One RTU to Serve Them All

Communications and Control for a Peaker Plant

denotes Lessons Learned

presented by
Tony Locatelli, PE MSEE
Kiewit Power Engineering

Overview

Claribel Energy Center integrates four blocks of small, reciprocating-engine generators into a single 48 MW plant that provides peak power during statewide grid emergencies. Kiewit interconnected this microgrid generating system by Enchanted Rock into a utility substation at 13.8 kV, developed relay protection, and programmed the **Remote Terminal Unit (RTU)** serving as the plant's data hub, communications gateway, and master display.

- This was a unique challenge due to the many protocols, devices, logic functions, data channels, and stakeholders involved.
- The utility selected OrionLX+ to be the RTU automation platform. Kiewit partnered with its Lenexa-based manufacturer, Novatech, to design / build the panel, develop new functionality, and support troubleshooting.
- Unlike most power plants with a large **Distributed Control System (DCS)**, all features had to be implemented in a single, compact box on a fast-track schedule. Control functions are performed on generator devices but coordinated by the RTU.
- The plant is owned by the State of California, operated by Enchanted Rock, and dispatched by the local utility, who feeds Claribel data to the **California Independent System Operator (CAISO)**. Kiewit collaborated with these entities throughout design and testing to ensure all requirements were met.

Protocols

Novatech's **Cascading Orion** ethernet communications between the RTU and I/O box allows for transparent programming and point-mapping of many devices in one setting file. It is a proprietary protocol released a few years ago for the current generation of Orion products.

Modbus is one of the oldest and most widely-adopted industrial protocols. Numerous variations exist based on age, manufacturer, and application. Claribel's RTU uses Modbus to interface with Schneider PLCs in each of the four Generator Master Control (GMC) cabinets.

- These links use serial communications to avoid bridging the generator network and the plant network. This improves cybersecurity and is feasible because of the relatively small dataset being exchanged.
- Claribel's two-wire, RS-485, point-to-point serial Modbus channels were somewhat challenging to commission. Originally designed for a different GMC device, they required hardware adapters to be installed at the PLCs. Orion port #1 communicated right away, but ports #2, #3, and #4 required additional troubleshooting. Cards and cables were swapped, parameters were adjusted, and driver software was checked on both ends until all links came online.

(LL) Memory register addressing can be complex: Orion starts its index at 1, whereas the PLC calls that same register 0. Also, some "server" implementations of Modbus (including Orion's) require an additional 4 at the beginning of each register. Taken together, the memory register with PLC address = 40000 would be seen by Orion as 440001.

(LL) Analog values such as integers and floating point numbers have predefined data types, but using a register to hold individual status bits can vary between devices. It is important to know which end of the register is "significant": is bit #1 at the left (**big-endian**) or right (**little-endian**)? Orion's convention is opposite of the PLC, so the data were initially off by a mirror image (i.e. bits 1…16 became 16…1). This was resolved by remapping points inside the Orion.

- The GMCs also use a different variation, Modbus TCP, over cellular internet to communicate with Enchanted Rock's operations center.

The RTU talks to protective relays over ethernet with **Distributed Network Protocol (DNP3)**, a standard for the electric utility industry. It provides well-defined data types, easy point mapping (independent of device memory addresses), and quality bits.

(LL) Control functions such as opening/closing breakers were implemented. It is important to know exactly which DNP3 data codes each device expects and how to map them. For example, GE relays require both "on" and "off" logic for each control bit. They also process their control data map sequentially and will ignore anything after an empty point.

