SMARTEN Rod Lift Automation

Operation Manual Version 4.3

October 2021

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This manual refers to the installation of the SMARTEN and SMARTEN Edge pump-off controllers (POCs), which throughout the remainder of the manual will be referred to as SMARTEN or SMARTEN Edge.

Record of Change

Rev. #	Date	Section	Description of Change
0.6	June 2014	All sections	Initial Release
0.7	December 2014	All sections	Edits corresponding to GENESIS® v2.5.1.0
0.8	June 2015	All sections	Edits corresponding to GENESIS® v2.8.0.9
1.0	October 2015	All sections	Edits corresponding to GENESIS® v3.0.0.25
1.1	January 2016	All sections	Edits corresponding to GENESIS® v3.1.0.18
1.2	July 2016	3.1 -3.4, 4.1-4.3, 7.2.5.2, 9	Edits corresponding to GENESIS® V3.2.0.31
1.3	September 2016	3.4, 4.3, 7.2.5, App. D	Edits corresponding to GENESIS® V3.3.0.18
1.4	November 2016	3.4.4, 3.4.5, 7.1, 8.2, 8.5	Edits corresponding to GENESIS® V3.4.0.21
1.5	January 2017	3.4, 4.1, 4.2, 7.2.5, 8.1-8.4	Edits corresponding to GENESIS® V3.5.0.23
1.6	May 2017	2.4, 4.1, 4.3, 6, 7, 8.3	Edits corresponding to GENESIS® V3.6.0.38
3.7	October 2017	3.4, 4.2.1, 7.5.3, App. E,	Edits corresponding to GENESIS® v3.7.1.0. Initial Genesis® Release, grounding of the Genesis® RIB, added ® to all mentions of Genesis®
3.8	January 2018		Edits corresponding to Genesis® V3.8.0.31
3.9	August 2018	1.1, 3.2.3, 3.2.4, 3.3.1, 3.4, 3.2.5, 3.3, 4.2, 4.4, 7.5.3.4, 7.5.3.5, 8.3	Edits corresponding to Genesis® V3.9.0.41
4.0	November 2018	3.1.3, 3.2.5, 3.3.3, Section 4, App. A, App. B, App. C, App. D	Edits corresponding to SMARTEN V4.0.0.9. Rebranding SMARTEN, addition of SMARTEN Edge
4.1	June 2019	3.5.2.6-3.5.2.8, 3.6, App. D	Edits corresponding to Hall Effects, Toshiba AS1 and communications.
4.2	March 2020	1.1.1, 1.1.3, 2.2, 3.1.2, 3.2.6, 3.2.7, 4.1.4, 4.5, 5.1, 5.1.8-5.1.13, 7, 8.3.5, A.3, App B, C.2	Edits corresponding to SMARTEN V4.2
4.3	October 2021	All sections	Edits corresponding to SMARTEN V4.3 and ChampionX rebranding from legacy Apergy.

Table of Contents

Section 1: Introduction

This Operator's Guide provides a walkthrough of the configuration and operation process of the SMARTEN and SMARTEN Edge pump-off controllers (POC) from ChampionX.

Following installation, the SMARTEN controller can be powered on using the power switch located on the inner swing door below the display. The SMARTEN POC will not turn on the well or control the well until the SMARTEN program has fully booted. If digital output channels are configured to operate the Fault and Run relays (see Section 4.1.4), the Fault Relay will close once the SMARTEN program has fully booted and the Run Relay will close following the Start Delay. This is dependent on the HOA switch being in the Hand or Auto positions and HOA Status enabled on the digital input channels (Section 4.1.3).

1.1 SMARTEN Human-Machine Interface (HMI)

The SMARTEN and SMARTEN Edge controllers have been designed to improve oilfield production operations that use artificial lift to optimize oil and natural gas recovery. Artificial lift systems are used to lift liquids to the surface when the well's downhole pressure is not enough for it to flow on its own.

Data and information that is compiled by the SMARTEN or SMARTEN Edge is accessible from anywhere in the world, provided that the user and the well have connection to the Internet.

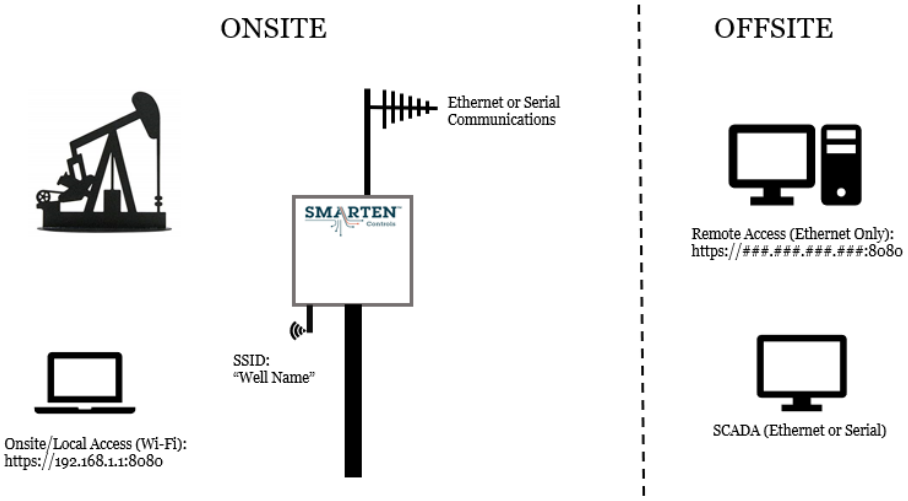
1.1.1 Using the SMARTEN Display, Wi-Fi and Remote Access

The SMARTEN controller comes equipped with a 10-in. color touchscreen through which all configuration and well monitoring can be done. The SMARTEN Edge controller comes equipped with a 7-in. color touchscreen. The look and features available are the same on both platforms. The user can also connect to the SMARTEN Wi-Fi (if equipped) onsite and login via web browser or connect remotely via web browser if an Internet connection is available on the well site and for the end user. All functions and features available on the touchscreen are also available via web browser whether accessed onsite or remotely. Instructions for configuration of the Wi-Fi board can be found in Appendix D.

If the SMARTEN or SMARTEN Edge controller is equipped with a Wi-Fi module, the operator can login to SMARTEN onsite by connecting to the SMARTEN Wi-Fi signal. The name of the Wi-Fi signal will be the same as the Well Name as entered on the Well Configuration screen (see Section 3.1). Once connected, open a Web browser and navigate to https://192.168.1.1:8080 or whatever IP address is assigned to the Wi-Fi module. When prompted, enter the username and password then click **Login**. For additional instructions for logging into SMARTEN please see **Appendix C.**

If the controller is equipped with a modem or a radio, then remote access is also available. A high-speed connection to the controller – either a modem or Ethernet radio – allows for access to the controller via web client or SCADA. A serial connection allows for connection to SCADA only. With a high-speed connection, the controller's webpage can be accessed by entering the IP address of the modem or radio on site along with the port number. For example, if a modem is installed on site with IP address 123.456.789.123 then the controller's web page can be accessed with the URL https://123.456.789.123:8080 with the same login credentials used for the onsite access via Wi-Fi.

The graphic below shows the options for connecting with the SMARTEN controller.



NOTICE

NOTE: *All login credentials can be obtained from ChampionX personnel unless specific to the customer.*

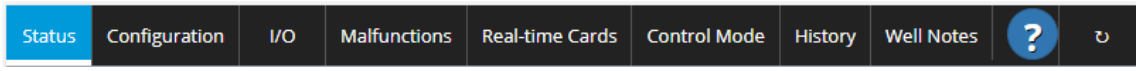
Once the hardware installation has been verified as operational, initial programming of the SMARTEN system can commence using the display, Wi-Fi connection or remote connection. Regardless as to how SMARTEN is accessed, initial configuration must include **Well Configuration** (Section 3) and **Malfunction Setup** (Section 5).

NOTICE

NOTE: *Prior to any configuration, the software must be upgraded to the most recent version. See* ***Appendix C*** *for software update instructions.*

The SMARTEN Launcher is an optional desktop application that can store well names along with their IP addresses. The launcher can also be used to quickly access the well's webpage, locally or remotely. See **Appendix C** (Logging into SMARTEN) for more details.

1.1.2 Menu Header



Once you have successfully logged into the SMARTEN system, you will be taken to the **Well Status** page. In the **Menu Header** at the top of the page, you will see eight (8) tabs:

- Status
- Configuration
- I/O (Inputs/Outputs)
- Malfunctions
- Real-time Cards
- Control Mode
- History
- Well Notes

By clicking on the first eight (8) tabs you will be presented with specific information regarding the well's operation and production. Some tabs, such as **Configuration, I/O, Malfunctions** and **History**, will have sub-tabs on their pages that allow access to additional well-configuration parameters and production information.

The "**?**" at the right of the **Menu Header** operates as the system's **Help** function. To activate, click the "**?**" button. At that time, your computer's cursor will turn into a "**?**" icon. Move the "**?**" icon over a heading and click to see a description of the selected operation or field's function. Note that this feature isn't fully implemented and is available on only select fields.

Example: In the **Well Config** tab under the Configuration tab, in the **Tapers, Tubing & Pump** field, click on **Pump Size** and the description, "The diameter of the downhole rod pump." will appear. Click again to close the description box.

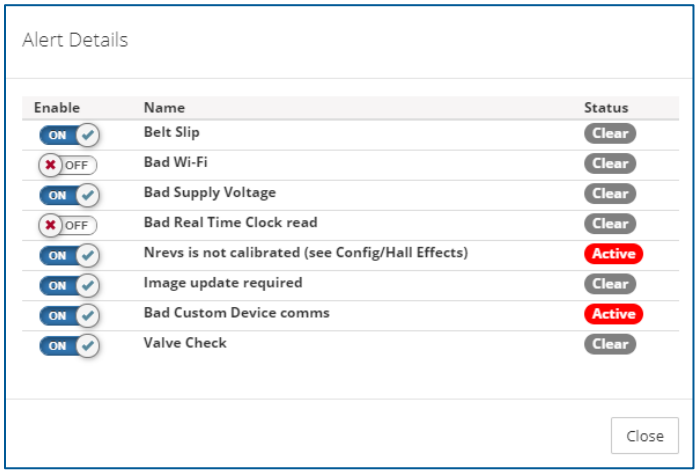
There is a **Refresh Arrow** at the far right of the Menu Header. Clicking on the arrow refreshes all data on the screen.

1.1.3 Bottom Toolbar

At the bottom of the page, eight (8) status items and the logout button are displayed:

- HOA Status: Shows the position of the HOA switch
- System State: Displays the System State as indicated on the Well Status page
- Alert Status
- Well Name
- Company
- Date & Time
- Software Version of the controller
- Logout: Click this button to log out of the SMARTEN system.

The Alert Status displays any alerts that are currently active. Pressing on the Alert Status opens a window that shows the status of all alerts as seen in the screenshot below. Those that are enabled have the Enable toggle switch in the ON position. The Status column shows which alerts are currently "Active" and which are "Clear." An Alert is a notification only and does not trigger a shutdown or any other action in the controller, however, an active alert will create an event in the Event Log.


Alert Details
Enable
Name
Status
ON
Belt Slip
Clear
OFF
Bad Wi-Fi
Clear
ON
Bad Supply Voltage
Clear
OFF
Bad Real Time Clock read
Clear
ON
Nrevs is not calibrated (see Config/Hall Effects)
Active
ON
Image update required
Clear
ON
Bad Custom Device comms
Active
ON
Valve Check
Clear
Close

Section 2: Status

On the Status page are two sub-tabs:

- Well Status
- VFD Status

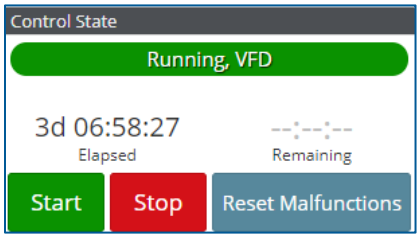
2.1 Well Status

The SMARTEN system's **Well Status** tab has been designed and configured to give the viewer a quick look at the status of a well's operational and production parameters. There are five (5) areas of information within the **Well Status** tab:

- Control State
- Equipment
- Operational Status
- Gauges
- Pump Dynagraph Card

In addition to these items, there are also three buttons: **Start, Stop** and **Reset Malfunctions.**

2.1.1 Control State



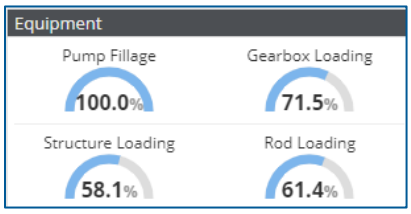
The **Control State** area lists the following operational statuses:

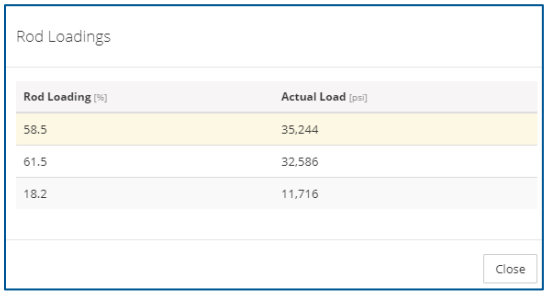
- **System State:** Indicates whether the well is Running, Idle or in Malfunction. See Appendix B: System States for a list of possible system states.
- **Well State Elapsed Time:** A counter that records the time a well has been Running or Idle in its current state
- **Well State Remaining Time:** A counter that records the time a well has remaining to run in its current state

The three (3) buttons located in the **Control State** area operate as follows:

- **Start:** Used to begin well operation remotely.
- **Stop:** Used to discontinue well operation remotely.
- **Reset Malfunctions:** Enables the user to reset the SMARTEN well-malfunction conditions.

2.1.2 Equipment





The **Equipment** section displays loading information in four (4) areas:

- **Pump Fillage (%):** A measure of how full the pump is, expressed as a percentage.
- **Gearbox Loading (%):** Indicates the stress placed upon the gearbox relative to its maximum capacity, expressed as a percentage. This value is only available when the controller is integrated with a variable speed drive otherwise the value with show “N/A”.
- **Structure Loading (%)**: Indicates the stress placed upon the structure relative to its maximum capacity, expressed as a percentage.
- **Rod Loading (%)**: Indicates the stress placed upon the rod string relative to its maximum capacity, expressed as a percentage. The value shown is the highest for the entire rod string. Clicking the **Rod Loading** gauge opens a window that displays the rod loading of all tapers along with their **Actual Load** measured in psi.

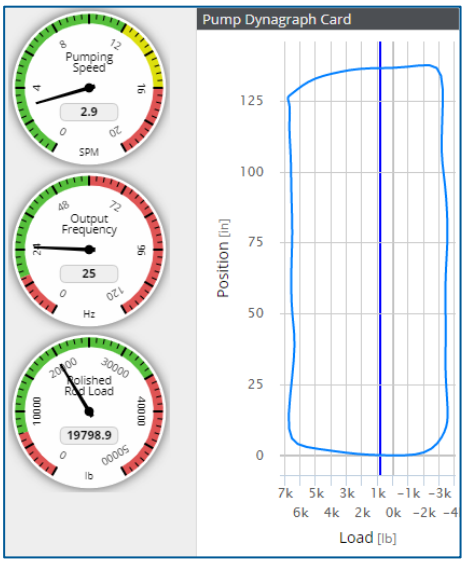
2.1.3 Operational Status

Operational Status		
	Today	**Yesterday**
Oil [BBL]	18.9	29.8
Water [BBL]	71.2	112.3
Total Fluid [BBL]	90.1	142.1
Cycles [c/day]	0	0
Runtime [h:m:s]	15:16:21	23:59:59
Runtime [%]	100.00%	100.00

The **Operational Status** area displays production in six (6) areas for both the current day (**Today**) and previous day (**Yesterday**). The **Today** information is a real-time running total, while the **Yesterday** information is the final recorded production level from the previous day:

- **Oil (BOPD):** The amount of oil produced Today and Yesterday, measured in barrels of oil per day (BOPD).
- **Water (BWPD):** The amount of water produced Today and Yesterday, measured in barrels of water per day (BWPD).
- **Total Fluid (BPD):** The combined amount of oil and water produced Today and Yesterday, measured in barrels per day (BPD).
- **Cycles (c/day):** The number of times the well turned off Today and Yesterday.
- **Runtime:** The total amount of time the well has run Today and Yesterday.
- **Runtime (%):** The total amount of time the well has run Today and Yesterday, expressed as a percentage.

2.1.4 Gauges & Pump Dynagraph Card



The **Gauges** give a “dashboard” glimpse of several operational characteristics. The default display parameters for the gauges are:

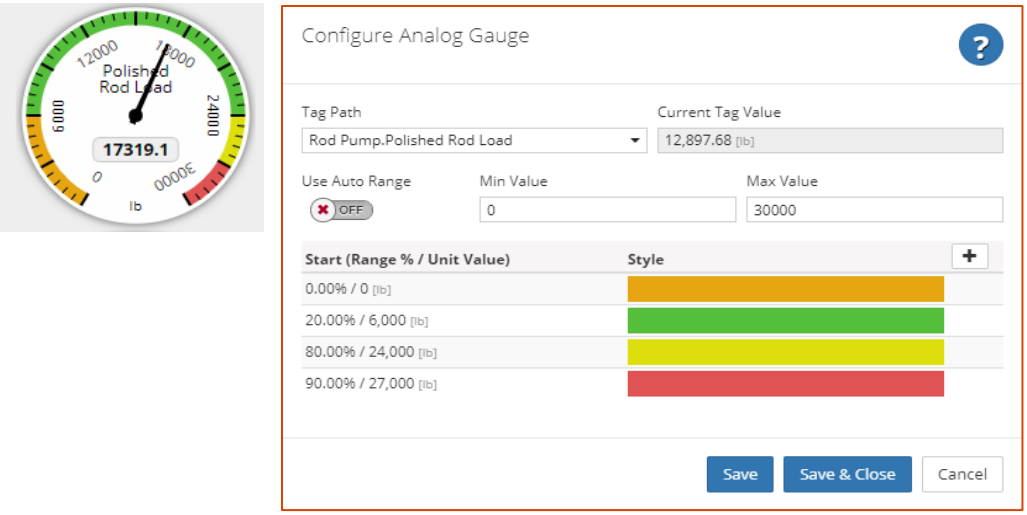
- **SPM:** Indicates the well’s pumping speed in strokes per minute (SPM).
- **Polished Rod Load**: Indicates the load exerted on the polished rod as measured by the load cell, measured in pounds (lbs.).
- **Fluid Load:** The weight of the fluid lifted by the downhole pump during the upstroke, calculated from the most recently completed stroke.
- **Pump Dynagraph Card:** Shows the well’s current calculated downhole dynagraph card.

Each gauge can be configured to present any tag in SMARTEN. Clicking/pushing a gauge opens a Configure Analog Gauge window. Select the desired Tag using the Tag Path drop-down box. Several Tag options are available including Custom channel settings, Rod Pump quantities, VFD quantities or Casing, Tubing or Flowline Pressures. If a Custom Analog channel is to be represented on a gauge, then that channel must first be set up and enabled on the I/O page. Once a Tag is selected, the Current Tag Value will be shown in the box to the right.

The Auto Range feature can be used if the system can determine an appropriate range for the Tag. When activated, the range is determined for data sources driven by analog inputs or the unit type of the source. If the Auto Range is not used, then Min and Max Values need to be set for the gauge. Negative values can be used for the gauges as well.

Color bands can also be selected for each gauge. Clicking the (+) on the right side of the page will add as many as five (5) color bands. The Start value on the left side of the table is the position where that color band will start. Clicking on the Start value allows the user to edit the value and enter it as a percentage or number with units. A color (red, orange, yellow, green) can be chosen to represent each range in the Style column. Colors can be used multiple times if so desired. A sixth color band can be created if the first Start value is a value other than 0%. This additional color band will be white. When a line in the table is clicked on for editing, it can be deleted by clicking the "X" on the right side.

The setup below shows an example for the Polished Rod Load gauge.



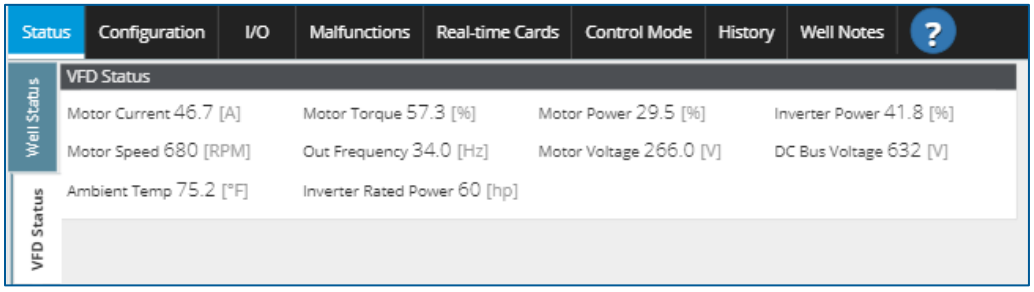
2.2 VFD Status

On the **VFD Status** tab, several status registers from the VFD can be viewed. The available registers vary by inverter type. The VFD Status page for each inverter includes all or some of the following registers: **Motor Current (A), Motor Torque (%), Motor Power (%), Inverter Power (%), Output Frequency (Hz), Motor Speed (RPM), Motor Voltage (V), DC Bus Voltage (V), Ambient Temperature (F)** and **Inverter Rated Power (hp)**. These are inverter status registers and are read only. Definitions for all status registers are below:

- **Motor Current:** the real-time motor amperage. Clicking on the Motor Current will display the percent of inverter rated current.
- **Motor Torque:** the real-time motor torque, expressed as a percentage of the torque current of the motor.
- **Motor Power:** the real-time motor power, expressed as a percentage of the motor's power rating.
- **Inverter Power:** the real-time power delivered to the inverter, expressed as a percentage of the maximum.
- **Output Frequency:** the real-time inverter output frequency sent to the motor measured in Hertz.
- **Motor Speed:** the real-time motor speed, as reported by the inverter measured in RPM.

