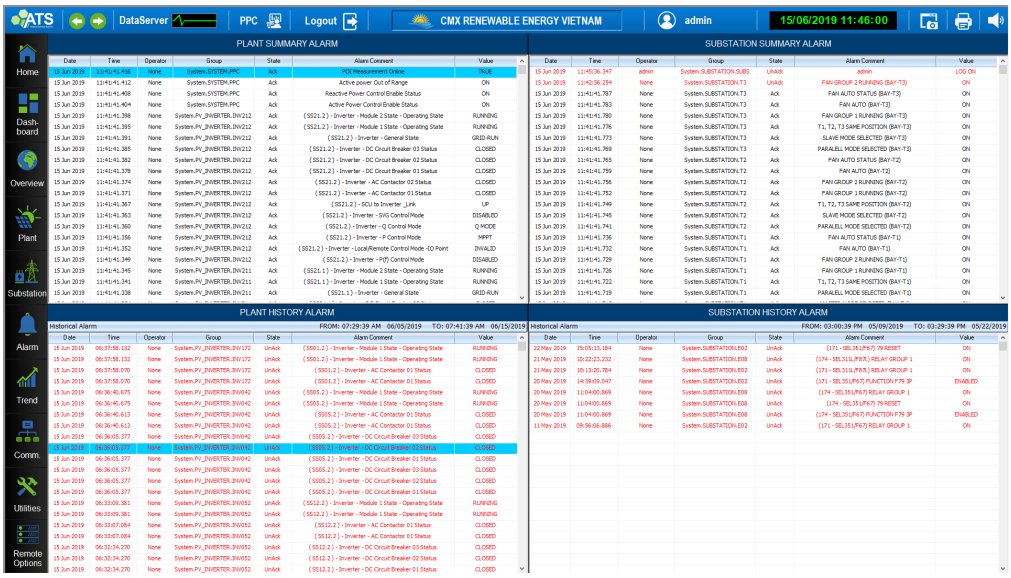

Figure 19. Alarm presentation window

Figure 20. Trending window

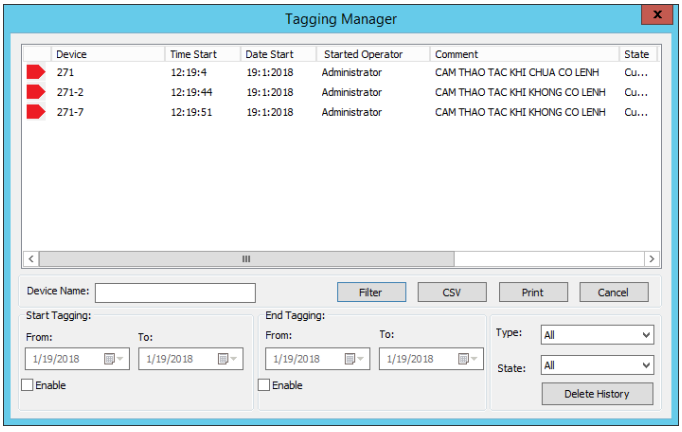

Figure 21. Equipment tagging window

4.4.6. Solar generation forecast

Accurate solar generation forecast is one of the key tools to mitigate challenges created by intermittent nature of energy generation from Renewable Energy systems.

We offer Renewable Energy Generation Forecasting Software for hour-ahead, day-ahead, week-ahead for individual PV power plants or distributed solar power systems.

We deliver power forecasts for several levels:

- Single solar parks
- Areas
- Countries

We provide AI-powered SaaS Solutions. Our Solution offers features as:

- Hour-ahead forecasting
- day-ahead forecasting
- Week-ahead forecasting
- Custom modeling and development
- Highest Accuracy
- Uncertainty bands
- Support multiple format types as xml, csv, sql or support multiple data sources included but not limit to mysql, cloud sql, bigquery, and more.
- SCADA Interfaces

Our System includes two key components:

- Offline Training:
  - Use multiple ML/AI models for PV power dynamics modeling and Pattern Discovery method.
  - Methods used include artificial neural networks, regression models, autoregressive models, support vector machines, and Markov chains, as well as composite methods, such as using genetic algorithms to optimize a neural network.
- Online Forecasting:
  - Use temperature, solar irradiance and history measured PV power with ML/AI model to forecast PV power at time (t + k)

4.4.7. Fault diagnosis

Fault diagnostic function is the integrated solution in @IRIS system for managing the operation of renewable energy plants. It provides services to accurately identify failure situations of devices during real-time operation. The system is designed to comply with IEC61724 standard to ensure smooth operation of PV arrays and optimize power production.

The application will continuously monitor the operation of PV array to detect operation points below the design threshold. It provides data collection in real time as well as the statistics needed to report system status to the operator via computer system, email, browser or SMS.

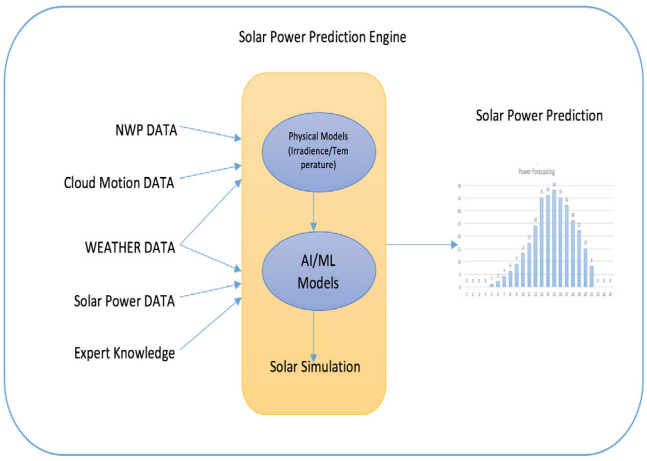

Figure 22. Solar generation forecast engine

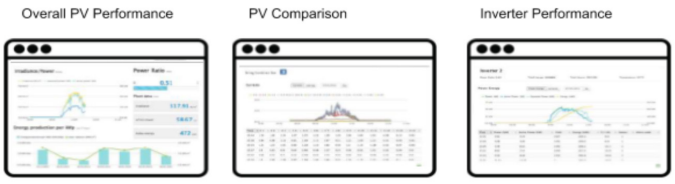

Figure 23. Continuously monitor the plant operation

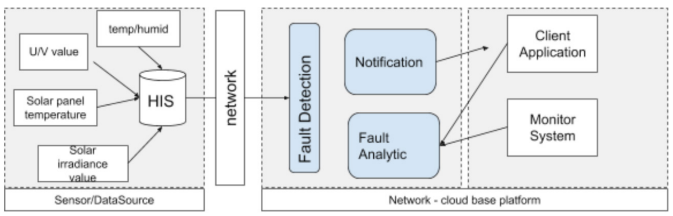

Figure 24. Fault diagnosis

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