The plant's revenue meters are manufactured by **Schweitzer Engineering Labs (SEL)**, and it is easiest to use their native protocol family:

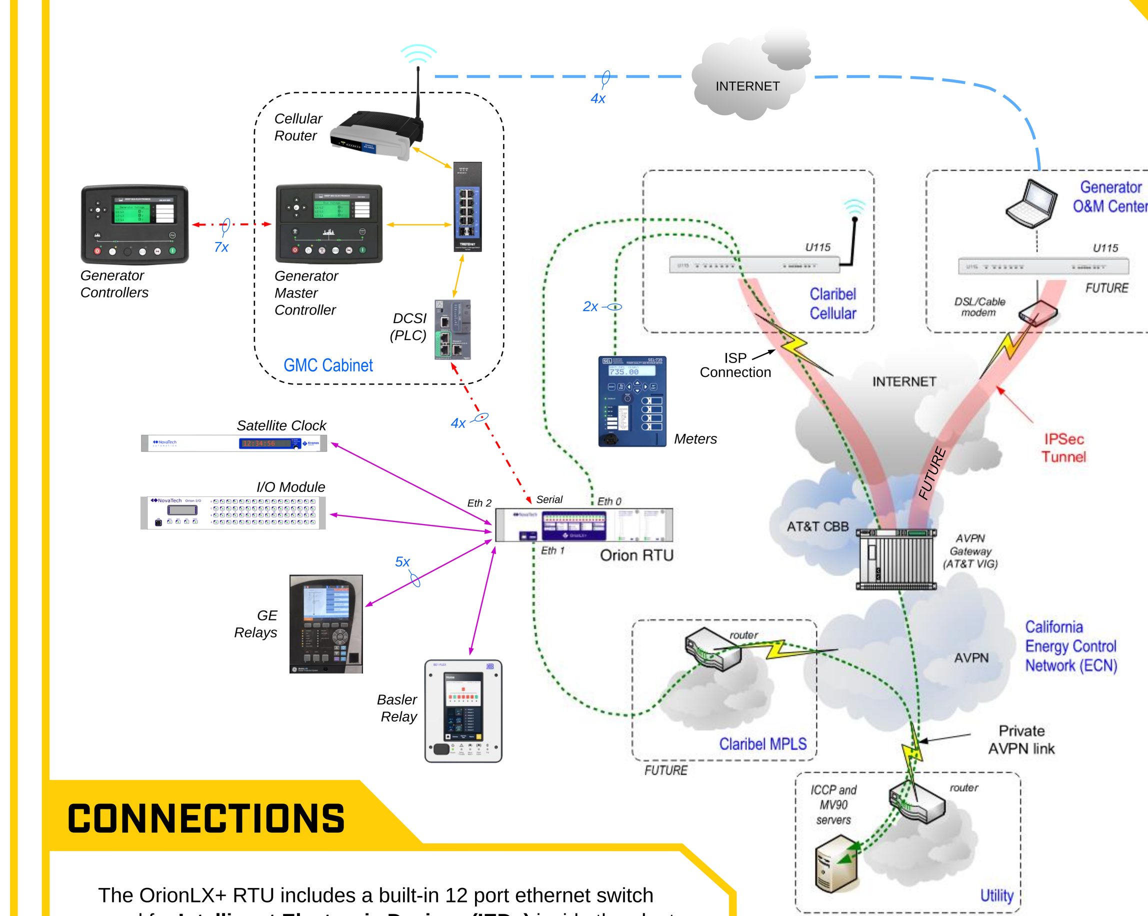
- ASCII text for general access including reading meter values, changing settings, downloading event reports, etc. (See screenshot of the pass-through CLI menu in *Real Time Visibility* below.)
- Fast Meter for status bits and analog values, Fast Operate for controls. Drivers handle memory mapping, so the values are read by name.
- Claribel uses SEL protocol over ethernet, but it can also be applied over serial channels.

Simple Network Management Protocol (SNMP) is common among switches, routers, and other IT devices. It features two main data types: traps (alarm bits) and analogs. At Claribel, SNMP is used between the Kronos clock and Orion RTU for status and alarm management over the plant network.

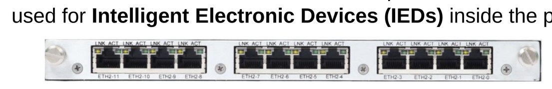
The local utility required Claribel's RTU to communicate with their SCADA system using **Inter Control Center Protocol (ICCP)**, since it is the only language they can support over the California **Energy Control Network (ECN)**. Also known as TASE.2 and IEC-60870-6, it is an "application layer" protocol that is usually implemented on IT servers instead of field devices.