- **Motor Voltage:** the real-time inverter output voltage to the motor.
- **DC Bus Voltage:** the real-time inverter internal power supply voltage.
- **Ambient Temperature:** the real-time measurement of the inverter's internal air temperature.
- **Inverter Rated Power:** the output power rating reported by the inverter measured in horsepower.

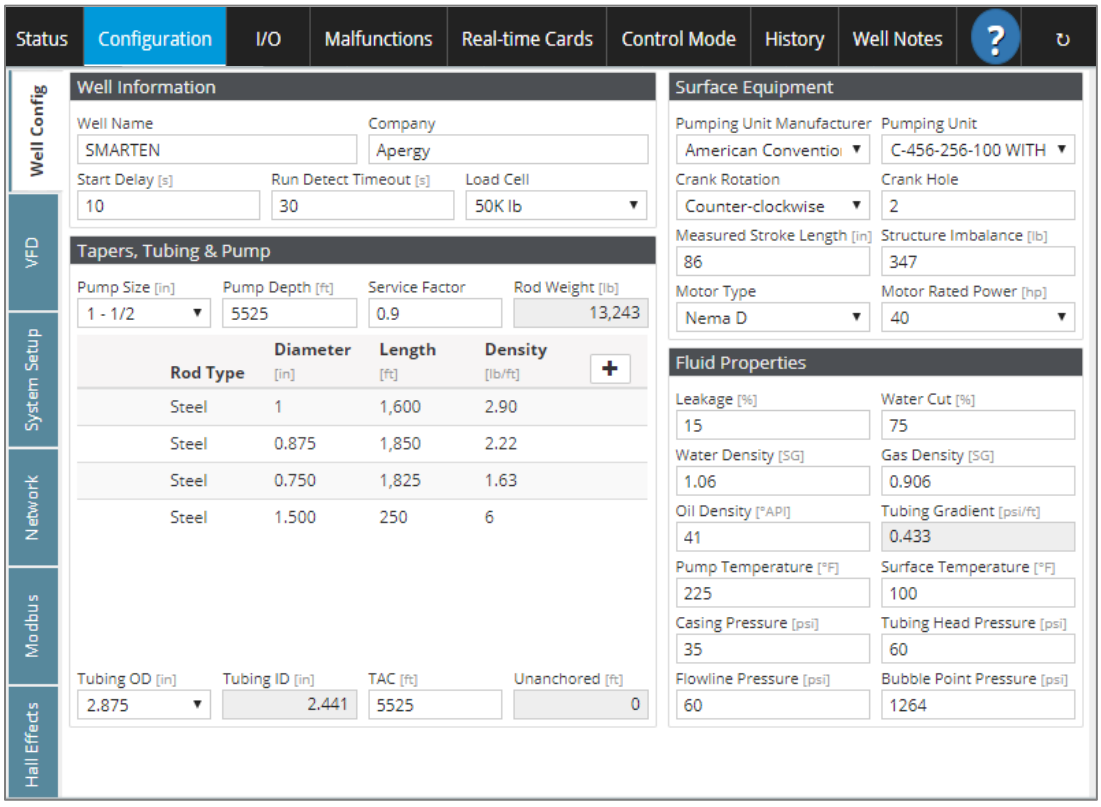
The image below shows the status from the Fuji FRENIC-MEGA inverter, which includes all status registers. The Toshiba AS3 and AS1 each show a subset of the registers mentioned above.



Section 3: Configuration

The SMARTEN **Configuration** tab has been designed and configured to give the viewer a look at the well's configured properties. There are six (6) sub-tabs within the **Configuration** section:

- Well Configuration
- VFD (appears only VFD client is enabled on the Modbus page)
- System Setup
- Network
- Modbus
- Hall Effects

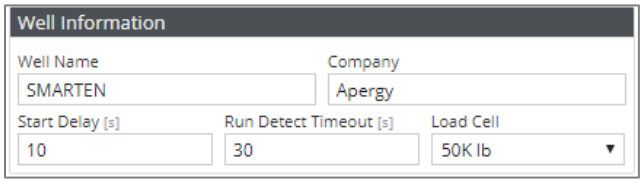


3.1 Well Configuration

The **Well Configuration** sub-tab features configuration information displayed in four (4) fields. They are:

- Well Information
- Tapers, Tubing & Pump
- Surface Equipment
- Fluid Properties

3.1.1 Well Information



Fill in the correct information for **Well Name** and **Company** in the **Well Information** field. If the SMARTEN controller is equipped with a Wi-Fi card, the network name (SSID) will be the same as the **Well Name**.

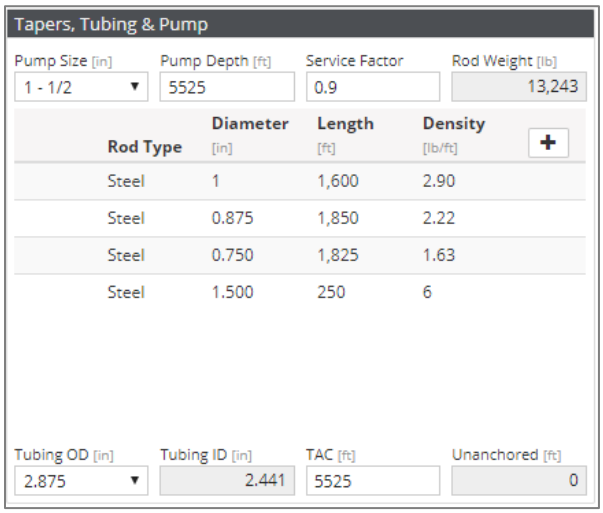
The **Start Delay(s)** is the amount of time (in seconds) the SMARTEN controller will delay starting the pumping unit after it has been told to begin running. The passage of this amount of time is signaled by a "beep" from the controller.

***NOTE**: It is recommended that the **Start Delay(s)** time be set to 30 seconds or more if a soft-start device or variable frequency drive (VFD) is used in conjunction with the controller. This will ensure that the unit has stopped moving before it is required to restart, reducing the chance of overloading the device.*

The **Run Detect Timeout** is the amount of time the controller will attempt to determine if it is running. If successful, the controller will calibrate and run. If not, a fault message will be displayed in the **System State**. It is recommended that the **Run Detect Timeout** be set to 25 seconds.

The **Load Cell** type can be selected from the dropdown menu. The choices are either 30K lbs., 40K lbs., or 50K lbs. The load cell terminal provides a 10 V excitation voltage. The signal from the ChampionX 50K load cell is 2 mV/V. Therefore, a 50,000 lb. load will return a signal of 20 mV. A 25,000 lb. load will return a signal of 10 mV. Other load cells may vary. Click the **Save** button when all changes have been made.

3.1.2 Tapers, Tubing & Pump



First, select the appropriate Pump Size from the **Pump Size (in)** dropdown menu. These values range from 3/4" to 6" and increase by quarter-inch increments.

The depth of the well should be entered in the **Pump Depth (ft)** field. The value of the pump depth will appear in red if it differs from the total length of the rod string by more than 50 feet. This is based on the length of the rod string.

The **Service Factor** field shows the reliability factor of the rods. This value is typically set at 0.9.

The rod string will be configured from top to bottom, meaning the first taper listed under **Rod Type** is the one closest to the well's surface.

To enter a new rod in this area, click the "+" button. In the **Rod Type** dropdown menu, select the rod's composition (i.e., Fiberglass, Steel, High Density Steel, Continuous Rod, Carbon Fiber or Sinker Bar). The rod tapers can be reordered by clicking on the taper and using the "∧" and "∨" to reposition.

***NOTE**: Carbon Fiber rods are only available as a 5/8" diameter.*

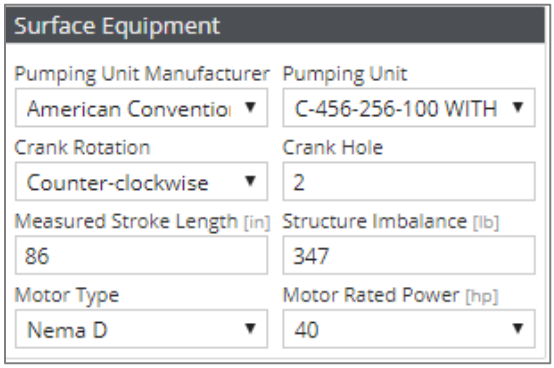
Choose the proper diameter for the rods in the **Diameter** dropdown menu and enter the proper length for each taper in the **Length** field. Once the rod diameter and taper length values are selected or entered, the density of the rods will appear in the **WPF (lb/ft)** fields.

Tubing specifications need to be entered in the **Tubing OD (in)** field and can be selected from the dropdown menu. When the **Tubing OD (in)** value is selected, the Tubing ID (in) field will be automatically populated.

The depth of the Tubing Anchor can be entered into the **TAC** box. The controller will calculate the amount of unanchored tubing once the TAC and Pump Depth values have been entered and place it in the **Unanchored Tubing (ft)** field.

The **Rod Weight (lb)** is the total dry weight of the entire rod string.

3.1.3 Surface Equipment



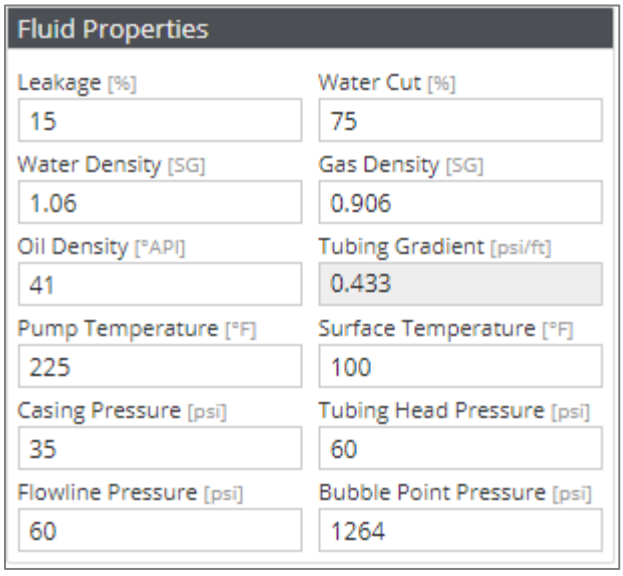
***NOTE**: If Hall Effects are used for position measurement then it is critical that the correct surface equipment be selected since the pumping unit's geometry is used to determine position. If the exact pumping unit cannot be found in the list of pumping units then it is necessary to set up the custom pumping unit dimensions found on the Admin pages.*

The parameters for the pumping unit and its prime mover are entered into the eight (8) fields in the **Surface Equipment** field:

- **Pumping Unit Manufacturer:** Select the equipment manufacturer.
- **Pumping Unit:** Select the API description of the pumping unit. This is a series of numbers/letters that can be found on the nameplate of the pumping unit, typically on the side of the Samson post. An example of this would be: 320-305-100, with the respective values meaning:

    - **320:** This is the Gearbox Rating, or peak torque rating, in thousands of inch-pounds. Example given: (320 x 1,000 = 320,000 inch-pounds).
    - **305:** This is Structure Rating, or peak polished rod-load rating, in hundreds of pounds. Example given: (305 x 100 = 30,500 pounds).
    - **100:** The stroke length, measured in inches.
- **Crank Rotation:** Select the direction that the crank is rotating, either Clockwise or Counter-clockwise. The direction of crank rotation is determined by viewing the pumping unit with the wellhead to the right and by observing the direction of rotation of the counterweights.
- **Crank Hole:** Select the position of the crank hole used. This value, along with the selected Pumping Unit determines the stroke length.
- **Measured Stroke Length (in):** This value will be automatically populated once the correct Pumping Unit and Crank Hole has been selected. As a best practice, a tape measure should be used to verify the true stroke length. If the stroke length measured differs from the value populated when the Pumping Unit and Crank Hole were selected, then edit the **Measured Stroke Length** value accordingly. The stroke length for each crank-pin hole is usually listed on the unit's nameplate.
- **Structure Imbalance (lb.):** This value is found on the manufacturer's nameplate on the pumping unit. This value indicates whether the pumping unit is horse-head heavy or tail heavy.
- **Motor Type:** Choose Nema D, UHS or Gas Engine from the dropdown menu; the default position is Nema D.
- **Motor Full Load (hp):** Enter the corresponding motor horsepower.

3.1.4 Fluid Properties



A total of eleven (11) values must be entered into the **Fluid Properties** section, which lists the properties of the production fluid:

- **Leakage (%):** This value will adjust the production values by incorporating an approximate pump-leakage percentage. The default value is 15% but can be changed to whatever percentage is believed to be correct.
- **Water Cut (%):** The approximate proportion of water that exists in the production fluid. While this value changes with each well, the default value is set at 75%. This value means that for a given sample of production fluid, 75% will be water while the remaining 25% will be oil.
- **H_2O Density (SG):** The relative density of the water in the well compared to a sample of pure water; the default value is 1.05.
- **Gas Density (SG):** The density of the gas in the well compared to a sample of air; the default value is 0.906.
- **Oil Density (API):** Compares the weight of the oil to the weight of water; the default value is 41.
- **Tubing Gradient (psi/ft):** Describes how the pressure increases per foot of depth in the well. This value is automatically calculated by SMARTEN and is a read-only value.

- **Pump Temperature (ºF):** Defaulted to a value of 150ºF.
- **Surface Temperature (ºF):** Defaulted to a value of 75ºF.
- **Casing Pressure (psi), Tubing Head Pressure (psi)** and **Flowline Pressure (psi):** These values can be viewed on the gauges at the wellhead. If pressure transducers have been installed to measure these values the real-time gauges on the **Well Status** page can be configured to display their current values. See section 2.4 of the Operator's Guide for more information.

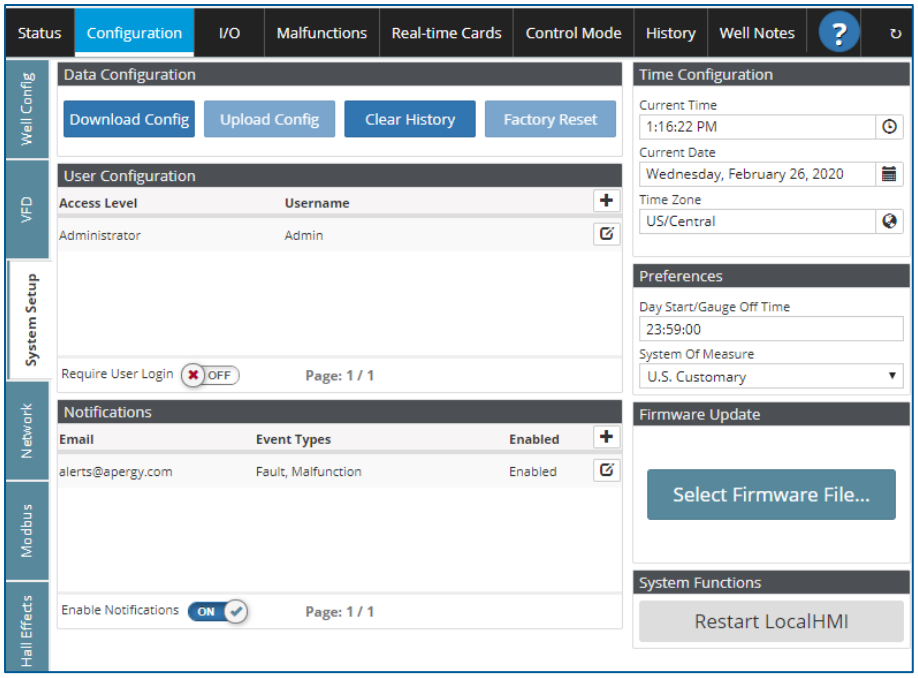
***NOTE**: If pressure transducers have been installed to measure these values at the wellhead, there is no need to enter a value in these fields and they will be grayed out.*

- **Bubble Point Pressure (psi):** This is the pressure at which gas bubbles start to break out of the oil; the default value is 1,264 psi.

Once all values in the **Well Information, Tapers, Tubing & Pump, Surface Equipment** and **Fluid Properties** fields have been entered, click the "Save" button. If any items need to be modified, click the appropriate text box, and enter any new values. Click "Save" when all revisions are complete.

***NOTE:** If changes are made to any of the user-selected variables in the four (4) sections of the **Well Configuration** tab and the user attempts to leave the **Configuration** section without clicking **Save,** the following error message will appear: "Your changes have not been saved! If you leave this page, your pending changes will be discarded." Click **Go Back** to return to the **Configuration** section and click **Save,** or click **Leave** to void any unsaved changes. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Saving configurations settings…Success!" if the changes have been saved successfully.*

3.2 System Setup

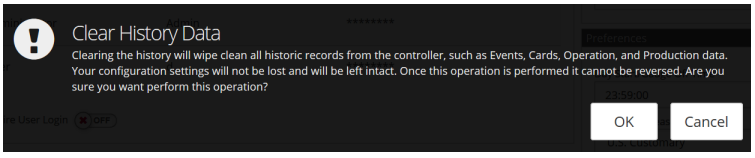


The **System Setup** area within the **Configuration** tab of the SMARTEN controller allows the operator to create or modify accounts, input time settings and the measurement units that well-production/operation data will be presented in. There are five (5) areas within this tab: **Data Configuration, User Configuration, Time Configuration, Preferences**, **Firmware Update** and **Notifications.**

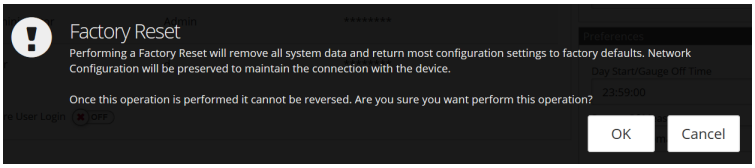
3.2.1 Data Configuration

The **Data Configuration** area allows the user to save, upload, clear or reset the controller's configuration parameters.

- **Download Config:** Allows the user to download and save well configuration to a USB flash drive or to a computer connected locally via Wi-Fi or remotely. Be sure to name the file appropriately with the well's name so that it can be identified in the future.
- **Upload Config:** Allows the user to upload and a previously saved well configuration from a USB flash drive or a computer connected locally via Wi-Fi or remotely. If uploading from a flash drive, the flash drive must be inserted to one of the controller's USB ports and contain the configuration file for SMARTEN. This function can only be done when the well is idle.
- **Clear History:** Clearing the history will wipe clean all historic records from the controller, such as Events, Cards, Operation, and Production data. The configuration settings will not be lost and will be left intact. When the Clear History Button is pushed a warning banner will be displayed confirming the action.



- **Factory Reset:** Performing a Factory Reset will remove all system data and return all configuration settings to factory defaults. Once this operation is performed it cannot be reversed. When the Factory Reset Button is pushed a warning banner will be displayed confirming the action. This function can only be done when the well is idle.



3.2.2 User Configuration

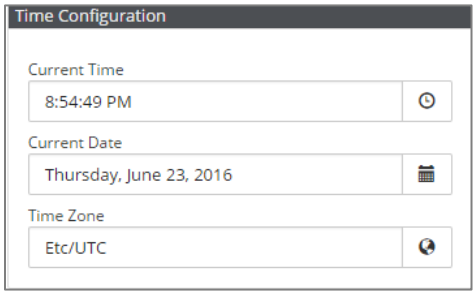
A new user account can be created by the System Administrator simply by clicking the "+" button and entering the **Access Level** (either Administrator or User from the dropdown menu), **Username** and **Password** in the appropriate fields, then clicking the **Save** button. The **Require User Login** button can be toggled from **On** to **Off,** as required. When **Require User Login** is enabled the controller access will automatically be in "User" mode. If any configuration changes are attempted, the user will be prompted to enter an Administrator's credentials after which configuration changes can be made. If the logout button is pushed or after 10 minutes of inactivity, the administrator will automatically be logged out and the controller will be left in "User" or view only mode.

Once a user account has been created, it can be modified by clicking on its **Access Level, Username or Password** and making the desired changes before clicking the **Save** button. Clicking the box with the "X" will delete that User, provided the **Save** button is clicked.