- ICCP does not have point maps of data arrayed in a specific order, but instead, it matches unique variable names to pre-shared bilateral tables.
- Orion's basic implementation of this protocol did not mesh well with the utility's SCADA system. (See *External Data* below.)

Connections

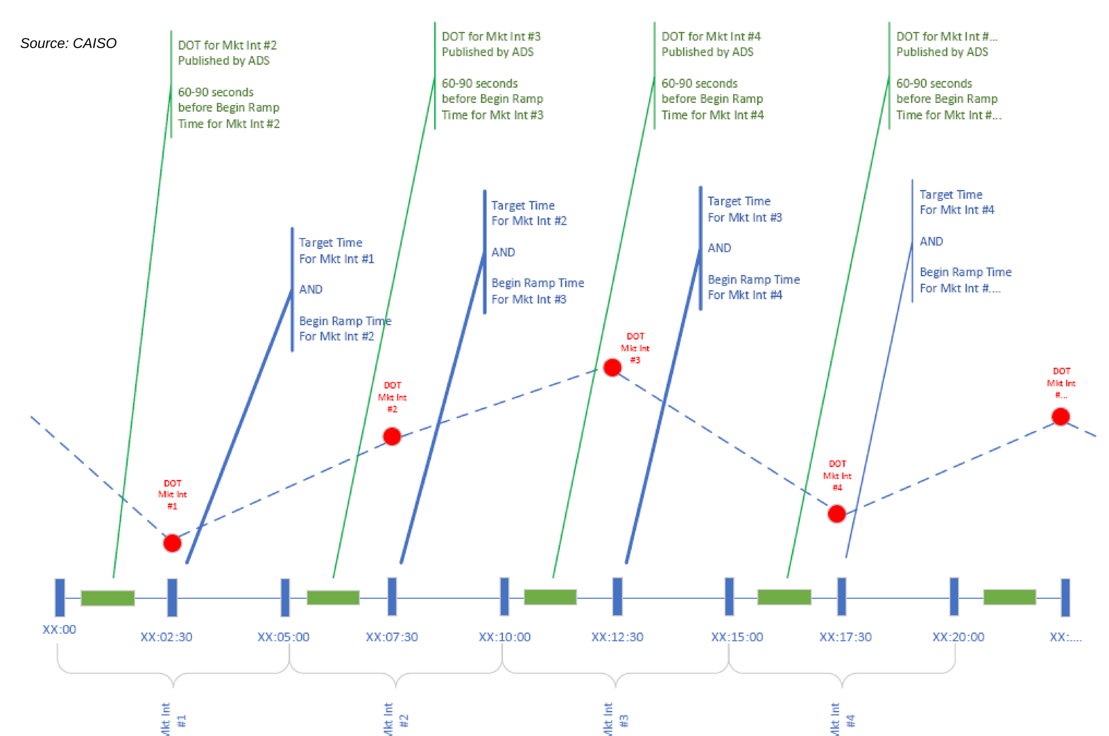


The OrionLX+ RTU includes a built-in 12 port ethernet switch used for **Intelligent Electronic Devices (IEDs)** inside the plant.



Control Scheme

The plant typically operates in **market mode**, responding to wide-area grid shortages. Every five minutes, CAISO's **Automatic Dispatch System (ADS)** runs balancing calculations and sends **Dispatch Operating Targets (DOT)** signals to generators across the state. The local utility receives DOTs through the Energy Control Network, then forwards dispatch commands to Claribel's RTU as needed. CAISO expects the units to ramp up or down as directed over the next 2.5 minutes, then measures the state of the grid for the next balancing calculation. Claribel's generators can adjust much faster than this, so an artificially slow ramp rate is activated to meet CAISO's timing target.



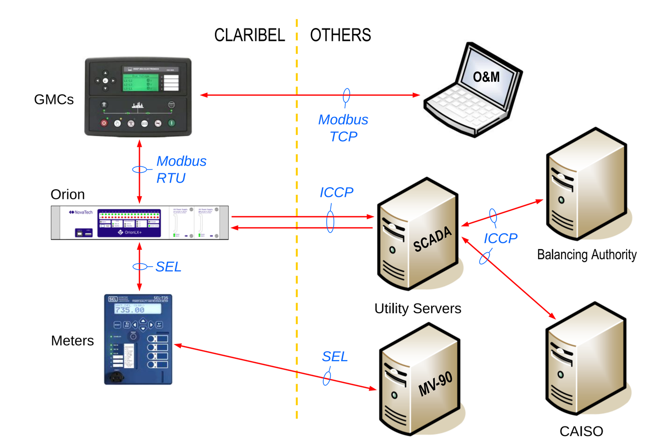
The local utility can also run Claribel in **demand mode** to make up their own grid needs. In this case, the ramping constraint is turned off, and the plant can adjust as quickly as the engines allow (usually about 15 seconds). Claribel's RTU determines the operating mode by a variable in the utility's ICCP data and passes that on to the **Generator Master Controllers (GMCs)**.

Each GMC coordinates a 12 MW generator feeder by communicating with several downstream gen-set controllers. It also handles the block's load-balancing and synchronization to Claribel's main 13.8 kV Switchgear. Because there are four GMCs, an additional layer of coordination between them is required to balance the whole plant. This is done by four PLCs known as **Data Concentrator of Site Intelligence (DCSI)**, each of which talks to the Orion RTU over Modbus serial protocol.

Each DCSI reports some variables such as MW available, real-time measurements, and alarms for only its individual feeder; the RTU must add or logically combine them to determine plant totals. Other data such as the target MW are reported by DCSIs in plant-total values. Defining this data exchange in a **points list** spreadsheet was critical to the project and took several iterations.

Panel Layout

External Data

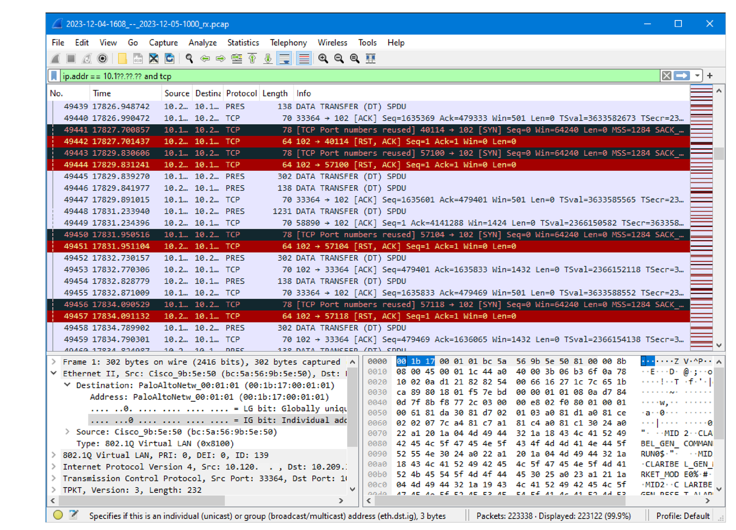


Claribel's revenue meters serve dual functions:
[1] providing real-time telemetry to the RTU, and
[2] having their registers read remotely by the utility's iTron MV-90 servers every month for account settlement. Meters were originally to be connected on the plant network, with the Orion RTU acting as a router / firewall that could pass MV-90 traffic through. During settings development and testing, it was discovered that Orion could not do the required **Network Address Translation (NAT)** or **port forwarding** between its three network interface cards. The meters were moved to the AT&T router on the **Energy Control Network (ECN)** to allow direct access by MV-90 servers, and the RTU can still receive meter telemetry on a different port. Orion's routing abilities will be enhanced in an upcoming firmware release, so this workaround may not be required on future projects.

The utility uses OSI Monarch as its **Supervisory Control And Data Acquisition (SCADA)** platform. This software maintains two different data tables, import and export, which were initially mapped to a single ICCP channel with SCADA as the master and Orion RTU as the follower. This setup had worked with the utility's other ICCP connections, which are generally between servers at control centers. For Claribel, only the imported data (status, analogs) worked during testing. It was then discovered that Orion did not support bidirectional ICCP sessions, so a second channel was set up for export data (commands to the plant) with SCADA as follower and the RTU as master. This required additional Orion logic, since the utility operates three SCADA servers with different IP addresses.