***NOTE**: "Administrator" rights enable the user to change all parameters in the controller, while "User" rights provide "view-only" privileges to the controller. "User" privileges also allow the user to reset malfunctions and start/stop the well.*

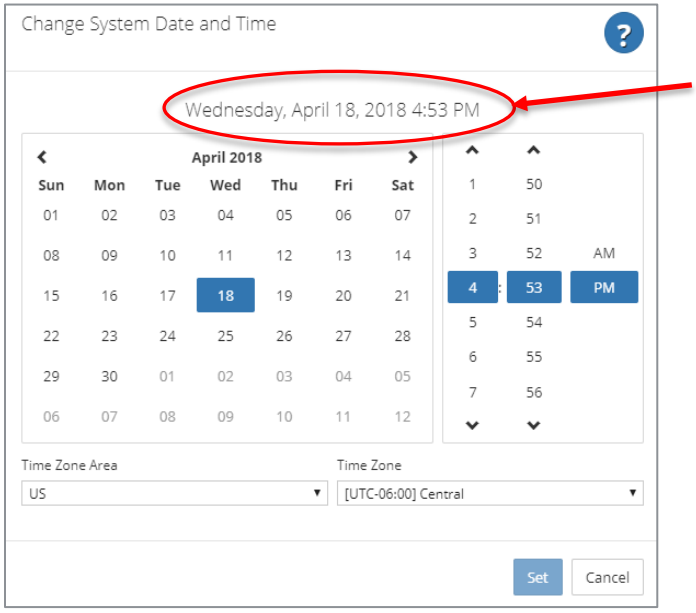
***NOTE**: All modifications to User files are time-stamped and recorded in the controller's history. The history records who logged in by time and date, when the user logged out and any changes that were made. For that reason, it is prudent to keep Usernames and Passwords private.*

3.2.3 Time Configuration



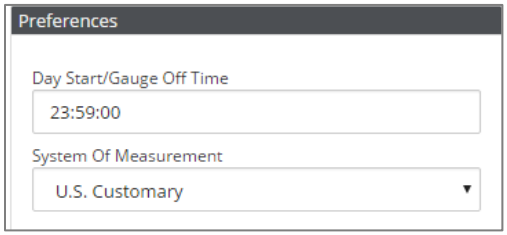
The system's time and date can be set by clicking on the **Current Time**, **Current Date** or **Time Zone** fields. This opens the **Change System Date and Time** window where the time and date can be set. Begin by selecting the correct **Time Zone.** Then select the correct year, month, date, and the time.

For the date to be changed, the current year followed by the current month and date must be selected. Only then will you be able to push the "Set" button. When the date has been properly set, the correct date will appear above the calendar. Also, choose the correct time. Push the "Set" button when the date and time above the calendar is correct.



Must match correct date and time.

3.2.4 Preferences



The **Day Start/Gauge Off Time** is the time when production recording will begin. For example, if the time is set to 7 a.m., production data for the day will be calculated and displayed beginning at 7:00 a.m. and will end at 6:59 a.m. the next day. The **Day Start/Gauge Off Time** is expressed in 24-hour clock format.

The desired units can be selected in the drop-down box labeled **System of Measurement**. Options include **US Customary**, **Metric** and **Canadian**. Canadian units use common units of measurement from the US Customary and Metric systems.

3.2.5 Updating SMARTEN Firmware

The SMARTEN firmware requires periodic updates. Firmware updates can come in the form of an image update or a SMARTEN application update. A flash drive or SD card must be used for image updates. Updating the SMARTEN application can be done using a flash drive or by uploading the update file to the controller.

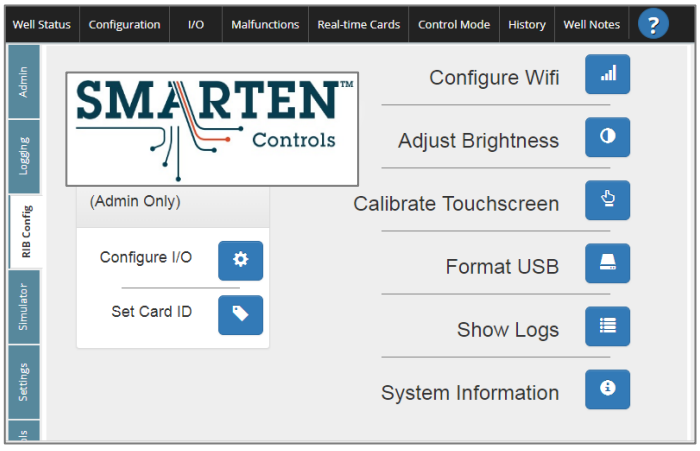
3.2.5.1 Flash Drive Requirements

- Must be USB 2.0
- Must be at least 2 GB in size
- Must be formatted prior to use

3.2.5.2 Formatting the USB Flash Drive

Formatting the USB Flash Drive only needs to be done on a flash drive that is new or has been used for other purposes. Once the flash drive has been formatted it will not need to be formatted again, assuming its sole purpose is to update SMARTEN controllers. The following steps must be done on a SMARTEN or SMARTEN Edge controller to format a flash drive:

1. Insert a USB flash drive 2.0 into one of the USB ports on the SMARTEN Wi-Fi expansion card or on the processor board. It does not matter which USB port is used. Depending on the physical size of the flash drive, the connectors for digital input channels 7 and 8 may need to be removed. On an Edge device, the Wi-Fi cable may need to be unplugged from the USB port on the processor board to perform the update.
2. Go to the Admin page on the display or on a wireless device.
3. Click on the RIB Config tab.



4. Click on the **Format USB** button. This will start the formatting process. A blue banner will appear in the upper right corner of the screen indicating that the formatting process has started.

When complete, a green banner will appear in the upper right corner of the screen:

5. The flash drive can now be removed and loaded with the SMARTEN firmware update files.

3.2.5.3 Updating the SMARTEN Image

On occasion, the system image must be updated. This process **must** be done using a USB flash drive or SD card. The USB flash drive must have the following items in the main/root directory:

- **boot** (folder containing several other update files)
- **SystemUpdate-YYYMMDD.tar** (where YYYYMMDD represents the date stamp)

To update the image:

1. Insert the USB flash drive into the USB port on the small processor board or on the Wi-Fi board (if equipped).
2. Power down the controller.
3. Power up the controller.
4. Image update progress will be visible on the display. Once the update is complete the screen will show “DONE.” This process will take approximately five (5) minutes.
5. After “Done” appears on the display, remove the USB drive. The controller will self-reboot.
6. Allow SMARTEN to complete a fully reboot and verify that the software version on the controller is correct. If not, then repeat the previous steps.

3.2.5.4 Updating the SMARTEN Application

The version of the SMARTEN application can be updated by using the USB port on the small processor board or on the Wi-Fi board (if equipped). To update the SMARTEN software, a file with the name smarten-x.x.x.x.tar (x.x.x.x corresponds to the software version) must be in the main/root directory of the flash drive to be used. The smarten-x.x.x.x.tar file can be obtained from ChampionX personnel or via download. Be sure that the smarten-x.x.x.x.tar file on the flash drive is for the desired software version. Note that the same update file can be used for the SMARTEN controller as can be used for the SMARTEN Edge.

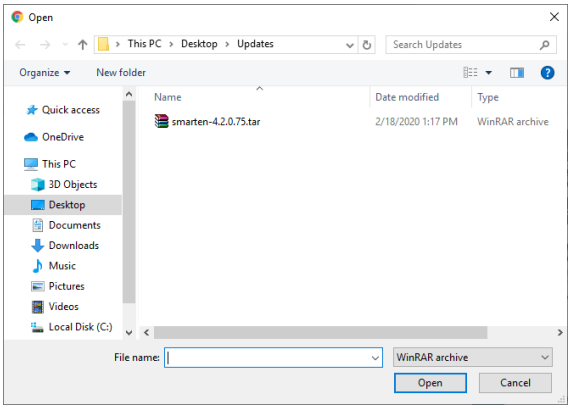
1. With SMARTEN on and running, plug the flash drive into a USB port on the controller.
2. Navigate to the **System Setup** screen (Configuration > System Setup).
3. Push the button in the bottom-right corner of the **System Setup** screen labeled **Select Firmware File…** A window will pop up that says, "The Update file is present on the USB. Do you want to perform the update?" Click **OK**. The new program will now load and SMARTEN will restart with the new software version running. If the update file is not found on the flash drive, a message will appear stating this.

3.2.5.5 Updating the SMARTEN App via File Upload (Locally or Remotely)

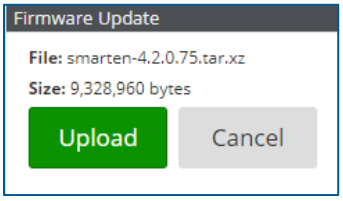
The SMARTEN application can also be updated by uploading the smarten-x.x.x.x.tar file from your computer. This can be done locally, when connected directly to the SMARTEN Wi-Fi or remotely if a high-speed internet connection is available at the well. To do so, the smarten-x.x.x.x.tar file must by present on your computer or a flash drive connected to your computer.

To update the software via file upload:

1. Navigate to the **Configuration, System Setup** screen and click on the **"Select Firmware File…"** button in the bottom-right corner.
2. This will open a window where you can select the "**smarten-x.x.x.x.tar**" file to upload.



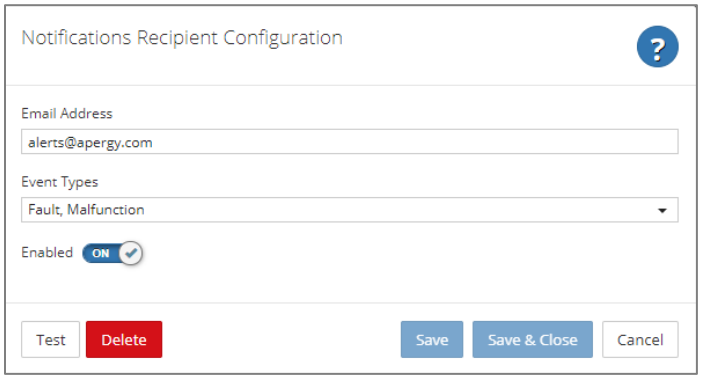
3. Select the appropriate file and click **Open.** The file will then be queued for upload. Click the **Upload** button.



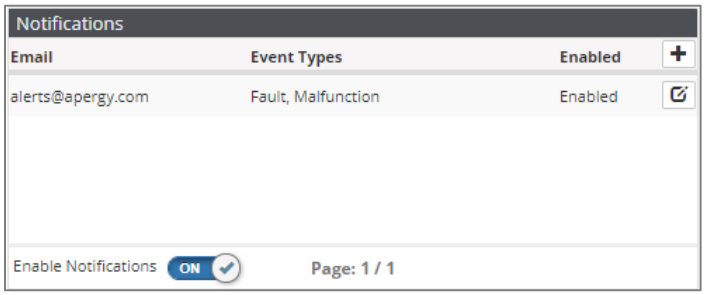
4. After clicking **Upload**, a progress bar will appear that states the percentage of the file upload that has been completed. After the file upload is complete, the controller will reboot during which communication with the controller will be lost if logged in from a computer. Click the **Refresh** button in your browser to login again.

3.2.6 Notifications

Notifications can be sent to the email addresses entered in the **Notifications** box. To add a new email address, click the "**+**" in the upper right corner of the **Notifications** box. A window will open in which an email address can be entered along with the **Event Types**. The **Event Types** that trigger the notification can be customized for each email address. Select the **Event Types** from the drop-down list and click the check mark at the bottom of the list when finished. **Event Types** include **All, Access, Configuration, Fault, Malfunction, Power, Running, Alert**, **Gauge-off** and **Direct CSV Data Logger**. Once the **Event Types** have been selected the **Enable** button can be toggled to the **ON** position to allow the current email address to receive notifications. Click the **Save** button or **Save & Close** to return to the **System Setup** page.

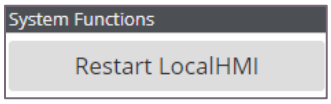


Clicking the **Test** button will send a test notification email to the email address being edited. Clicking the Delete button removes the email address from the notifications list.



To turn on the **Notification** feature, toggle the **Enable Notifications** button to the ON position. When in the OFF position, email notifications will not be sent.

3.2.7 System Functions Restart Local HMI



In the event that the display is unresponsive or does not show current data, the display can be restarted by pushing the Restart Local HMI button. This restarts the display only and not the entire controller. Therefore, control of the well will be maintained while the display restarts.

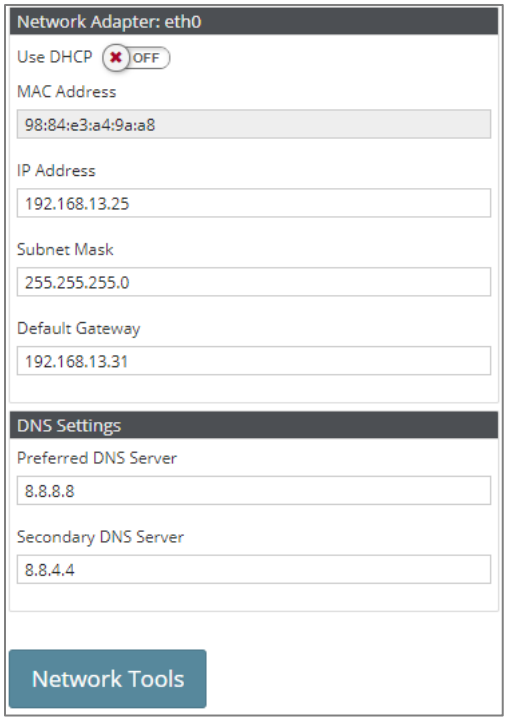
3.3 Network

Network Adapters ETH0

On the **Network** tab the user can configure the Network Adapter for the Ethernet port on the processor board. The factory configured **IP Address** of the Ethernet port is 192.168.13.25, **Subnet Mask** 255.255.255.0, and **Default Gateway** 192.168.13.31. To set the IP Addresses for the network adapters, **Uses DHCP** must be turned off. The default settings are 192.168.0.104, 255.255.255.0 and 192.168.0.1. Note that pushing the **Factory Reset** button will not restore the default network settings.

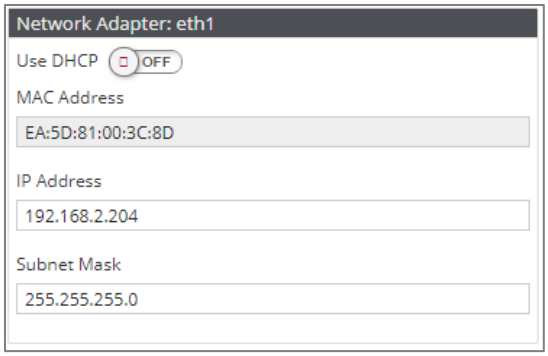
The Ethernet port can be set up to allow to connect directly with a communications network. Before making changes to the network settings please consult your network system's administrator.

For modem configuration (if installed) please see **Appendix D**.



3.3.2 Network Adapter ETH1

A secondary Ethernet port is available on the optional Wi-Fi module for the SMARTEN controller only and is not available for the SMARTEN Edge. This secondary network adapter can be configured to work with LAN devices only.



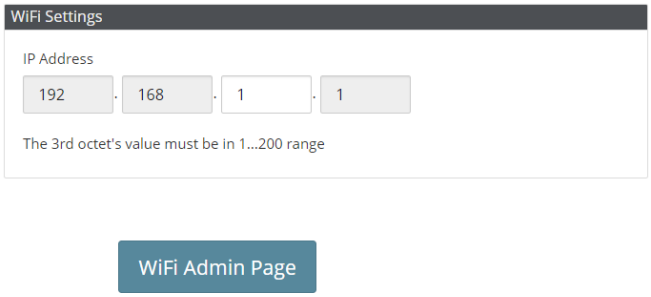
The address 192.168.2.204 is used as the default to communicate with the Toshiba AS3 Inverter.

3.3.3 Wi-Fi Settings

A Wi-Fi module is also available to allow for local wireless connection. Please see the Installation Guide for information regarding installation of the Wi-Fi module.

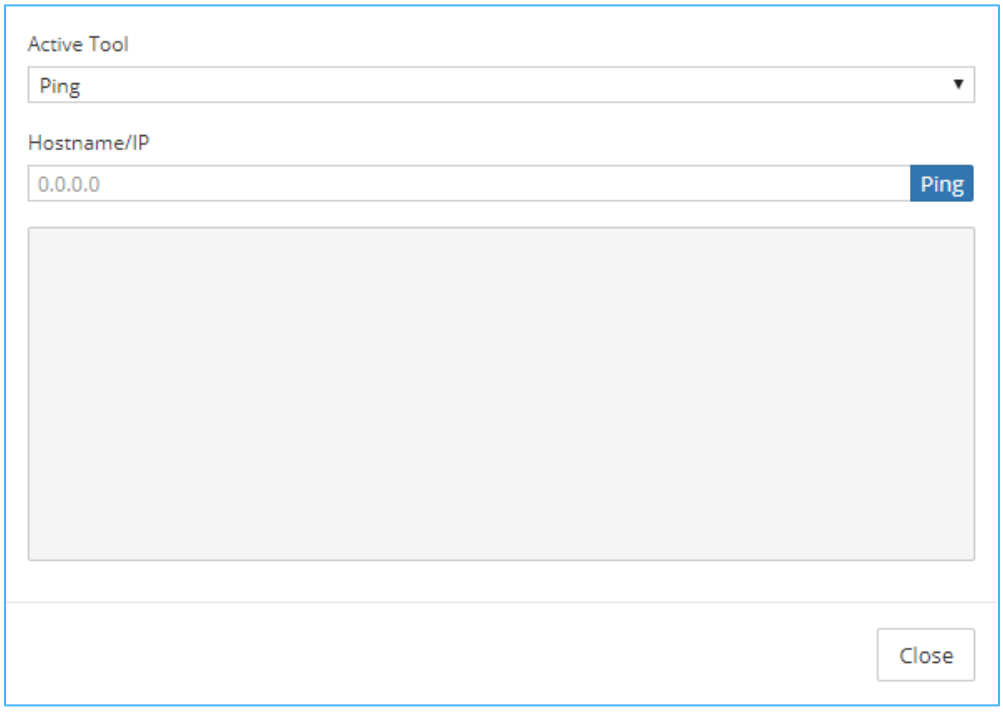
Connecting to SMARTEN using Wi-Fi can be done on a computer or wireless smart device (smart phone or tablet).When within range of SMARTEN Wi-Fi, search nearby Wi-Fi SSIDs for *MyWell* (will possibly have numbers next to the *MyWell*). Your device will prompt you for a password. The default password is A5B4C3D2E1. The password and SSID can be changed by selecting **Wi-Fi Admin Page**.

The IP Address of the Wi-Fi can be configured to not conflict with other network settings. The default IP address of the Wi-Fi module is 192.168.1.1 so to login to SMARTEN onsite via Wi-Fi the address https://192.168.1.1:8080 must be entered. If this address is used by another network device connected to the controller, then communication (remotely and locally via Wi-Fi) may be lost due to an IP conflict. If this is the case, then the third octet of the Wi-Fi IP address can be changed. For example, if the Wi-Fi IP address is changed to 192.168.10.1 then then address https://192.168.10.1:8080 must be used to login to the controller onsite via Wi-Fi.



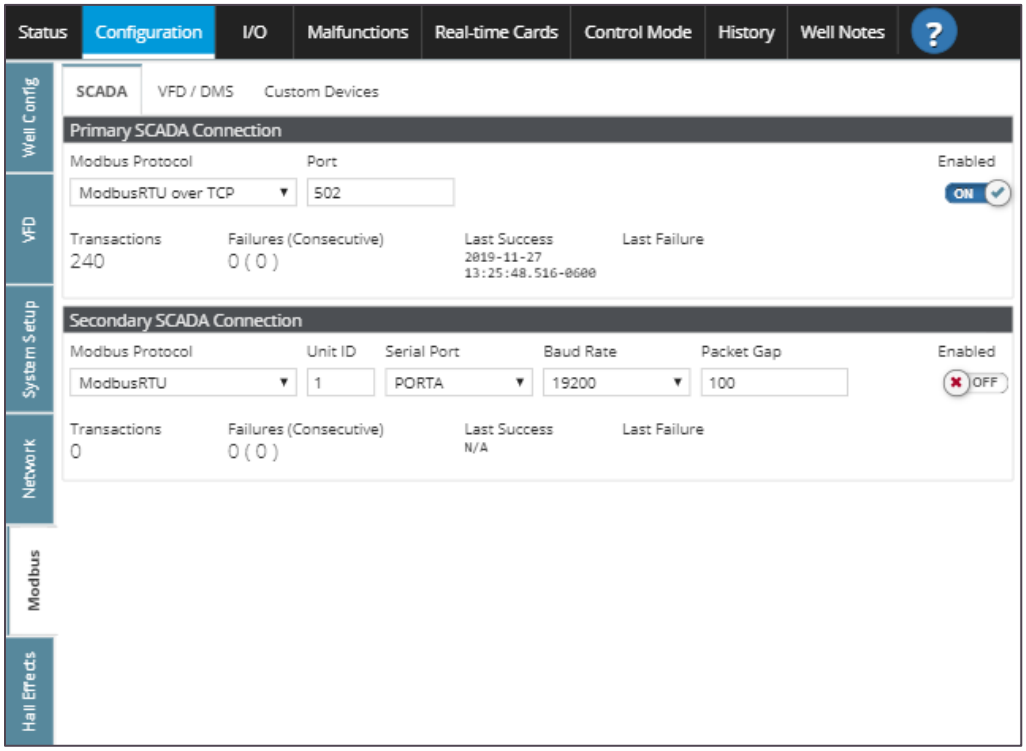
3.3.4 Network Tools

Clicking the **Network Tools** button opens a window where the IP address of other devices connected to the controller can be “pinged”.