Claribel is connected to the ECN using a cellular radio. During startup, the utility noticed channel dropouts. The import and export channels rarely dropped at the same time, so a common-mode failure seemed unlikely.

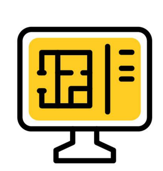
Date/Time	Origin	Description	Event	Value
		MID_TO_ERO		
12/18/23 13:54:15	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Offline
12/18/23 13:31:18	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Online
12/18/23 13:24:55	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Online
12/18/23 12:40:49	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Online
12/18/23 12:40:38	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Offline
12/18/23 12:39:34	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Online
12/18/23 12:37:15	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Offline
12/18/23 12:27:22	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Online
12/18/23 12:27:19	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Online
12/18/23 12:22:05	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Offline
12/18/23 12:22:05	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Offline
12/18/23 12:13:39	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Online
12/18/23 12:13:33	ICCP	MID_TO_EROCK_B MID_TO...	VCC State (Remote: EROCK)	Online



These could occur infrequently or many times per day. Such instability was not acceptable, so the issue became critical to start commercial operation of the plant. Novatech analyzed packet captures with Wire Shark, and OSI supported the troubleshooting from the SCADA side.

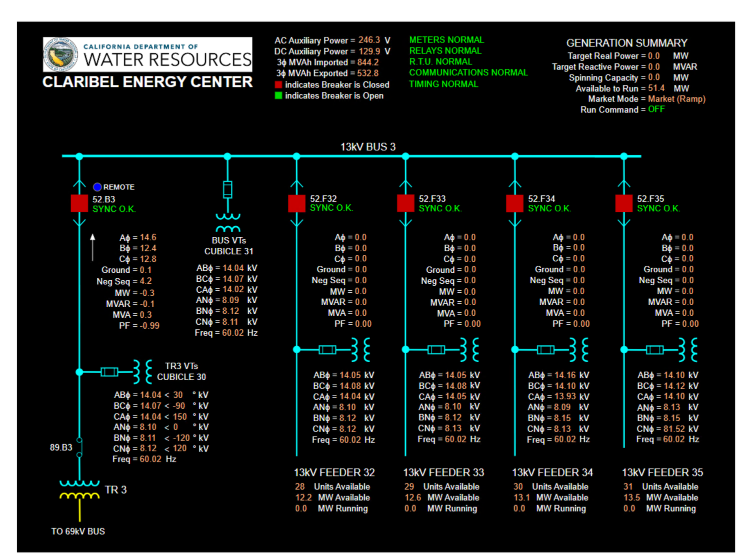
(LL) Cellular antennas were initially located inside the wood-framed control house and appeared to be fixed on the U115 router. Radio signal seemed strong enough (60-70%) for initial testing until ICCP dropouts were noticed. Enchanted Rock personnel later realized that these antennas were removable and swapped them for external units, similar to those on the GMC cabinets: the new antennas boosted signal strength to over 90% and resolved the ICCP issue. So, the import and export channels actually *did* experience a common-mode failure at the radio signal; the asymmetry observed in alarms was likely due to channel time-out delays in the SCADA program.

Real-Time Visibility

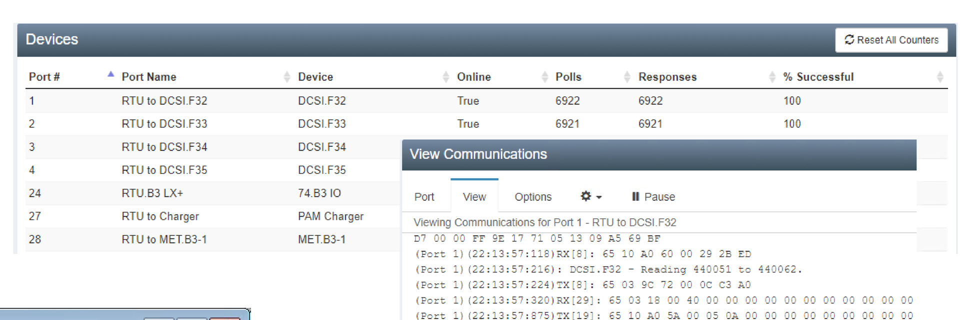


A variety of monitoring, control, and maintenance functions can be performed through the RTU's **Command-Line Interface (CLI)** and **Human-Machine Interface (HMI)**. CLI terminals can be accessed via serial / USB connection or Telnet / SSH network protocols. HMI screens are generated by a built-in web server, then viewed through ethernet connections or a local display.

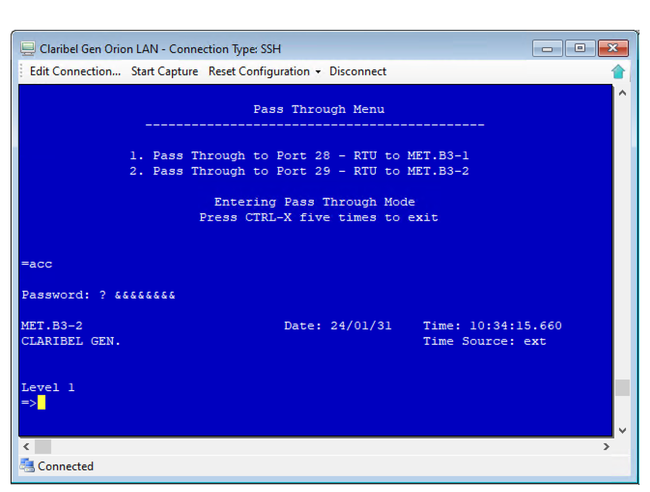
Kiewit designed an interactive One-Line Diagram on the HMI to provide an overview of plant status, analog values, and breaker controls. Elements on this screen are tied to points in the RTU's database, including primary / secondary pairs as mentioned in the *Logic* section.



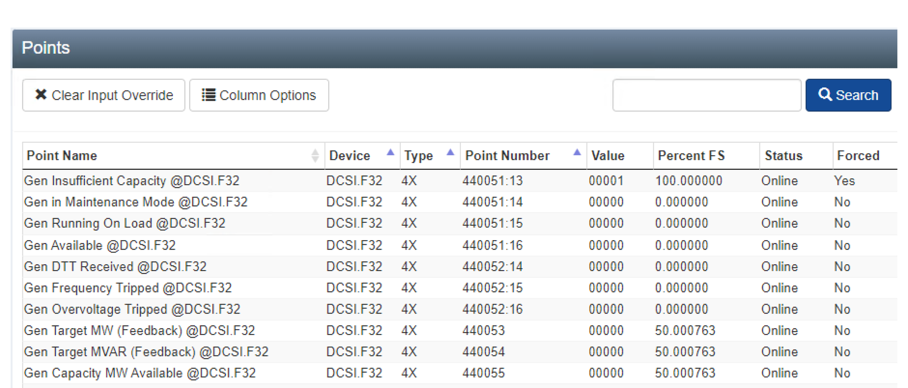
Device communications are reported in an overall summary of statistics, and port traffic details can be captured for troubleshooting in a separate screen.



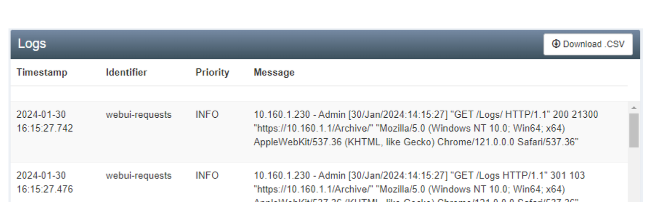
Among other functions, the CLI provides a "pass through" menu to access SEL-735 meters. This can work with any device that uses ASCII text interface.