3.4 Modbus

3.4.1 Servers



The **Modbus** tab contains three subtabs: **SCADA, VFD/DMS and Custom Devices.** On the **SCADA** tab, the operator can configure the SMARTEN/SMARTEN Edge to send data from the controller to XSPOC or another SCADA host via serial radio, Ethernet radio or cell modem. Select the appropriate protocol from the **Modbus Protocol** field along with the other accompanying settings. The **Enabled** button must be in the ON position to function.

Selecting **Modbus RTU over TCP** from the dropdown menu allows the controller to communicate with the SCADA host using an Ethernet radio or modem. The **Unit ID** and **Port** fields must be configured to match what is entered in the SCADA system for each well. A radio connection or cell modem along with configuration of the SCADA system is required for the controller to communicate with the SCADA host. The **Enabled** button must be in the ON position to function.

Selecting **Modbus RTU** from the dropdown menu allows the controller to communicate with the SCADA host via a serial radio. A **Port** must also be selected. On the SMARTEN controller, the **Serial Ports** are labeled Port A, Port B, Port C and Port D. Note that serial ports A and B have an isolated ground whereas ports C and D are not isolated. On the SMARTEN Edge, the Serial Ports are labeled COMM1, COMM2 and COMM3. See section 2.3.1 of the SMARTEN Installation Guide for information on the board's grounding.

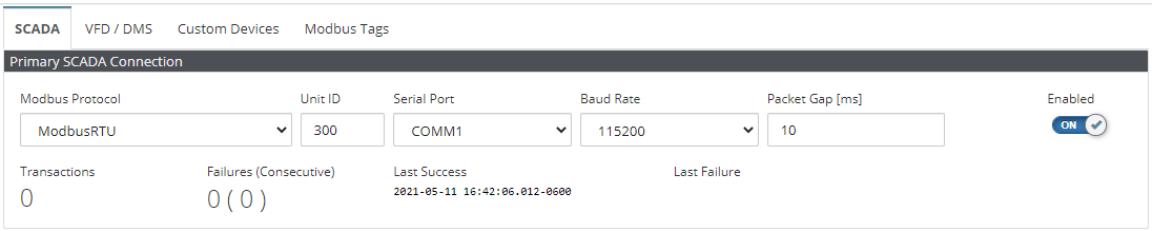
***NOTE**: A modem or Ethernet-based radio system allows for communication with a SCADA system and remote access to the controller's user interface. Remote access to the user interface is not available via serial radio.*

A Secondary Modbus Server can also be configured similarly to the Primary server to be used for another purpose.

On the SMARTEN RIB, the serial ports are located above the DI Channels in the center of the board. The serial ports can be configured for RS-232 or RS-485 communication using the jumpers found above each port. These jumpers are labeled J10 and J14 (Port A), J11 and J15 (Port B), J12 and J16 (Port C) and J13 and J17 (Port D). With the jumper on the left-most pins on both jumpers, the port will be configured for RS-232. With the jumper on the right-most pins on both jumpers, the port will be configured for RS-485.

On the SMARTEN Edge board, the serial ports are located along the top edge of the board on connecter J2. The ports can be configured for RS-232 or RS-485 using the switches found below each port. Note that the ports must also be set up in the SMARTEN software on the **Configuration → Modbus** page prior to use.

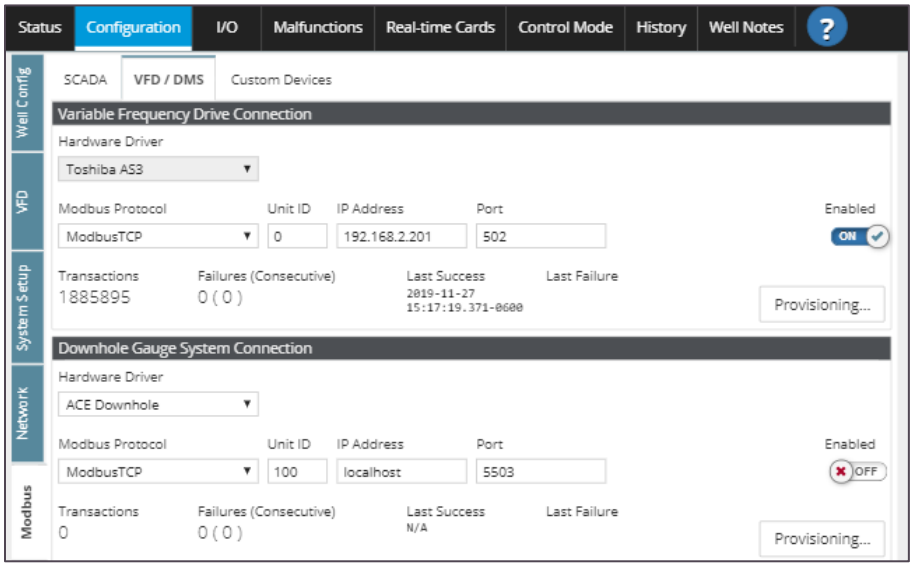
3.4.2 Extended Modbus



Standard Modbus RTU node address are ranged 1-257. However, with SMARTEN Extended Modbus Unit ID values can be extended greater than 257, allowing SMARTEN controllers to be addressed up to 2295 RTU node addresses on the same serial network, while combining existing Modbus RTU devices to be addressed 1-257.

***NOTE**: If changes are made to any of the user-selected variables in the **Modbus Protocol, Unit** ID or **Port** fields and the user attempts to leave the **Communication** section without clicking **Save,** the following error message will appear: "Your changes have not been saved! If you leave this page, your pending changes will be discarded." Click **Go Back** to return to the **Configuration** section and click **Save,** or click **Leave** to void any unsaved changes. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Saving configurations settings…Success!" if the changes have been saved successfully.*

3.4.3 VFD/DMS

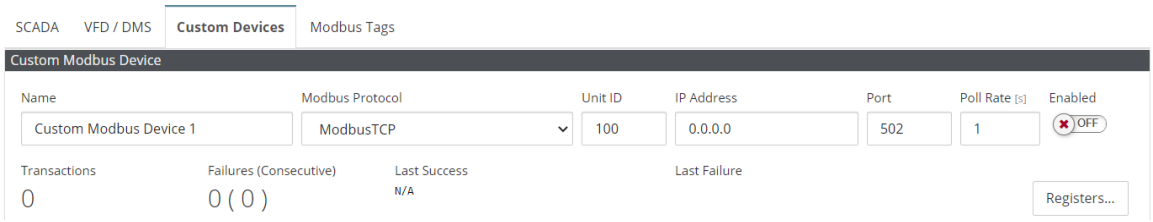


Communication with the VFD inverter can be setup under the Variable Frequency Drive Connection heading. Modbus communication is available for the Fuji FRENIC-MEGA, Toshiba AS3 and Toshiba AS1 inverters. Once set up and enabled the VFD tab will appear along the left side of the screen. See section 3.5 for complete instructions on how to configure communication settings with the VFD.

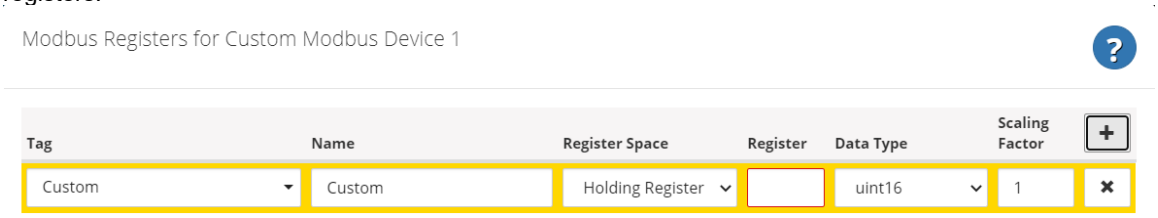
The Downhole Gauge System Client can be setup to work with the ACE downhole device, commonly used for ESP applications.

3.4.4 Custom Devices

Communication with a generic Modbus device can be setup under the **Custom Devices** heading. This allows SMARTEN to read Modbus registers from another Modbus device via serial or Ethernet. If using serial ports, see section 2.3.1 of the SMARTEN Installation Guide for information on the board's grounding.



Select **Registers** to add desired registers. SMARTEN currently supports one device and an unlimited number of registers.



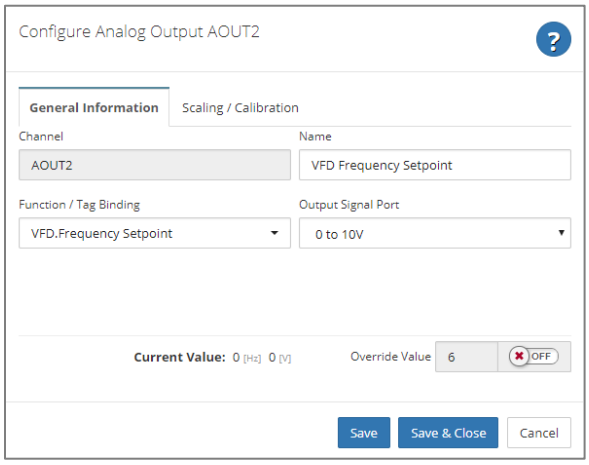
3.5 Variable Frequency Drive (VFD)

SMARTEN can control any drive provided there is an available 0-10 V or 4-20 mA analog input channel on the inverter. SMARTEN can also integrate fully with the Fuji FRENIC-MEGA, the Toshiba AS3 and the Toshiba AS1 drives and communicates with these inverters via Modbus. The sections below explain how to wire and configure the controller and the drive in order to control via analog or Modbus.

3.5.1 VFD Analog Output Setup and Control

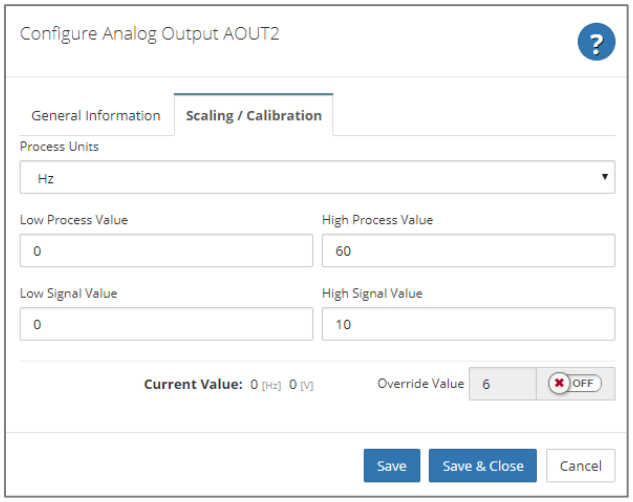
For the variable frequency drive to work in conjunction with the SMARTEN controller, hardware on the SMARTEN RIB must be set up correctly. If the VFD is to be controlled via an **Analog Output** channel, then this channel must be configured to output a 0-10V signal or a 4-20 mA signal. For voltage output, jumper J19 on the SMARTEN RIB must be on the pins labeled 0-10V. For milliamp output, jumper J19 must be on the pins labeled 4-20mA. Once the output signal is set on the board **Analog Output** channel must be configured in SMARTEN. AOUT2 is the default channel for VFD control and is set up as follows:

Name: VFD.FrequencySetpoint
Function/Tag Binding: VFD.Frequency Setpoint and
Output Signal Port: 0 to 10V



If the VFD is to be controlled using the 4-20 mA output, then the **Output Signal Port** must be set to 0 to 20 mA (4-20mA) instead of 0 to 10V.

On the **Scaling/Calibration** tab the default **Process Units** are set as Hz, with the **Low Process Value** and **High Process Value** set as 0 and 60 Hz respectively. The **Low Signal Value** is set at 0 V and the **High Signal Value** is set at 10 V for a voltage output. If the 4-20 mA output is to be used, then the **Low Signal Value** should be set to 4 mA and the **High Signal Value** set to 20 mA.

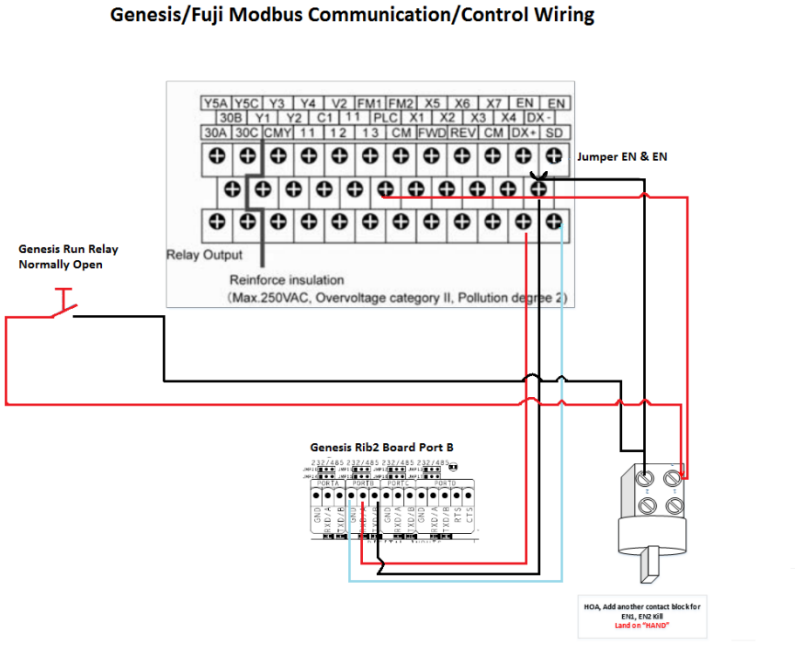


Once all values have been entered, click the **Save** button.

3.5.2 VFD Modbus Setup and Control

SMARTEN can communicate with the **Fuji FRENIC-MEGA** or **Toshiba AS3** inverters via Modbus. This allows for the reading and writing of several configuration and status registers in the inverter through the SMARTEN interface.

3.5.2.1 Fuji FRENIC-MEGA Modbus Wiring



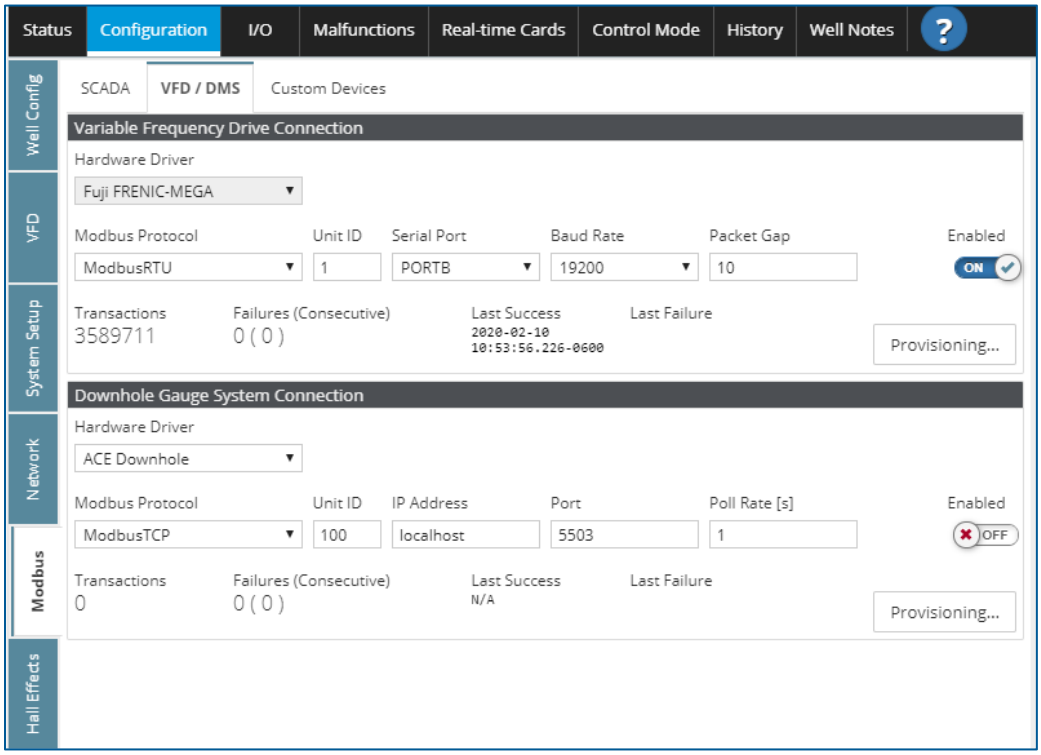
In order to interface with the inverter, the system must be wired up properly. Using the **SPIRIT ISD Modbus Cable**, connect the red wire to the **RXD/A** terminal on **Serial Port B**, the black wire to the **TXD/B** terminal on **Serial Port B**

and the shield wire to **GND** on **Serial Port B**. The cable is to be routed safely out of the controller enclosure, into the drive enclosure and connected to the **DX+** and **DX-** terminals on the inverter. The red wire is to be connect to the **DX+** terminal and the black wire is to be connected to the **DX-** terminal. If necessary, the shield wire is to be connected to the **SD** terminal on the inverter. Whenever possible follow the route of available Panduit or other wires.

Additional wiring must be done between the **HOA**, **Run Relay,** and **Inverter** in order to control properly while in **Hand**, **Auto** and when the **Stop** button is pushed. From one of the terminals on the **Hand** side of the of the **HOA Switch**, run a wire to **EN1** or **EN2** of the **Inverter**. Insert a jumper wire between **EN1** and **EN2**. From the other terminal on the **Hand Side** of the **HOA Switch** run a wire to **COM** of the Run Relay. From **NO** of the run relay, run a wire to **EN1** or **EN2** of the inverter.

See above schematic for details.

3.5.2.2 Fuji FRENIC-MEGA Modbus VFD Client Configuration

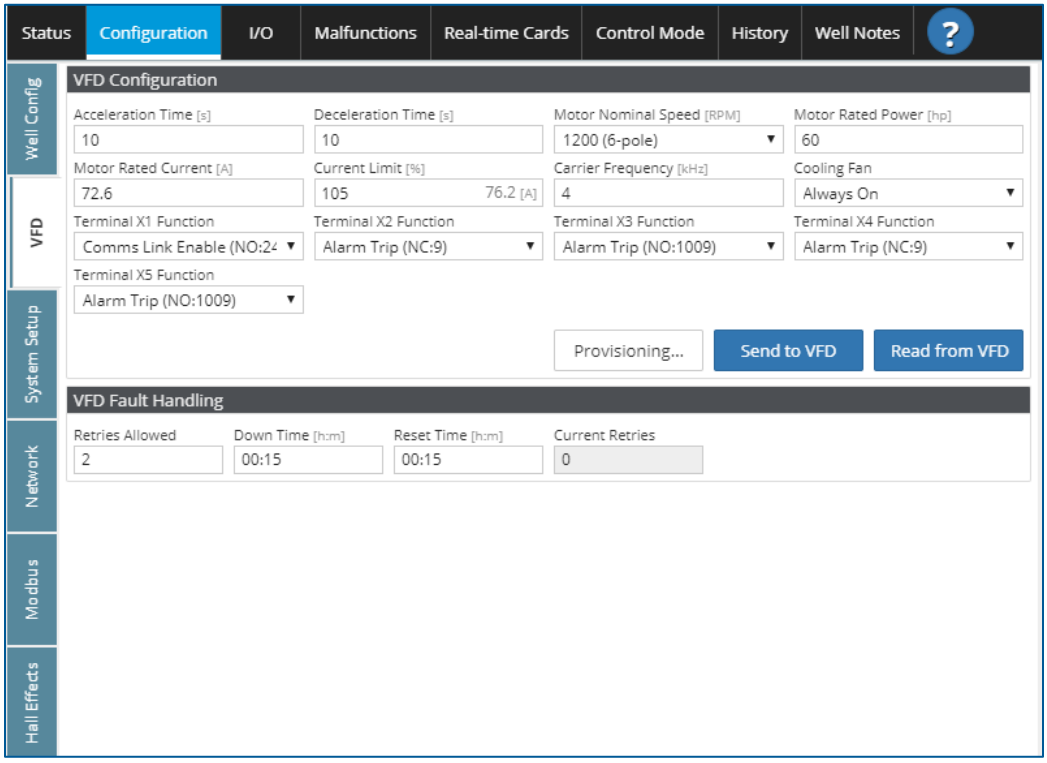


Once the Modbus cable and HOA wiring has been completed, the **Inverter** must be set up in the SMARTEN software. Initial setup of the **VFD Client** can be done on the **Modbus** subtab of the **Configuration** page or on the **VFD Config** subtab on the **Control Mode** page. Under the **Variable Frequency Drive Client** heading, select the correct inverter type from the **Hardware Driver** drop-down box. Select **Fuji FRENIC-MEGA** as the **Hardware Driver**, **ModbusRTU** as the **Modbus Protocol**, **UnitID** of **1**, **Serial PortB, Baud Rate 19200** and **Packet Gap 10.** Note that for Serial Port B to be set to RS 485, jumpers J11 and J15 must be on the rightmost pins. (Note that Serial Ports A and B have isolated grounds.) After the **VFD Client** has been configured, turn the **Enabled** button to the **On** position. Once enabled, the **VFD** tab will appear along the left side of the screen. The same configuration items can also be found on the **VFD Config** subtab of the **Control Mode** page.