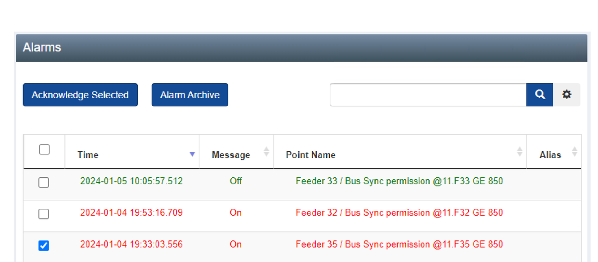


The Data Values screen shows real-time points as presented by external devices or internal services; this is useful for calibrating Orion's scale factors, logic, and other parameters. It also shows which specific points are online / offline and allows **forcing** (temporarily setting a fake value) to assist with testing.



Orion's Archive function shows historical values of assigned data points, and its **System Log (syslog)** records activities of the RTU's underlying Linux-based operating system. These values information is important for troubleshooting and compliance.





Plant alarms can be managed from a dedicated HMI screen with active conditions shown in red text. Each point is defined in the RTU's database along with options for alarm threshold, self-reset, label, etc. The graphical layout requires no additional setup and is intuitive for operators.

Programmable Logic

Claribel's Orion RTU includes a powerful logic engine based on the Lua programming language and a simple graphical logic tool called LogicPak. Several functions were developed to support the various protocols, communication channels, and control requirements.

(LL) Logic functions can be triggered by a fixed timer, or when their input is refreshed in the database, or when an input changes value more than its deadband setting. If misconfigured, these triggers can cause logic to update very rapidly, especially when database refreshes become a feedback loop. One example at Claribel involved the Modbus buffers overflowing, which locked up their port and disabled communications to the associated GMC. In another case, logic updates swamped the Orion's overall process and required a reboot. Issues were resolved by changing most applications from deadband or refresh to a fixed interval of 1 second. Shorter time intervals such as 0.5 seconds were successfully tested for time-sensitive functions, if needed.

Most plant-level alarms and status bits are derived from downstream device data using the **OR function** in LogicPak. For example, if any DCSI reports a generator under maintenance, then the plant status point "maintenance mode" activates.

As mentioned above left, some analog data is reported by DCSI PLCs on a per-feeder basis and must be combined by the RTU to report plant totals. This is accomplished with a Lua function **Add DCSI Inputs**, although some variables (e.g. power factor) are actually calculated by averaging or other mathematical functions.

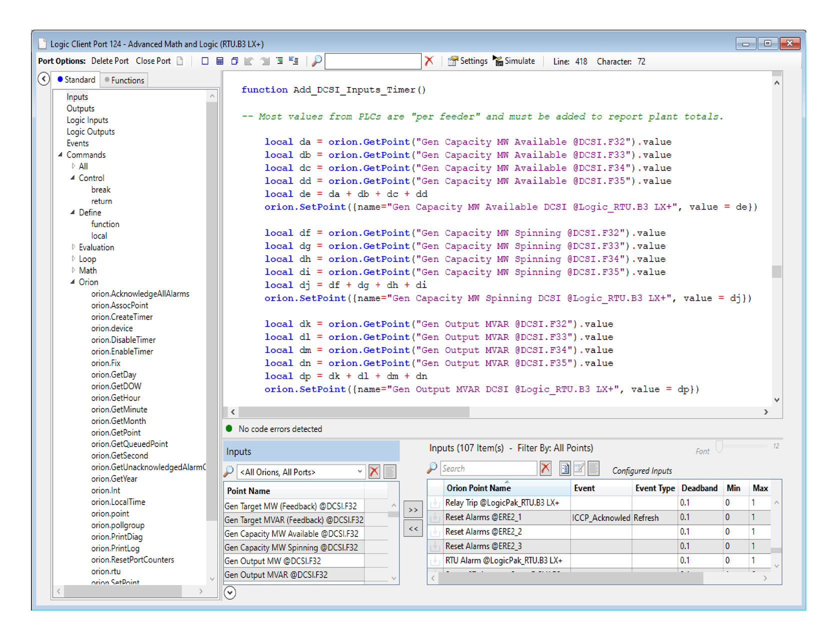
Point Type	Description
`State-1bit`	Single bit binary point with value 0 (off) or 1 (on).
`State-2bit`	Double bit binary point with the following values: 00 = 0 (in transition) 01 = 1 (open) 10 = 2 (closed) 11 = 3 (error)
`Discrete`	Numeric analog value
`Real`	Floating point value

The utility's SCADA servers use double-bit status for ICCP, but the plant's inputs are single-bit. So, we had to write a **One to Two Bit** conversion function in Lua. **Inputs to Outputs** and **Output Multiplier** are Lua functions that redistribute values from one source device to others. The related **Acknowledge Alarms** function takes a command from the utility (ICCP port 38) and distributes it to all plant devices that any alarm condition currently asserted should be reset if possible. The relays, GMCs, clock, RTU, and I/O box all have different commands associated with this action.

The plant-total metering quantities are critical for the GMCs and the utility, so we used LogicPak to create **primary / secondary data source pairs** between a revenue meter and the BE1-Flex bus relay. This allows metering data to continue flowing, even when either source device goes offline. The meter and relay signals are fed from different instrument transformers, further reducing the likelihood of common-mode failure. Like the OR function above, this could have been implemented in Lua, but it was easier in LogicPak.

The utility operates three different SCADA servers, each with their own IP address. The Lua function **ICCP Online** determines which one is sending commands to ICCP port 38, then writes those values into logic variables for other functions to access. If no server is online or multiple servers are trying to talk at once, the function "fails safe" by writing all zeroes, which shuts down any active generators at the plant.

As mentioned above, the satellite clock uses SNMP to communicate its status to the RTU. Previous firmware issues prevented the clock from generating traps correctly, however the same data was encoded in analog variables which were working fine. The fastest solution was to develop the **SNMP Alarms** function in Lua which reads analog variables, mathematically tests their value, and accordingly writes binary status / alarm values into Orion logic variables. The clock firmware issue has since been resolved at the factory, but this function has been retained at Claribel.



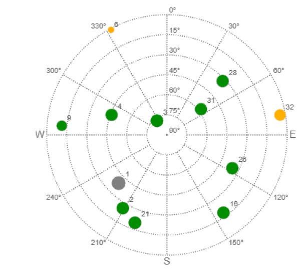
Timekeeping

Market dispatch signals, fault records, and system logs require precise timing. Claribel has a Kronos satellite clock with 60ns accuracy to align all relays and SCADA devices. Time data is distributed using **IRIG-B** signals on dedicated wires and **Simple Network Time Protocol (SNTP)** over the plant network as backup.

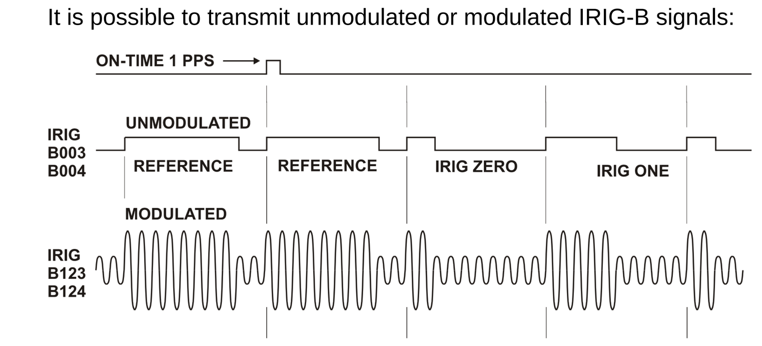
The utility requires Claribel to be in Pacific Standard Time without daylight saving adjustments. SNTP is always in **Coordinated Universal Time (UTC)**, so we set IRIG-B signals to match. This allows client devices to subtract 8 hours regardless of which time source is active. If SNTP was not being used, or if daylight saving time was required, it would be simpler to have the clock publish IRIG-B on local time offset and use default settings at the client devices.

IRIG-B is a family of formats, and it is important to know which is accepted by each device:

Sky plot of GPS and other satellites being tracked:



It is possible to transmit unmodulated or modulated IRIG-B signals:



(LL) Due to various formats and device setting limits, four different IRIG-B circuits were used at Claribel. This site is compact and has relatively few devices, but in general, designing an IRIG-B distribution system involves consideration of voltage drop (signal strength) and resonance (damping resistors).