As SMARTEN communicates with the inverter, successful transactions will be tallied under **Transactions** with the time, date, milliseconds and TZ offset. Communication failures are also tallied under the **Failures** heading.

Clicking the **Provisioning…** button opens a window that allows for setting up the drive's parameters required for Modbus communication and any others the user wishes to set. Clicking the "+" in this window requires the user to provide a Name, Address and Value for each register.

3.5.2.3 FRENIC-MEGA VFD Configuration



Under the **VFD Configuration** heading, several configuration registers can be viewed and edited including **Acceleration Time (s), Deceleration Time (s), Motor Nominal Speed (RPM), Motor Rated Power (hp), Motor Rated Current (A), Motor OL Current (A), Current Limit (%), Min Frequency (Hz), Max Frequency (Hz), Carrier Frequency (kHz), Cooling Fan (on/cycle)** and **Terminal Functions X1 – X5**. The defaults for these fields are configured to work with the **Fuji FRENIC-MEGA** inverter. Definitions for all configuration registers are below:

- **Acceleration Time (s):** the duration of the inverter's acceleration to reach maximum frequency starting from 0 Hz. Speed increase changes from values other than 0 Hz to the maximum frequency are scaled accordingly.
- **Deceleration Time (s):** the duration of the inverter's deceleration to reach 0 Hz starting from maximum frequency. Speed decrease changes from values other than the maximum frequency to 0 Hz are scaled accordingly.
- **Motor Nominal Speed (RPM):** the motor's nameplate speed and/or number of poles. Motor Rated Power is the motor's nameplate power rating.
- **Motor Rated Current (A):** the motor's nameplate amperage rating.
- **Motor OL Current (A):** the maximum permitted current before tripping a fault
- **Current Limit (%):** the desired threshold for the inverter's current limiter, as a percentage of the motor's rated current. The resulting amperage is displayed for your convenience.
- **Carrier Frequency (kHz):** Adjusts an audible noise generated by the motor or electromagnetic noise from the inverter itself. Adjusts the leakage current from the main output (secondary) wirings.
- **Cooling Fan Control:** control of the inverter's cooling fan can be set to be Always On or Cycle on and off with the inverter.
- **Terminal Function:** allows for the selection of the function for the terminals on the VFD. Refer to the VFD's documentation for terminal function uses and behaviors.

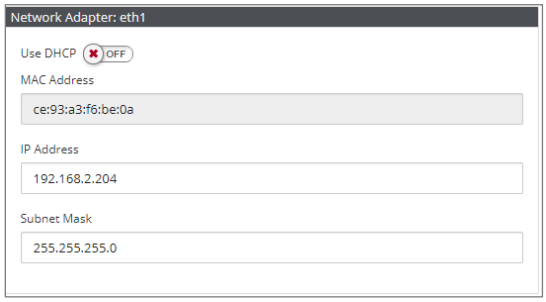
Edit these fields as needed and click the **Save** button when all changes have been made. Pushing the **Send to VFD button** will program the **VFD** by writing the current configuration settings to the device. Note that this is automatically done when saving any VFD configuration changes. For the changes to be sent to the **VFD** the well cannot be running. Parameters that can be viewed under **VFD Fault Handling** include **Retries Allowed, Down Time (hh:mm), Rest Time (hh:mm)** and **Current Retries** counter. Definitions for each of these items is below:

- **Retries Allowed:** the maximum number of times to allow the well to restart after being stopped/idled due to faults reported from the VFD. If the VFD continues to report faults after this number of restarts occurs, then the well will be halted and will not automatically restart.
- **Down Time:** the duration that the well will be off/idle in response to the VFD reporting a fault. After this time expires the well will be restarted, unless the **Retries Allowed** has been exceeded. During the fault **Down Time**, the **Well State** will display the violating VFD fault code along with the **Idle** status.
- **Reset Time:** the duration during which if the VFD has not reported any faults, then the Current Retries count is automatically reset back to zero.
- **Current Retries:** the current number of well restart attempts since going off/idle due to a fault reported by the VFD. If this count reaches the allowed number of retries and a VFD fault occurs again, the well will enter a **Malfunction** state.

3.5.2.4 Toshiba AS3 Modbus Wiring and Ethernet Setup

Modbus communication between SMARTEN and the Toshiba AS3 is done via Ethernet connection using the **ModbusTCP** protocol. As of this release, serial communication between the controller and the AS3 is not available. An Ethernet cable runs between the Ethernet port found on the SMARTEN Wi-Fi board and Eth1 of the Toshiba AS3. The Ethernet port on the SMARTEN Wi-Fi board must be configured as Eth1 on the **Configuration → Network** page of SMARTEN (s) as follows:

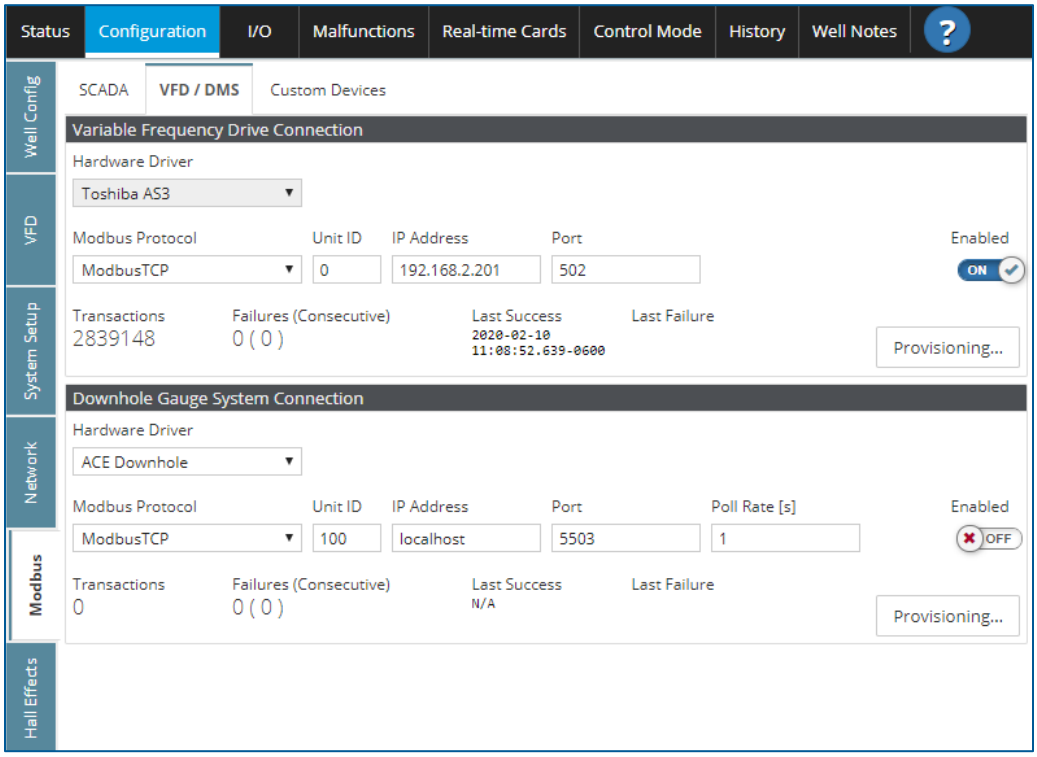
Use DHCP: Off
IP Address: 192.168.2.204
Subnet Mask: 255.255.255.0



***NOTE**: Integration with the Toshiba AS3 is limited to the SMARTEN controller since the SMARTEN Edge contains only one Ethernet port.*

On the **Configuration→Modbus** page the **Variable Frequency Drive Client** must be set up as follows:

Hardware Driver: Toshiba AS3
Modbus Protocol: ModbusTCP
Unit ID: 0
IP Address: 192.168.2.201
Port: 502
Enabled: ON



In the Toshiba AS3 the **Embedded Ethernet Settings** must be configured to communicate with the SMARTEN controller. Follow the steps below to establish communication between the controller and the inverter.

From Standard Mode screen on the Toshiba AS3 keypad:

1. Push [ESC] key → Select "3 Guidance Function"

2. Push [OK] key → Select "3.1 Embedded Ethernet"

3. Edit Ethernet Settings as follows:

   IP Setting = Fixed
   IP Address = 192.168.2.201
   Mask: 255.255.255.0
   Gateway: 192.168.2.204

4. Return to the Standard Mode screen then follow the steps above to verify settings.

5. Values for IP address monitor, Mask monitor, and Gateway monitor should now match what was entered in step 3.

6. Change CMOd in the drive to 2: Embedded Ethernet

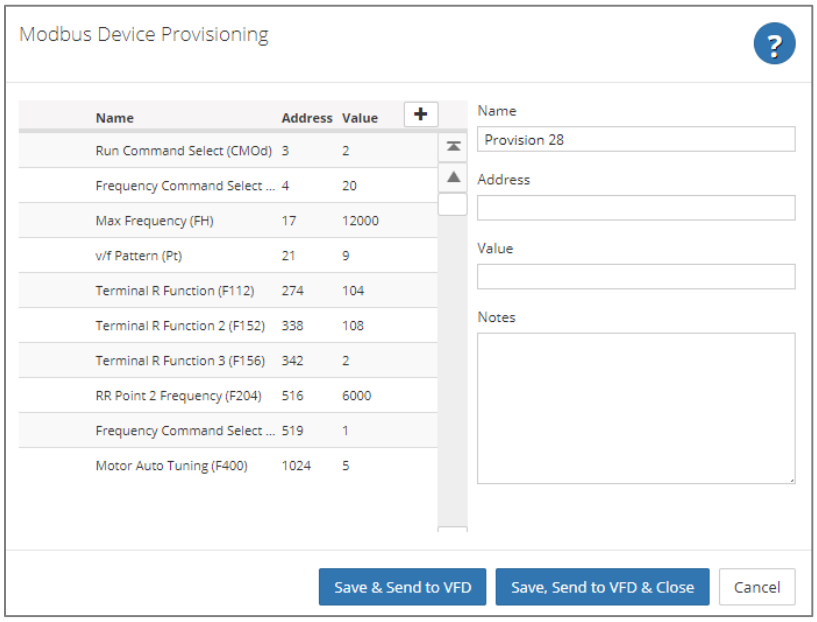
7. Change FMOd in the drive to 20: Embedded Ethernet

8. Confirm AUE – Eco-standby power setting is set to 0.

9. Once all settings have been saved, reboot the drive and communication to the controller will commence.

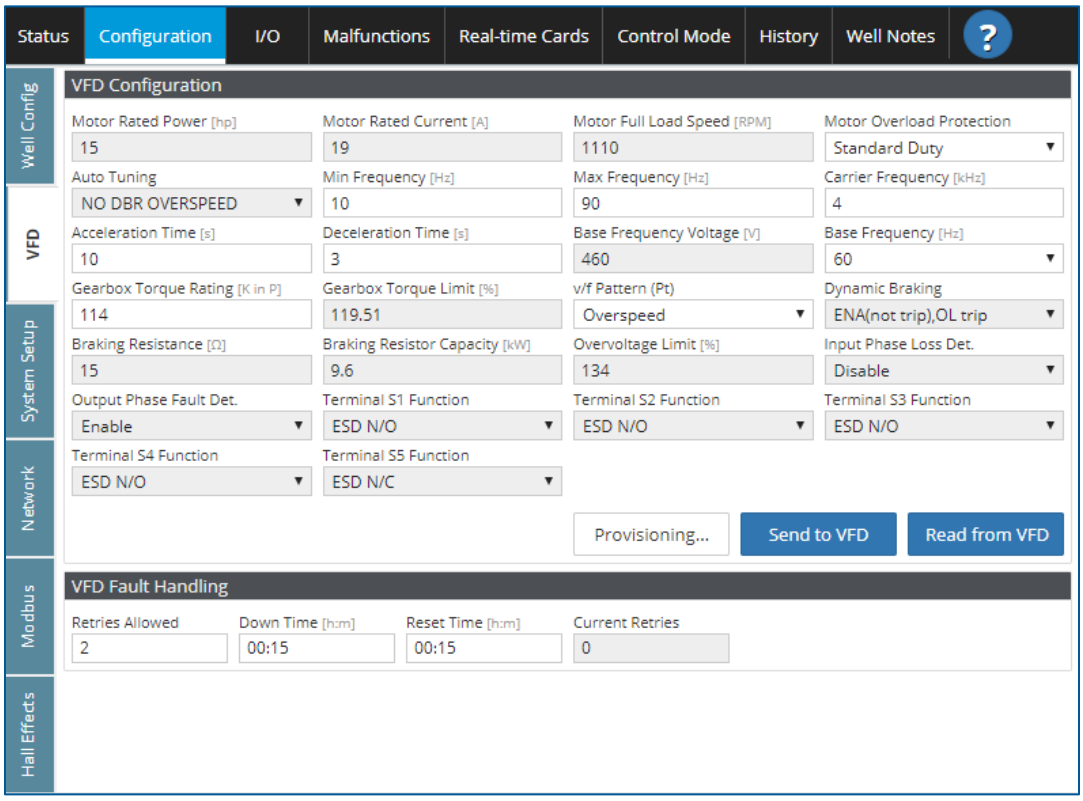
As SMARTEN communicates with the inverter successful transactions will be tallied under **Transactions** with the time, date, milliseconds and TZ offset. Communication failures are also tallied under the **Failures** heading.

Clicking the **Provisioning…** button opens a window that allows for setting up the drive's parameters required for Modbus communication and any others the user wishes to set. Clicking the "+" in this window requires the user to provide a Name, Address and Value for each register.



Clicking Save & Send to VFD will save changes made to the **Modbus Device Provisioning** table in the SMARTEN database and will send them to the VFD only when the drive is idle. If the well is running, an error message will be shown in the upper right corner stating that register values could not be written to the drive. At a later time, with the well idle, pushing the Send to VFD button on the Configuration → VFD page will send the register values to the inverter.

3.5.2.5 Toshiba AS3 Configuration



Under the **VFD Configuration** heading several configuration registers can be viewed and edited. These registers are listed and defined below:

- **Motor Rated Power (hp):** the motor's nameplate HP power rating.
- **Motor Rated Current (A):** the motor's nameplate amperage rating.
- **Motor Full Load Speed (RPM):** the motor's nameplate RPM.
- **Motor Overload Protection:** the motor overload protection based upon motor type
- **Min Frequency (Hz):** the minimum frequency of the inverter for all frequency commands
- **Max Frequency (Hz):** the maximum frequency of the inverter for all frequency commands
- **Carrier Frequency (Hz):** the frequency at which the output transistors are switched
- **Acceleration Time (s):** the duration of the inverter's acceleration to reach maximum frequency starting from 0 Hz. Speed increase changes from values other than 0 Hz to the maximum frequency are scaled accordingly.
- **Deceleration Time (s):** the duration of the inverter's deceleration to reach 0 Hz starting from maximum frequency. Speed decrease changes from values other than the maximum frequency to 0 Hz are scaled accordingly.
- **Base Frequency (Hz):** the motor's nameplate rated frequency
- **Gearbox Torque Rating (K in-lb)**: the gearbox rating as listed on the pumping unit's nameplate.
- **Gearbox Torque Limit (%)**: the permitted gearbox load as a percentage of Motor Rated Torque
- **Dynamic Braking:** prevents DC Bus Voltage from exceeding trip levels using a Dynamic Braking Resistor (DBR)
- **Braking Resistance (Ohms):** Dynamic Braking Resistor (DBR) rated Ohms
- **Braking Resistor Capacity (kW):** the Dynamic Braking Resistor (DBR) rated kW
- **Terminal Functions S1-S5:** allows for the selection of the function for the terminals on the VFD. Refer to the VFD's documentation for terminal function uses and behaviors.

Parameters that can be viewed under **VFD Fault Handling** include **Retries Allowed, Down Time (hh:mm), Rest Time (hh:mm)** and **Current Retries** counter. Definitions for each of these items is below:

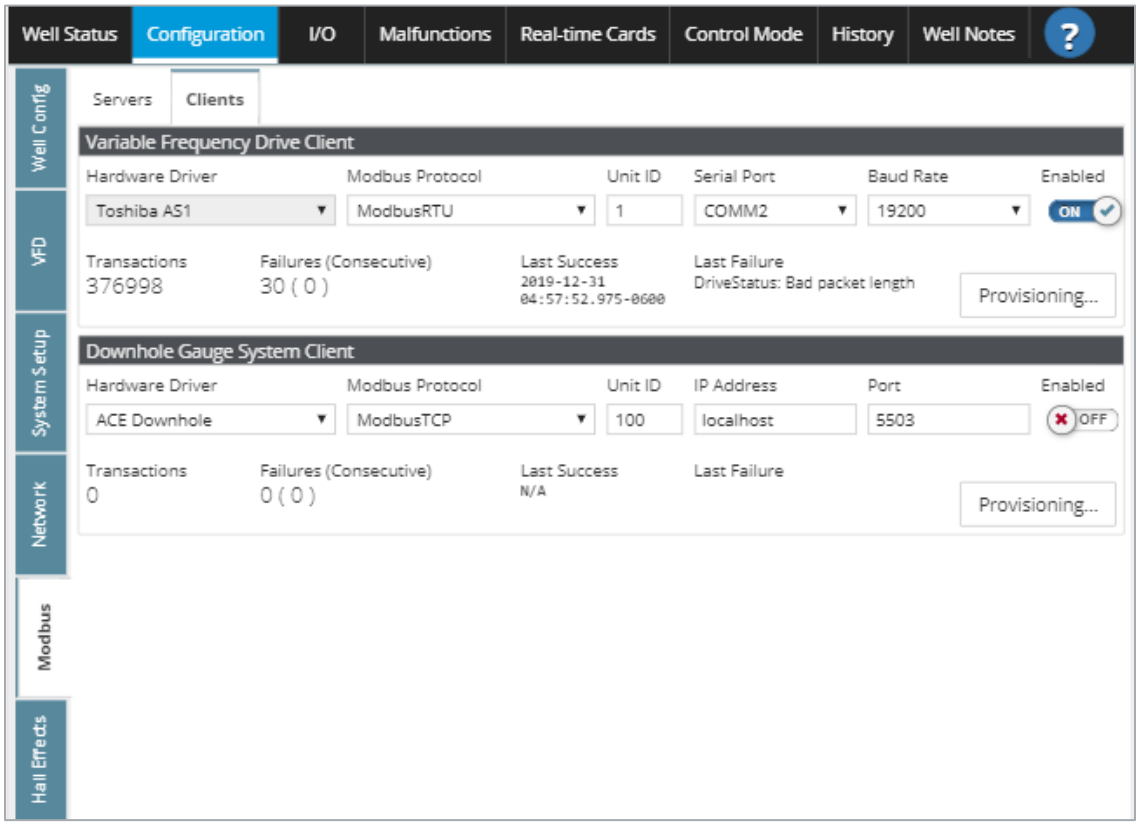
- **Retries Allowed:** the maximum number of times to allow the well to restart after being stopped/idled due to faults reported from the VFD. If the VFD continues to report faults after this number of restarts occurs, then the well will be halted and will not automatically restart.
- **Down Time:** the duration that the well will be off/idle in response to the VFD reporting a fault. After this time expires the well will be restarted, unless the **Retries Allowed** has been exceeded. During the fault **Down Time**, the **Well State** will display the violating VFD fault code along with the **Idle** status.
- **Reset Time:** the duration during which if the VFD has not reported any faults, then the Current Retries count is automatically reset back to zero.
- **Current Retries:** the current number of well restart attempts since going off/idle due to a fault reported by the VFD. If this count reaches the allowed number of retries and a VFD fault occurs again, the well will enter a **Malfunction** state.

3.5.2.6 Toshiba AS1 Modbus VFD Client Configuration

Once all wiring is complete, the **AS1 Inverter** must be configured to communicate with the SMARTEN Edge. To do so, the following registers must be set in the drive:

F802 (Inverter Number) = 1
F827 (RS485(1) Protocol) = 0
F829 (Protocol Selection 4-wire RS 485) = 1

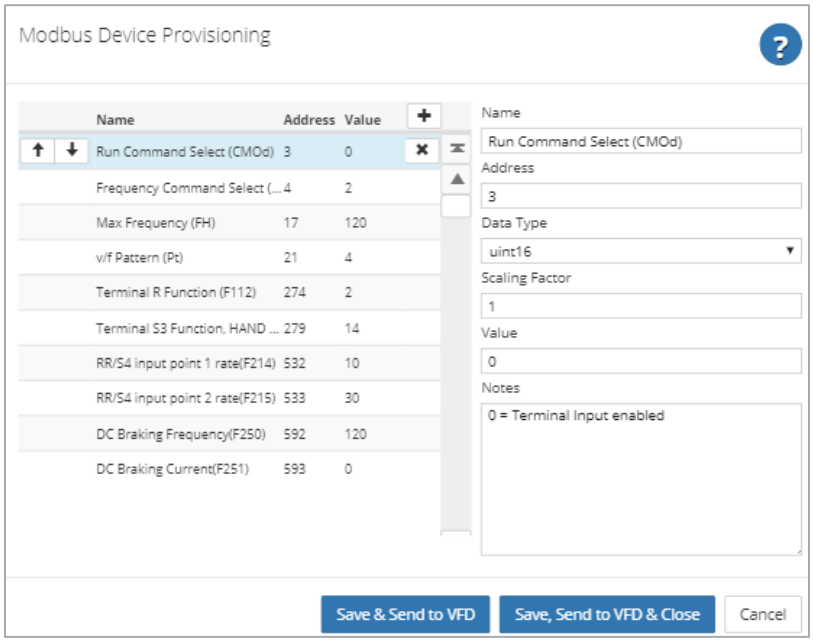
Once these registers have been set, remove power from the inverter long enough for the VFD display to go blank. Once that is complete, power may be restored.



Initial setup of the **VFD Client** in the controller can be done on the **Modbus → Client** subtab of the **Configuration** page or on the **VFD Config** subtab on the **Control Mode** page. Under the **Variable Frequency Drive Client** heading, select the correct inverter type from the **Hardware Driver** drop-down box. In this case, select **Toshiba AS1** as the **Hardware Driver**, **ModbusRTU** as the **Modbus Protocol**, **UnitID** of **1**, **COMM2** (or COMM1) for the **Serial Port** and **Baud Rate 19200**. Note that the COMM port must be set to RS-485. This is done with the switch found just below the serial ports. After the **VFD Client** has been configured, turn the **Enabled** button to the **On** position. Once enabled, the **VFD** tab will appear along the left side of the screen.

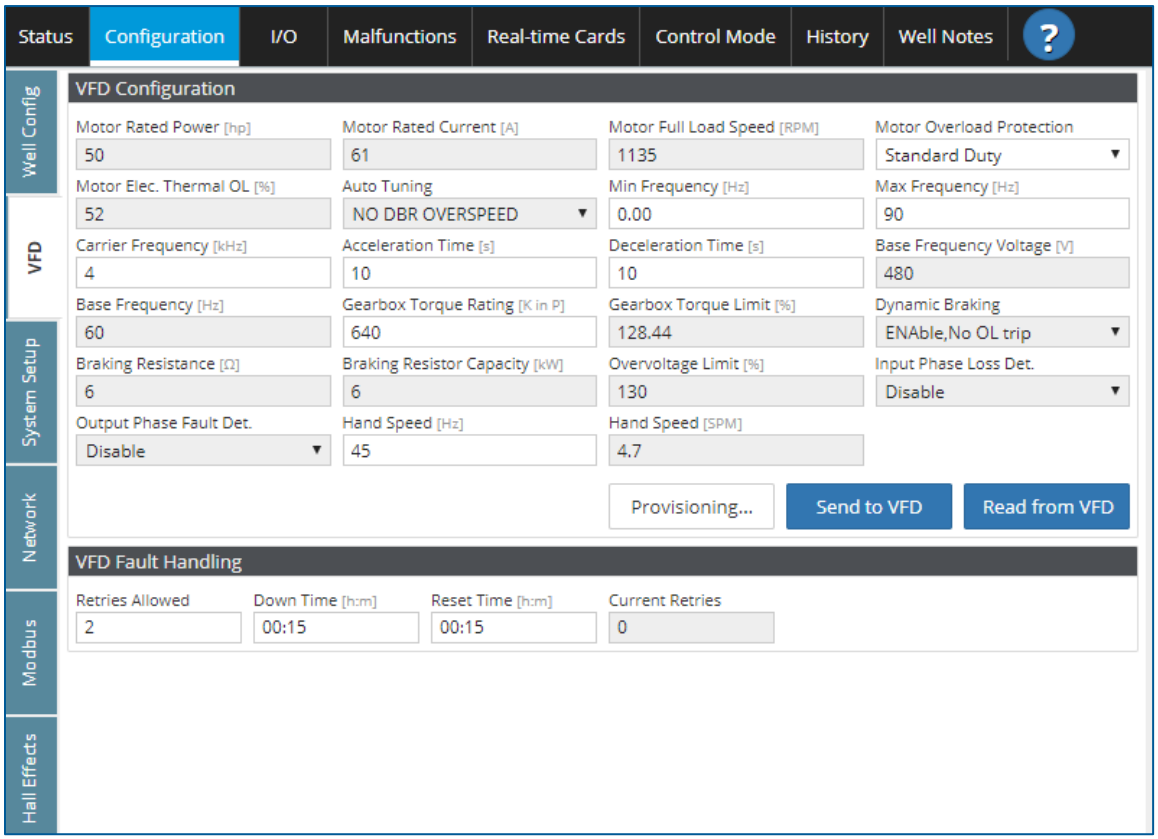
As the SMARTEN Edge communicates with the inverter, successful transactions will be tallied under **Transactions** with the time, date, milliseconds and TZ offset. Communication failures are also tallied under the **Failures** heading.

Clicking the **Provisioning…** button opens a window that allows for configuration of additional drive parameters. Clicking the "+" in this window requires the user to provide a Name, Address and Value for each register. Clicking an existing register allows for editing of all the register's attributes.



Clicking Save & Send to VFD will save changes made to the Modbus Device Provisioning table in the SMARTEN database and will send them to the VFD only if the drive is idle. If the well is running, an error message will be shown in the upper right corner stating that register values could not be written to the drive. At a later time, with the well idle, pushing the **Send to VFD** button on the Configuration → VFD page will send the register values to the inverter.

3.5.2.7 Toshiba AS1 Integration



Under the **VFD Configuration** heading, several configuration registers can be viewed and edited. These registers are listed and defined below:

- **Motor Rated Power (hp):** the motor's nameplate HP power rating.
- **Motor Rated Current (A):** the motor's nameplate amperage rating.
- **Motor Full Load Speed (RPM):** the motor's nameplate RPM.
- **Motor Overload Protection:** the motor overload protection based upon motor type
- **Motor Elec. Thermal OL (%):** the motor overload protection as a percentage of inverter rated current (Auto Calculated)
- **Auto Tuning:** allows the drive to measure the impedance of a motor in order to determine current and voltage relationships at different speeds. This can be enabled/disabled.
- **Min Frequency (Hz):** the minimum frequency of the inverter for all frequency commands
- **Max Frequency (Hz):** the maximum frequency of the inverter for all frequency commands
- **Carrier Frequency (Hz):** the frequency at which the output transistors are switched
- **Acceleration Time (s):** the duration of the inverter's acceleration to reach maximum frequency starting from 0 Hz. Speed increase changes from values other than 0 Hz to the maximum frequency are scaled accordingly.
- **Deceleration Time (s):** the duration of the inverter's deceleration to reach 0 Hz starting from maximum frequency. Speed decrease changes from values other than the maximum frequency to 0 Hz are scaled accordingly.
- **Base Frequency Voltage (V):** the motor's nameplate rated voltage
- **Base Frequency (Hz):** the motor's nameplate rated frequency
- **Gearbox Torque Rating (K in-lb)**: the gearbox rating as listed on the pumping unit's nameplate.
- **Gearbox Torque Limit (%)**: the permitted gearbox load as a percentage of Motor Rated Torque
- **Dynamic Braking:** prevents DC Bus Voltage from exceeding trip levels using a Dynamic Braking Resistor (DBR)

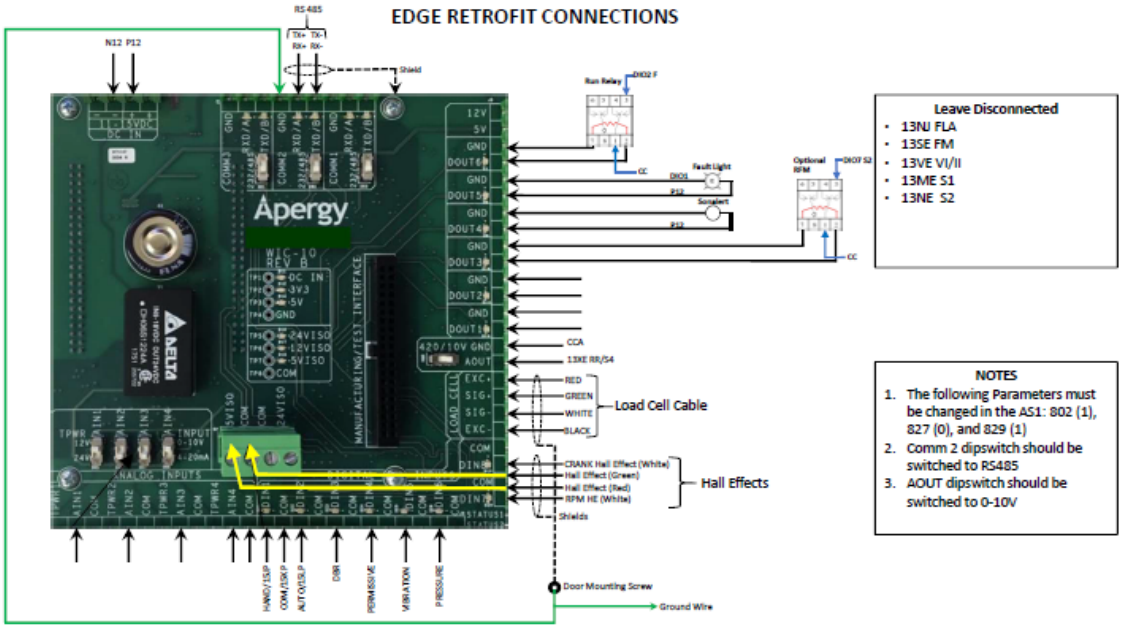
- **Braking Resistance (Ohms):** Dynamic Braking Resistor (DBR) rated Ohms
- **Braking Resistor Capacity (kW):** the Dynamic Braking Resistor (DBR) rated kW
- **Overvoltage Limit (%):** a percentage of DC Bus rated voltage at which Over Voltage Limit operation begins
- **Input Phase Loss Detection**: detects the loss of an incoming leg of three-phase power
- **Output Phase Fault Detection:** identifies the loss of a three-phase power leg between the drive and the motor
- **Hand Speed (Hz):** the operating speed with the HOA switch in Hand measured in Hz
- **Hand Speed (SPM):** the operating speed with the HOA switch in Hand measured in SPM

Parameters that can be viewed under **VFD Fault Handling** include **Retries Allowed, Down Time (hh:mm), Reset Time (hh:mm)** and **Current Retries** counter. Definitions for each of these items is below:

- **Retries Allowed:** the maximum number of times to allow the well to restart after being stopped/idled due to faults reported from the VFD. If the VFD continues to report faults after this number of restarts occurs, then the well will be halted and will not automatically restart.
- **Down Time:** the duration that the well will be off/idle in response to the VFD reporting a fault. After this time expires the well will be restarted, unless the **Retries Allowed** has been exceeded. During the fault **Down Time**, the **Well State** will display the violating VFD fault code along with the **Idle** status.
- **Reset Time:** the duration during which if the VFD has not reported any faults, then the Current Retries count is automatically reset back to zero.
- **Current Retries:** the current number of well restart attempts since going off/idle due to a fault reported by the VFD. If this count reaches the allowed number of retries and a VFD fault occurs again, the well will enter a **Malfunction** state.

3.5.2.8 Toshiba AS1 Integration with the SMARTEN Edge

The SMARTEN Edge Retrofit Kit can be integrated with the Toshiba AS1 inverter. Once installed, the SMARTEN Edge can communicate with the AS1 serially via Modbus. Wiring of the SMARTEN Edge including the serial connection to the AS1 inverter can be seen below. Note: Installation instructions for the SMARTEN Edge Retrofit Kit will be available soon.



3.6 Hall Effects

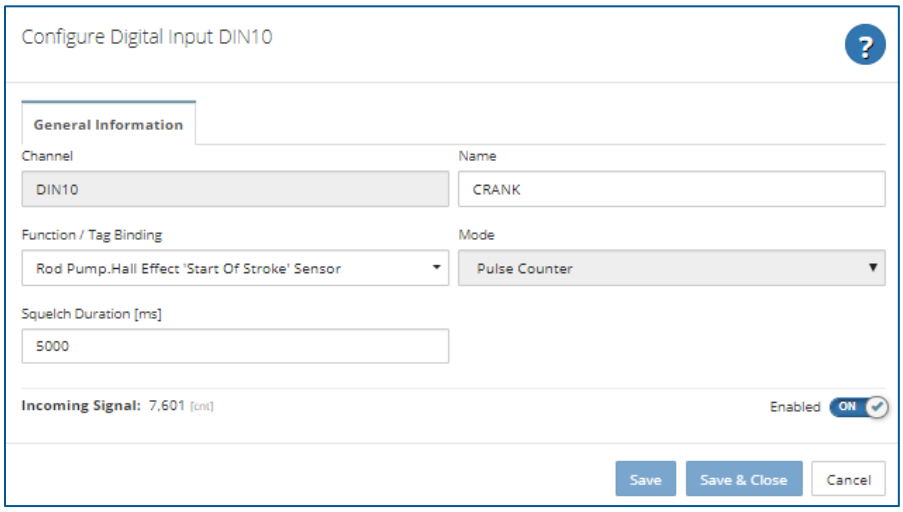
In order for position data to be acquired, a position measurement method must be chosen. Choices include Analog (Inclinometer, Accelerometer or Laser) or Hall Effects. Stroke Position from the Inclinometer is defaulted to AIN8 on SMARTEN and AIN4 on SMARTEN Edge. If Hall Effects is to be used for position, RodPump.StrokePosition cannot be assigned to an analog input channel.

3.6.1 Hall Effects Digital Input Configuration

***NOTE**: In order to use Hall Effects with a SMARTEN controller, MCU V29 or greater must be used.*

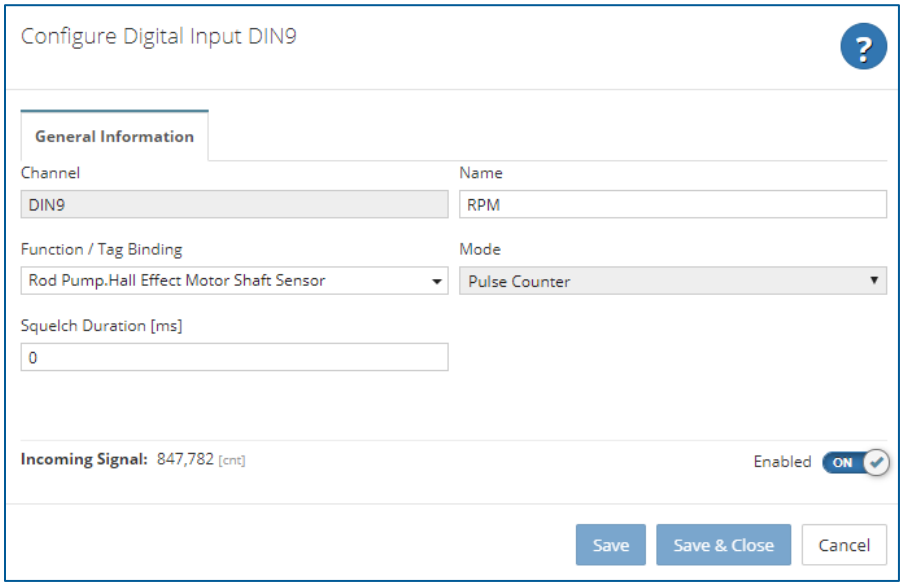
On the I/O tab, select the DIN channel that is to be used for the crank sensor. In the window that opens enter "Crank Sensor" as the **Name** and then RodPump.Hall Effect "Start Of Stroke" Sensor for **Function/Tag Binding**. The **Mode** will automatically set to Pulse Counter. The channel must then be enabled by toggling the Enabled switch to the ON position. The **Squelch Duration** (ms) must also be set. This is the duration during which the controller will "ignore" any other incoming pulses.

Clicking Save & Close will save all changes and will return to the I/O page.



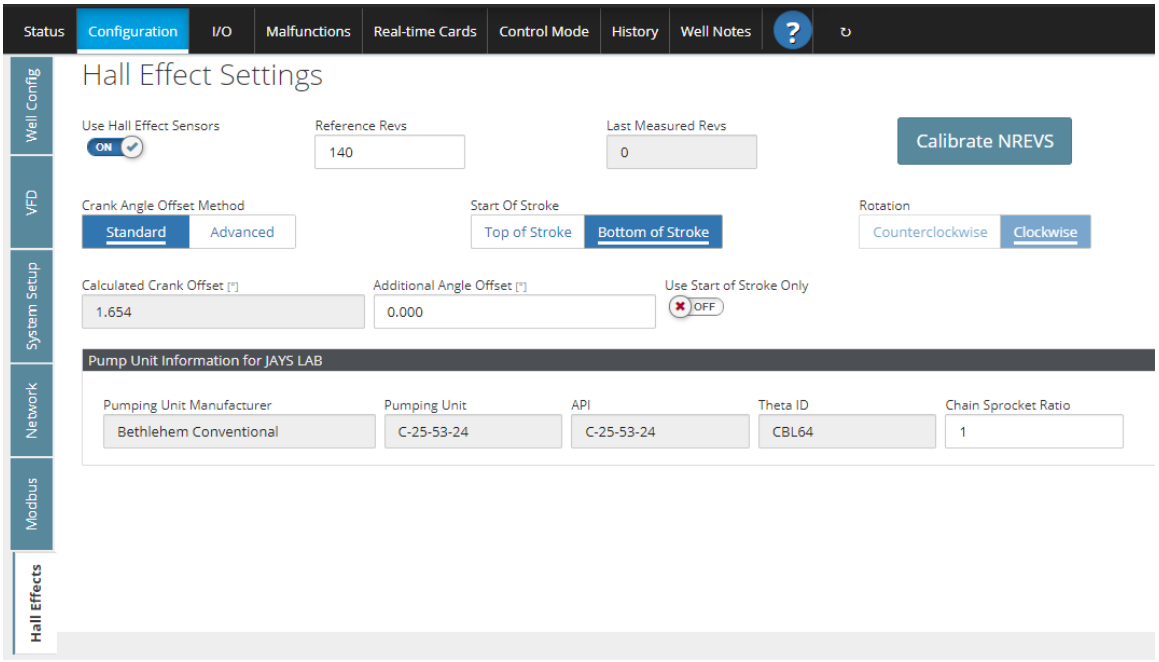
The same steps must be repeated for the motor sensor. Select the DIN channel to be used as motor sensor. In the window that opens, enter "RPM Sensor" as the name and then select "Rod Pump.Hall Effect Motor Shaft Sensor" for **Function/Tag Binding**. The Mode will automatically be set to Pulse Counter. The channel must then be enabled by toggling the Enabled switch to the ON position. The **Squelch Duration** for the Motor Shaft sensor can be 0.

Clicking Save & Close will save all changes and will return to the I/O page.



With the pumping unit running the crank sensor should increment once per stroke at the top or bottom of the stroke – wherever the Start of Stroke sensor has been installed. The motor sensor should increment at a much higher rate (approximately 1200 counts per minute assuming the motor is running at 60 Hz.) If either of the DIN channels do not increment, adjustments of the sensor or magnet may be necessary to ensure that the sensor is aligned correctly with the magnet.

3.6.2 Enabling Hall Effects for Position



***NOTE**: In order for Hall Effects to work correctly for position, the correct **Pumping Unit Manufacturer** and **Pumping Unit** must be selected on the Well Config page. Click the Save button prior to moving on to the next step.*

On the **Hall Effects** sub-tab of the **Configuration** page, toggle the **Use Hall Effect Sensors** button to the ON position. Select **Standard** or **Advanced** as the **Crank Angle Offset Method**.

***NOTE**: Standard mode, requires that the unit be stopped at the exact Top, or Bottom, of stroke for Dynagraph Card accuracy. It uses all input Data from the Pumping Unit Library to determine the correct Calculated Crank Offset. An Additional Angle offset may be entered for adjustments in this mode.*

Advanced mode, allows the user stop the unit in virtually any position while maintaining Dynagraph card accuracy. It requires the user to Measure and enter a Measured Angle Offset and together, with the other pumping unit data, will determine the correct Calculated Crank Offset.

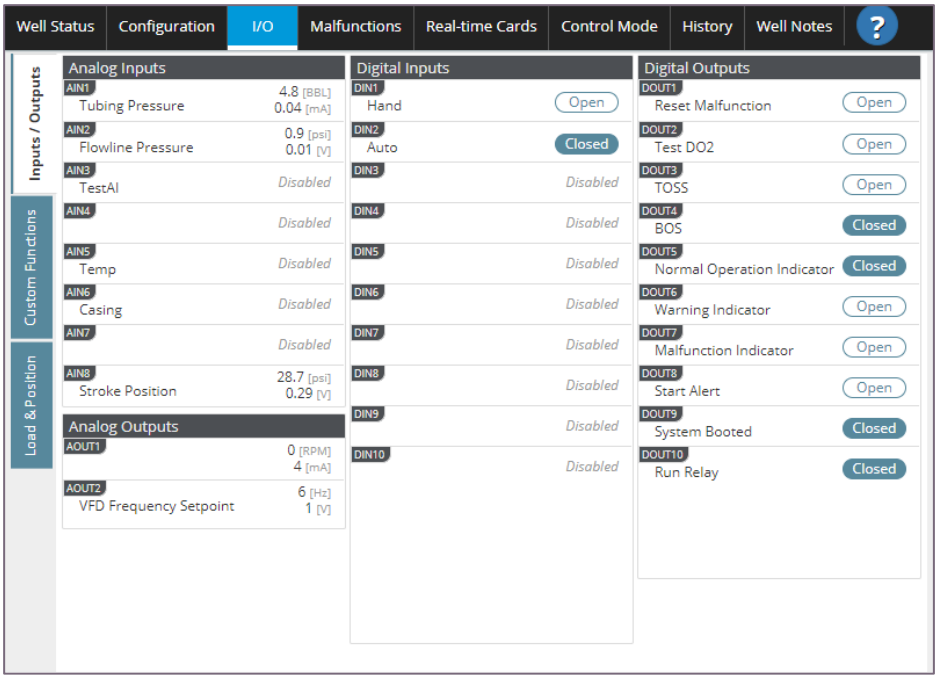
The **Start of Stroke** must be entered as either **Top of Stroke** (horsehead up when mounting crank sensor) or **Bottom of Stroke** (horsehead down when mounting crank sensor). Select the pumping unit **Rotation** as Clockwise or Counterclockwise. Click the Save button.

The value for **Reference Revs** is defaulted to 144. When all other configuration information has been entered, start the unit and allow it to run in AUTO. Select Calibrate Reference Revolutions and, within a few strokes, this value will be calculated and entered into the Reference Revs field.

The **Use Start of Stroke Only** toggle allows for SMARTEN to calculate surface position by just using the crank hall effect sensor only. This feature should only be used if the RPM hall effect sensor is not available or possible to be used.

Hall Effect configuration is now complete. Verify that card data on the **Real-time Cards** page is correct.

Section 4: Inputs/Outputs (I/O)



There are three (3) tabs within the I/O section: **Inputs/Outputs, Custom Functions** and **Load & Position.**

4.1 Inputs/Outputs

This tab displays the status of the **Analog Input, Analog Output, Digital Input** and **Digital Output** channels. The channel I/O, name, signal value (voltage or milliamps) and the process value (psi, kW, gal, etc.) are displayed on this page. The features and functions are essentially the same between the SMARTEN and SMARTEN Edge controllers. However, the amount of input and output channels differ between the two platforms. On the SMARTEN controller, there are eight (8) **Analog Input** channels, two (2) **Analog Output** channels, ten (10) **Digital Input** channels, and ten (10) **Digital Output** channels. On the SMARTEN Edge controller there are four (4) **Analog Input** channels, one (1) **Analog Output** channel, eight (8) **Digital Input** channels and six (6) **Digital Output** channels.

For wiring and ground information of all the I/O channels, please see section 2.3 of the SMARTEN Installation Guide.

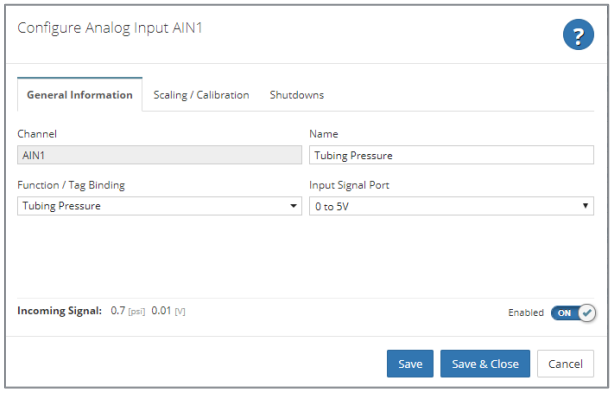
4.1.1 Analog Inputs

Along the bottom edge of the SMARTEN RIB2 are the eight (8) **Analog Input** channels. Using jumpers J39-J46 running parallel with these connectors, the transducer power can be set at 5V or 12V for each channel. For all channels the input can be set as 0-5V or 4-20 mA when a jumper is present on jumpers J47-J54. AIN7 and AIN8 can be set to accept 0-5V or 0-10V input using jumpers J55 and J56.

On the SMARTEN Edge, the four (4) **Analog Input** channels can be found along the bottom left edge of the board. The transducer power for each channel can be selected using SW5-SW8 located above the AIN terminals. If the switch is in the 0-10V position, the voltage at TPWR is 12 VDC. If the switch is in the 4-20 mA position, the voltage at TPWR is 24 VDC.

Clicking the individual fields in the **Analog Inputs** section of the **Inputs/Outputs** tab opens a box that features three (3) tabs where information for each analog input channel can be entered: **General Information, Scaling/Calibration** and **Shutdowns.**

General Information



The **Channel** field is read-only and identifies the channel as labeled on the SMARTEN RIB. Enter a **Name** that accurately describes the channel's purpose. The **Name** of the channel must begin with a letter. It cannot begin with a numeric value. The name will be displayed wherever the value of this channel is shown as well as part of the **Well Status** text if the channel causes a **Fault** or **Malfunction**. Select the **Function/Tag Binding** from the dropdown menu.

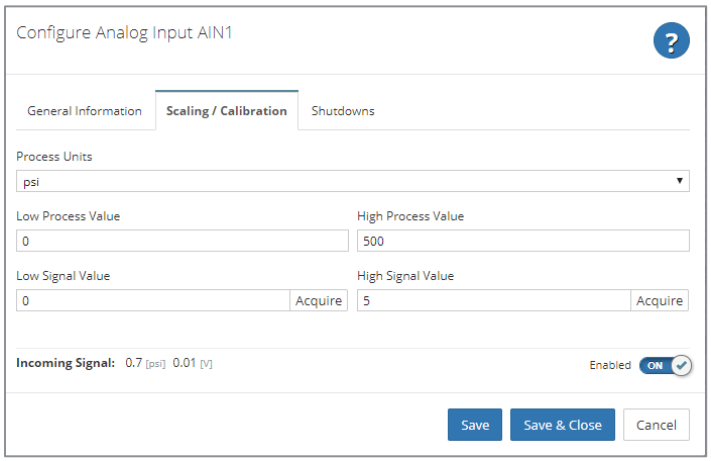
Input Tags are arranged in folders including **Custom** (analog or digital input values), **Rod Pump, Downhole Gauge,** or **VFD** to name a few. Other input tags include **Casing Pressure, Flow Line Pressure** or **Tubing Pressure**. Select the appropriate **Input Signal Port** from the dropdown menu. On the SMARTEN controller choices will be 0 to 5V or 0 to 20mA on AIN1-AIN6 or 0 to 5V, 0 to 10V or 0 to 20mA on AIN7 and AIN8 only. On the SMARTEN Edge controller choices for **Input Signal Port** are 0 to 10V or 0 to 20mA only.

The toggle button next to **Enabled** must be in the **ON** position for the **Incoming Signal** to be received. When toggled to the **OFF** position, the **Incoming Signal** is disabled**.**

***NOTE**: Stroke position is defaulted to AIN8 and AIN4 on the SMARTEN and SMARTEN Edge controller's respectively. Stroke position can also be set on AIN7.*

***NOTE**: On the SMARTEN and SMARTEN Edge controllers it is essential that jumper or switches are in the correct position for either 0 to 5V, 0 to 10V or 0 to 20mA input.*

4.1.1.2 Scaling/Calibration



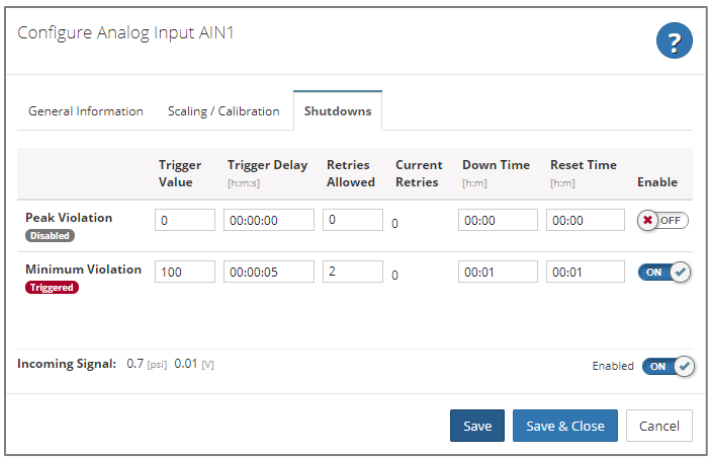
In the **Scaling/Calibration** box the type of signal can be chosen from the **Process Units** dropdown menu (Volts, PSI, Feet-Pounds, etc.). The **Low Process Value** and **High Process Value** fields list the minimum and maximum values (e.g., if a 2,000-psi pressure transducer is installed the **Process Unit** type would be PSI, the **Low Process Value** would be "0" and the **High Process Value** would be "2,000").

Low Signal Value sets the minimum signal value for the incoming analog signal (0V, 1V, 0 mA or 4 mA). By clicking the **Acquire** button, the **Low Signal Value** is set with the current incoming value. **High Signal Value** sets the maximum signal value for the incoming analog signal (5V, 10V, or 20 mA). By clicking the **Acquire** button, the **High Signal Value** is set with the current incoming value.

The **Incoming Signal** box displays the actual reading from the **Analog Input** device**.** Example: for the same pressure transducer, this would be a value between 0 and 2,000. The **Incoming Signal** shows the signal value in parentheses and the processed value in raw voltage or current that is being sent to the controller by the end device.

The toggle button next to **Enabled** must be in the **ON** position for the **Incoming Signal** to be received. When toggled to the **OFF** position, the **Incoming Signal** is disabled**.**

4.1.1.3 Shutdowns



The information entered in the **Shutdowns** box allows conditions to be set that will cause the controller to recognize an alarm condition.

The **Minimum Violation** and **Peak Violation** values can be set, along with **Trigger Value** (the value at which action is taken)**, Trigger Delay** (the amount of time that the violation is permitted, displayed in hh:mm:ss format), the number of **Retries Allowed** for each violation, **Current Retries**, **Down Time** and **Reset Time** for each violation (displayed in hh:mm format). After each violation, the well will enter a "Fault" state at which point the **Current Retries** value increments by 1. SMARTEN will attempt to restart the well after the **Down Time** has expired. **Down Time** is the amount of time the well will be in a "Fault" state if the **Trigger Value** has been violated. When the **Current Retries** value exceeds the **Retries Allowed** value then well will enter a "Malfunction" state. The **Reset Time** is the duration without any violations after which the **Current Retries** count will be automatically reset to zero. A **Reset Time** of 00:00 disables the automatic reset of **Retries**.

Toggle the **Enable** button from **OFF** to **ON** to activate the **Minimum** and **Peak Violation** settings. The violations will not function without being enabled. Example: If casing pressure should not fall below 60 psi and not rise above 200 psi, then these would be the **Minimum** and **Peak** Violation values for this **Analog Input**. The current status of each violation is shown below the name of the violation. Statuses include **Disabled (grey)**, **Nominal (green)**, **Violating (blinking amber)** and **Triggered (blinking red)**. Once Triggered, the well will shut down.

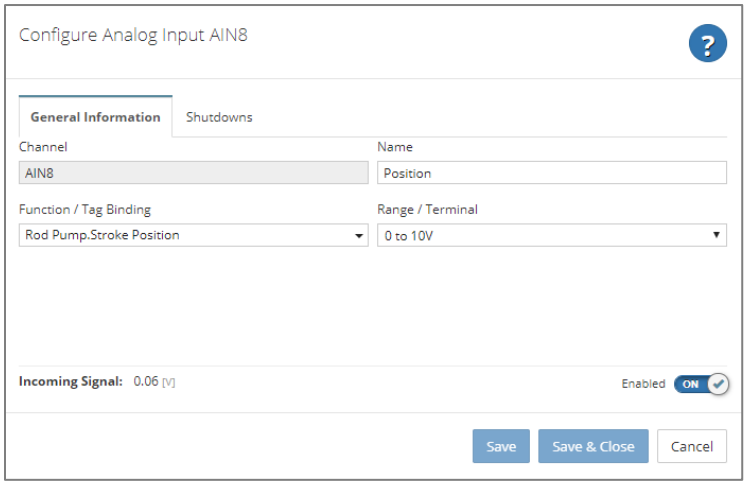
The toggle button next to **Enabled** must be in the **ON** position for an **Incoming Signal** to be received. When toggled to the **OFF** position, the **Incoming Signal** is disabled**.**

***NOTE**: Any changes made to the fields in the **General Information, Scaling/Calibration** and **Shutdowns** tabs are only saved if the **Save** or **Save & Close** buttons are clicked. Clicking the **Cancel** button voids any changes. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving I/O Channels…" followed by a ghosted green box with the message, "I/O configuration updated by 'User'…" if the changes have been saved successfully.*

4.1.1.4 Analog Input Position – Inclinometer

If the inclinometer is used for position with the SMARTEN controller, then the inclinometer must be connected to AIN7 or AIN8 (default) with 0-10V input selected. On the SMARTEN Edge, the inclinometer should be connected to AIN4. See the SMARTEN Installation Guide section 3.4.1.2 for position wiring instructions.

Once wired correctly, the AIN channel must be configured for position. To do so, enter Position as the **Name**, select RodPump.StrokePosition as the **Function/Tag Binding** and 0-10V as the **Range/Terminal**. Ensure that the Enabled button is in the ON position. Click the Save & Close button and position values should appear next to AIN8 on SMARTEN or AIN4 on the SMARTEN Edge on the I/O page.



NOTICE

***NOTE**: In order to use the Inclinometer for position, Hall Effects must be turned off.*

NOTICE

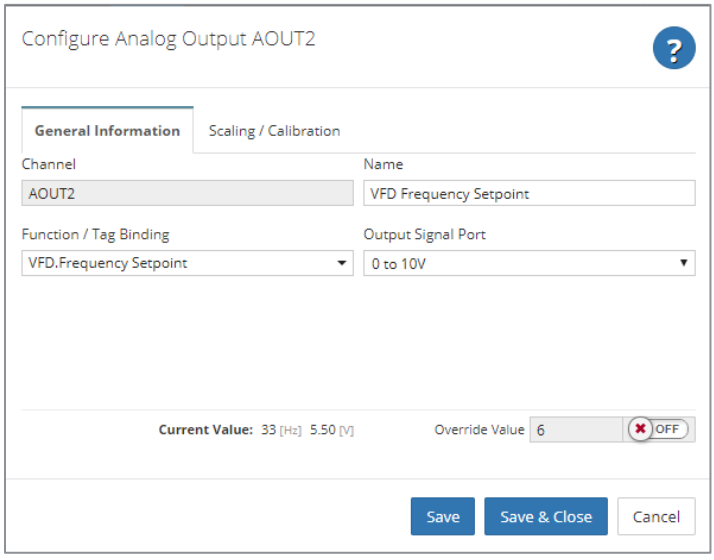
***NOTE**: If Hall Effects is to be used for position instead of the inclinometer, RodPump.StrokePosition must be removed from all AIN channels.*

4.1.2 Analog Outputs

Along the right edge of the SMARTEN RIB are the two (2) **Analog Output** channels. The output signal can be selected using jumpers J19 and J20 on the pins for 0-10V or 4-20mA output. On the SMARTEN Edge RIB the single **Analog Output** channel is located along the right edge of the board. The AOUT channel can be configured to output either 4-20mA or 0-10V. This configuration requires switching to the desired output on switch SW4 and selecting the correct output on the **I/O** page in the SMARTEN software.

Clicking the individual fields in the **Analog Outputs** section of the **Inputs/Outputs** tab opens a box that features two (2) tabs where information will need to be entered: **General Information** and **Scaling/Calibration.**

4.1.2.1 General Information

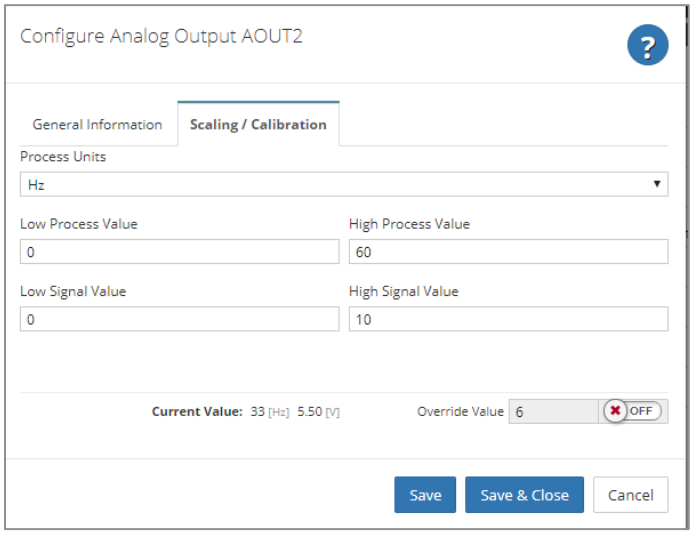


The **Channel** field is read-only and identifies the channel as labeled on the SMARTEN RIB. Enter a **Name** that accurately describes the channel's purpose. The **Name** of the channel must begin with a letter. It cannot begin with a numeric value. The **Name** will be shown wherever the value of this channel is displayed. Select the **Function/Tag Binding** from the dropdown menu. The selected **Tag** sets the output for this channel. Each time the **Tag** value changes, the corresponding **Current Value** (based off the **Scaling/Calibration**) is written to the channel. Select **Custom** to create your own **Tag** that corresponds to the Name given to this channel. Tags include **Commands, Custom, Rod**

Pump, State, System, VFD and several other **Input Functions**. Select the appropriate **Output Signal Port** from the dropdown menu (**0 to 10V** or **4 to 20mA**).

The **Current Value** is the voltage or the amperage that the **Analog Output** channel is pushing to the end device at the current time. The **Override Value** is the voltage or amperage that the user can set to push to the end device regardless as to what the control mode calls for. The toggle button next to **Override Value must be in the ON** position for an **Override Value** (0-10V or 4-20mA) to be selected and set. When toggled to the **OFF** position, the **Override Value** cannot be changed.

4.1.2.2 Scaling/Calibration



In the **Scaling/Calibration** tab the type of signal can be chosen from the **Process Unit** dropdown menu (Volts, PSI, Feet-Pounds, etc.). The **Low Process Value** and **High Process Value** fields list the minimum and maximum values. For example, if an **Analog Output** channel was controlling the frequency of a variable speed drive, then the **Low Process Value** would be "0" and the **High Process Value** would be "100 Hz" with 0V and 10V being the **Low** and **High Signal Values**. **Low Signal Value** sets the minimum signal value for the outgoing analog signal (0V, 1V, 0 mA or 4 mA). **High Signal Value** sets the maximum signal value for the outgoing analog signal (5V, 10V or 20 mA).

***NOTE**: Any changes made to the fields in the **General Information** and **Scaling/Calibration** tabs are only saved if the **Save** or **Save & Close** buttons are clicked. Clicking the **Cancel** button voids any changes. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving I/O Channels…" followed by a ghosted green box with the message, "I/O configuration updated by 'User'…" if the changes have been saved successfully.*

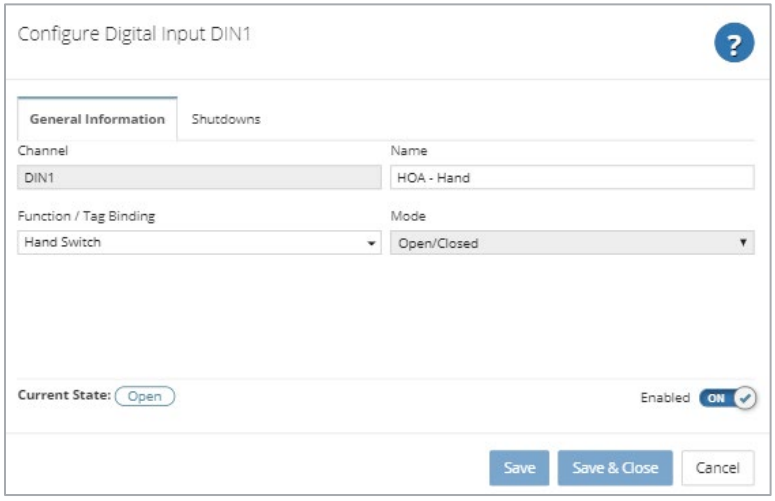
4.1.3 Digital Inputs

The ten (10) **Digital Input** channels can be found on the SMARTEN RIB running parallel with the bottom edge of the board and above the **Analog Input** channels. The DIN1 – DIN7 can be configured to operate as a regular DI and measure open/closed states, or they can be configured to function as pulse counters in the case of Hall Effects. Channels DIN8, DIN9 and DIN10 can be used as regular digital inputs or as high-speed counters. To function as regular digital inputs including Hall Effects, jumpers J21, J22 and J23 must be set on position "A" (the two left most jumpers). The "B" position is used to configure the input for differential input such as turbine, flow, and water meters that don't use the standard open-collector type of control. The IN+ and IN- pins on DIN8, DIN9 and DIN10 are for the differential signal connections from a flowmeter.

On the SMARTEN Edge RIB the eight (8) **Digital Input** channels are located in the lower right corner of the board. These DIN channels can also measure open/closed states or can function as high-speed pulse counters.

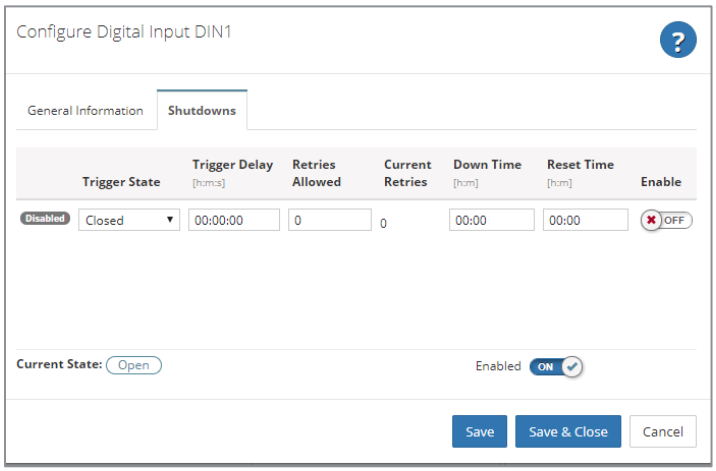
Clicking a digital input channel in the **Digital Inputs** section of the **I/O** page allows the channels to be individually configured. Doing so, opens a window that features two (2) tabs where information will need to be entered: **General Information** and **Shutdowns.**

4.1.3.1 General Information



On the **General Information** tab, the **Channel** field is read-only and identifies the channel as labeled on the SMARTEN or SMARTEN Edge boards. Enter a **Name** that accurately describes the channel's purpose. The **Name** of the channel must begin with a letter. It cannot begin with a numeric value. The name will be displayed wherever the value of this channel is displayed, as well as part of the **Well Status** text if the channel causes a **Fault** or **Malfunction**. The **Function/Tag Binding** selected from the dropdown menu is set by this input channel. Only Tags that are available to be set from an external source will be shown (**Commands, VFD, Custom, Auto Switch, Hand Switch)**. Each time this channel is scanned, the **Process/Scaled Value** is written to the Tag. Selecting **Custom** allows the user to create a new Tag that corresponds to the **Name** given to this channel. The **Mode** of the DIN channel can either be set as **Open/Closed** or **Pulse Counter**. When set as Open/Closed the DI channel will display the status simply as Open or Closed. When set as a **Pulse Counter**, the DIN channel can be used to count pulses for the purpose of **Hall Effects.**

4.1.3.2 Shutdowns



On the **Shutdowns** tab, select the **Trigger State** (open or closed, the state which triggers action)**,** set the **Trigger Delay** (the amount of time that the violation is permitted, displayed in hh:mm:ss) and enter the number of **Retries Allowed** for each violation. The **Down Time** and **Reset Time** for each violation (displayed in hh:mm format) must also be entered. After each violation, the well will enter a "Fault" state at which point the **Current Retries** value increments by 1. SMARTEN will attempt to restart the well after the **Down Time** has expired. **Down Time** is the amount of time the well will be in a "Fault" state if the **Trigger State** has been violated. When the **Current Retries** value exceeds the **Retries Allowed** value then well will enter a "Malfunction" state. The **Reset Time** is the duration without any violations after which the **Current Retries** count will be automatically reset to zero. A **Reset Time** of 00:00 disables the automatic reset of **Retries**.

The toggle button next to **Enabled** must be in the **ON** position for a **Current State** value to be received. When toggled to the **OFF** position, the **Current State** is disabled**.**

The current status of each violation is shown below the name of the violation. Statuses include **Disabled (grey)**, **Nominal (green)**, **Violating (blinking amber)** and **Triggered (blinking red)**. Once Triggered, the well will shut down.

The **Shutdowns** tab is not available if the **Mode** is set to **Pulse Counter.**

***NOTE**: Any changes made to the fields in the **General Information** and **Shutdowns** tabs are only saved if the **Save** or **Save & Close** buttons are clicked. Clicking the **Cancel** button voids any changes. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving I/O Channels…" followed by a ghosted green box with the message, "I/O configuration updated by 'User'…" if the changes have been saved successfully.*

4.1.3.3 Digital Input Position – Hall Effects

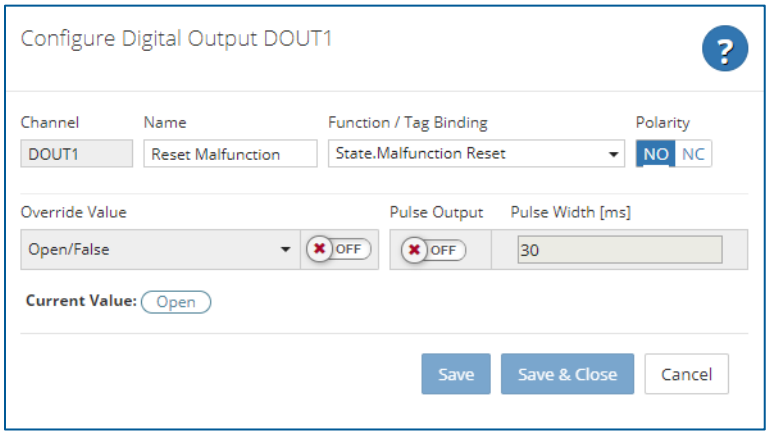
Please see section 3.6.2 for configuring DIN channels for Hall Effects.

4.1.4 Digital Outputs

Along the right side of the board are ten (10) **Digital Output** channels. The output voltage (5V or 12V) can be selected using jumpers J1-J9 or J18 running parallel with the DO channels. On the SMARTEN Edge board along the upper right edge are the (6) **Digital Output** channels. These DO channels output 12 V when triggered.

Clicking the individual fields in the **Digital Outputs** section allows each channel to be individually configured. After clicking on a channel name, a window opens that shows values for **Channel, Name, Function/Tag Binding, Polarity** and **Override Value.**

The **Channel** field is read-only and identifies the channel as labeled on the SMARTEN RIB. Enter a **Name** that accurately describes the channel's purpose. The **Name** of the channel must begin with a letter. It cannot begin with a numeric value. The **Name** will be shown wherever the value of this channel is displayed. The **Function/Tag Binding** sets the output value of this channel. Each time the Tag value changes, the corresponding signal value (based on the Scaling/Calibration) is written to the channel. Select **Custom** to create a Tag that corresponds to the Name given to this channel. Several other Tags are available to choose to assign to a DOUT channel. The **Polarity** for each channel can also be set as **NO** or **NC**.



Listed below are default functions that are assigned to digital output channels. Note that the default channel assignments are listed in parentheses. These channel assignments can be changed to match the needs of the operator.

- **System.Booted** – Fault Relay (DOUT9 SMARTEN, DOUT5 Edge)
- **Sytem.Run Auto** – Run Relay (DOUT10 SMARTEN, DOUT6 Edge)
- **Starting Safety Alert**: Closed during startup delay to indicate that that the pumping unit is about to start. (DOUT8 SMARTEN, DOUT4 Edge)
- **Process Halt:** Closes during a malfunction state. (DOUT7 SMARTEN)
- **Process Warning:** Closes during an Idle state other than pump off or idle timer. (DOUT6 SMARTEN)
- **Process Normal:** Closed when well is running without issue. (DOUT5 SMARTEN)
- **Malfunction Reset:** Closed briefly when the **Reset Malfunction** button is pushed. (DOUT1 SMARTEN

The **Override Value** can be either **Open** or **Closed.** This value can only be changed if the toggle button is in the **ON** position. The **Current Value** will display **Open** or **Closed** when the **Save** or **Save & Close** buttons are clicked.

The signal from the **Digital Output** channels can also be pulsed. To do so, the **Pulse Output** toggle button must be in the ON position. Also, select the Pulse Width [ms] duration. This is amount of time the DOUT channel will engage when triggered. For example, if a DOUT channel is set as NO with the **Pulse Output** enabled for 30 ms then the DOUT channel will close (providing 5 V or 12 V) for 30 ms (3 s) once triggered after which the DOUT channel will open.

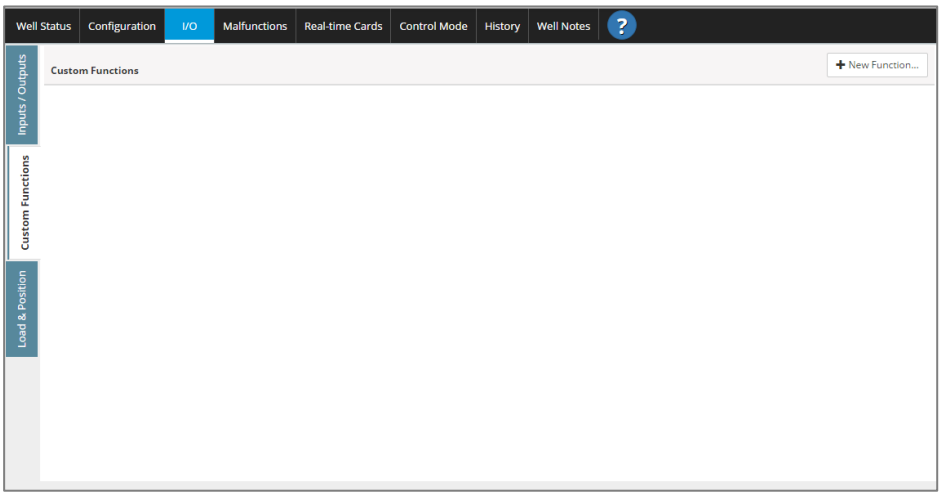
***NOTE:** Any changes made to the fields in any of the 10 **Digital Outputs** fields are only saved if the **Save** or **Save & Close** buttons are clicked. Clicking the **Cancel** button voids any changes. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving I/O Channels…" followed by a ghosted green box with the message, "I/O configuration updated by 'User'…" if the changes have been saved successfully.*

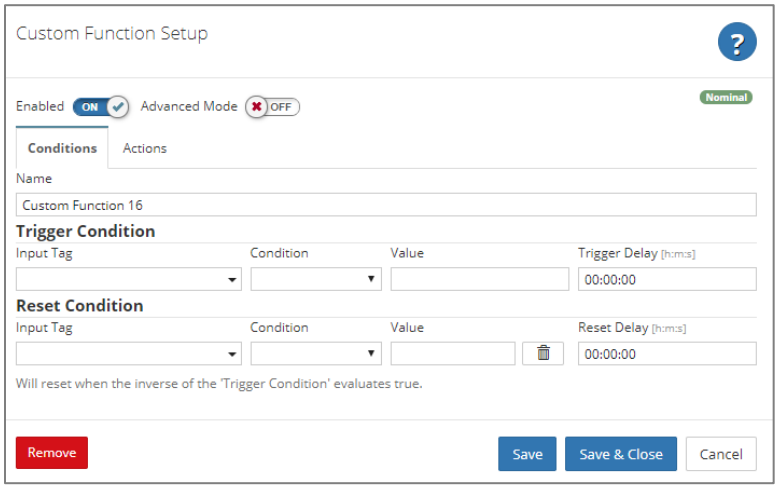
4.2 Custom Functions

The **Custom Functions** page allows the user to set up a series of triggers and actions based on the status of input triggers. A trigger can be either **Analog** or **Digital Input Channel** readings or some other calculated value from the controller. Actions can be as simple as a message banner displayed in the top right corner of the screen or as complex as closing multiple digital output channels, slowing down a VFD or stopping the well altogether. Complex rules can be created using this feature giving the user a great deal of flexibility for advanced controls.

4.2.1 Custom Function Setup

To set up a Custom Function click on **New Function** located in the upper right corner of the **Custom Functions** tab.





When a new **Custom Function** is created it is automatically **Enabled** with the toggle switch in the **ON** position. Click on the toggle switch to turn it off. The Current Status is shown in the upper right corner of the window. Statuses include **Disabled (grey)**, **Nominal (green)**, **Violating (blinking amber)** and **Triggered (blinking red)**.
Advanced Mode is **OFF** as a default. When **Advanced Mode** is **OFF** most of the configuration can be done by using pre-populated tags in the drop-down boxes. When **Advanced Mode** is **ON** the user must enter all trigger and action conditions by hand. This will be discussed in a later section.

4.2.1.1 Setting the Trigger Conditions

There are several fields that must be set on the **Custom Functions** page. Begin by giving the Custom Function an appropriate **Name**. A default name will be provided unless changed. Next, the **Trigger Condition** must be set. The **Trigger Condition** specifies the logic for when to move the function from a nominal to a triggered state. When triggered, the function will perform the trigger actions one time and then begin checking the reset condition.

The **Input Tag** is the variable that is checked to determine if the condition is true or false. **Input Tags** are arranged in folders including **Custom** (analog or digital input values), **Commands, RodPump** calculations, **State** conditions, **Downhole Gauge** measurements, **PCP** conditions, **System** conditions, **VFD** parameters and several others. **HOA status** and incoming measured pressures also serve as **Input Tags**. If an **Analog or Digital Input** channel is used as the **Input Tag**, it must be enabled on the **Inputs/Outputs** page prior to using it as an **Input Tag**, otherwise the **Analog or Digital Input** channel will not appear in the **Custom** folder of the **Input Tag** drop-down box.

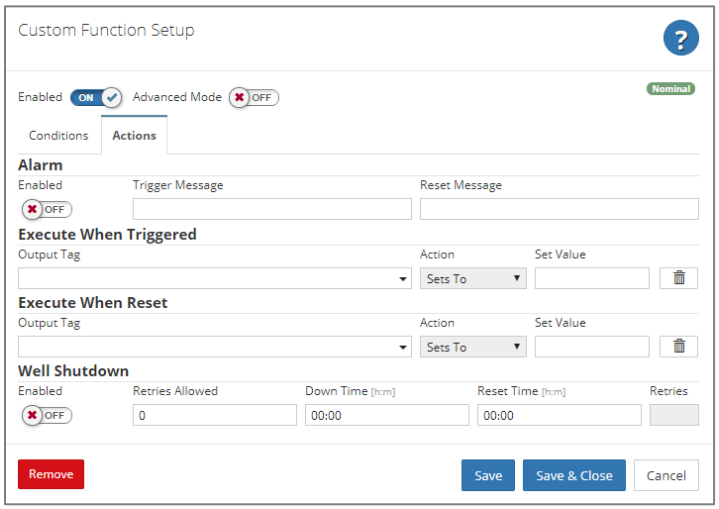
The **Condition** specifies the relationship between the **Input Tag's** value and the threshold value to determine if the condition is true or false. Options for the **Condition** include **Greater Than (>), Less Than (<) , Equal To (==)** and **Changes**. Select **"Changes"** if you simply want the trigger to fire immediately whenever the Tag value changes.

The **Trigger Delay** is the time duration that the **Input Tag** must continuously meet a true trigger condition before the function will trigger. If this condition exists for the duration of the **Trigger Delay** then the condition will trigger.

4.2.1.2 Setting the Reset Condition

The **Reset Condition** specifies the logic for when to move the function from the triggered state back to normal/reset. The function must first trigger before this condition is checked. When reset, the function will perform the reset actions one time and then begin checking the trigger condition again. Select the **Input Tag**, the **Condition**, **Value** and **Reset Delay** to reset the **Trigger Condition**. Several Tags are available as the **Input Tag** as stated in the previous section. As with the **Trigger Delay**, the **Reset Delay** is the time duration that the **Reset Input Tag** must continuously meet the reset condition before the custom function will reset.

4.2.1.3 Actions



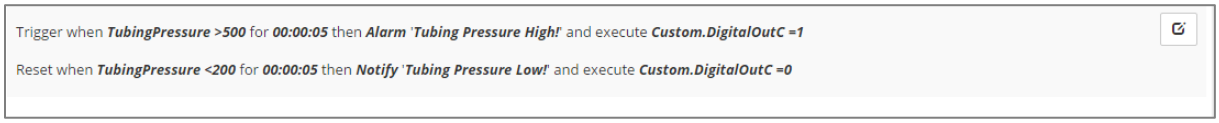
Click on the **Actions** tab to set up actions for the **Custom Function**. With the **Alarm** toggle switch in the **ON** position a popup message will appear in the upper right corner of the display and an **Event** will be logged whenever the function triggers or resets. The **Trigger Message** is the **Alarm** notification message to display on the HMI and in the **Event Log** whenever the function triggers. The popup message will stay on the HMI until the function resets. The **Reset Message** is the **Alarm** notification message to display on the HMI and in the **Event Log** whenever the function resets. Leave this blank if you do not want a reset notification.

In the **Execute When Triggered** box an **Output Tag** can be set to a value when the custom function triggers. Choices include **Commands, Custom** (AOUT or DOUT channels) or **VFD**. For digital values, use 0 for Open/False and 1 for Closed/True. When a digital output channel or function is used for the **Output Tag,** the tag can also be "pulsed." This option is available under the **Action** heading. When **Pulse** is selected the **Output Tag** will be triggered for the **Duration** specified in seconds. The pulse will occur once, after which the **Output Tag** will return to its untriggered state. To use **Analog or Digital Output** channels for this purpose the output channel must be set up and enabled on the **Inputs/Outputs** page prior to using it as an **Output Tag**. These channels can be found in the **Custom** folder for the **Output Tags**. Other **Output Tags** are contained in the **VFD** or **Commands** folders.

In the **Execute When Reset** box an **Output Tag** can be set to a value when the custom function resets. For digital values, use 0 for Open/False and 1 for Closed/True. As with the trigger action described above, the **Output Tag** can also be pulsed for the **Reset Condition**. To use **Analog or Digital Output** channels for this purpose the output channel must be set up and enabled on the **Inputs/Outputs** page prior to using it as an **Output Tag**. These channels can be found in the **Custom** folder for the **Output Tags**. Other **Output Tags** are contained in the **VFD** folder.

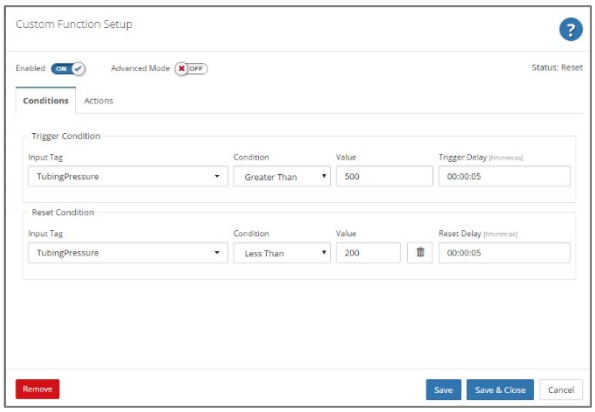
The **Custom Function** can also be configured to shut down the well. In the **Well Shutdown** box, the amount of **Retries Allowed** can be entered along with the **Down Time** to follow each **Custom Function** trigger. The well will only shut down on a **Custom Function** if the **Enabled** button is in the **On** position. If the **Custom Function** triggers, the well will shut down and remain idle for the duration of the **Down Time**. Following each shut down, the **Retries** will increment by 1.
If the **Custom Function** is triggered and the well shuts down, the well status will state **"Fault, Custom Function."** If the **Trigger Condition** clears for the **Reset Time** specified, then all **Retries** that have been tallied will be reset to 0. A **Reset Time** of 00:00 disables the automatic reset of **Retries**.

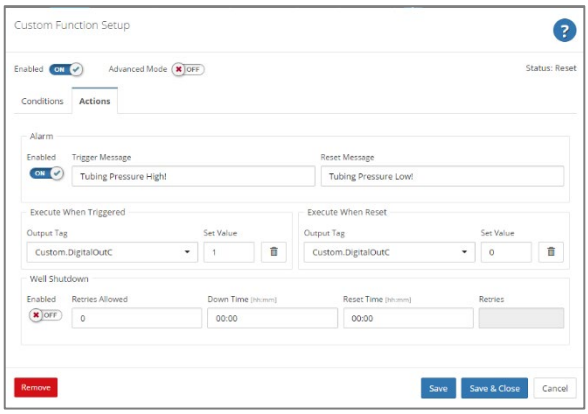
Once all fields have been completed click the **Save** button or the **Save & Close** button to return to the **Custom Functions** page. On the **Custom Functions** page, the **Custom Functions** that have been entered will be listed showing a condensed view of the logic. Each **Custom Function** is enabled unless **Disabled** is displayed to the right of the **Custom Function**. To edit a **Custom Function,** click on the row that contains the **Custom Function** to be edited or click the edit button to the right.



4.2.1.4 Custom Function Examples

Below is an example of a **Custom Function** that will be executed if **Tubing Pressure** is Greater Than 500 PSI for 5 seconds.



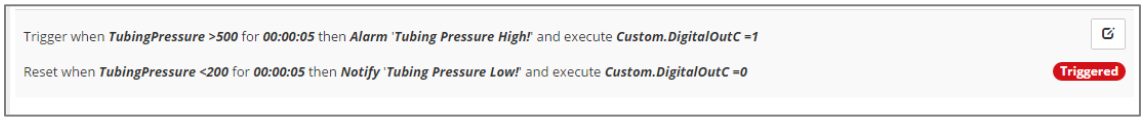


The **Custom Function** presented above will do the following:

If **Tubing Pressure** is greater than 500 PSI for a duration of 5 seconds, then **"Tubing Pressure High!"** will be displayed as an Alarm banner on the display and **Digital Output Channel C** will be set to 1 (closed). Clicking on the Alarm banner will close the banner. It will reappear after 10 seconds.

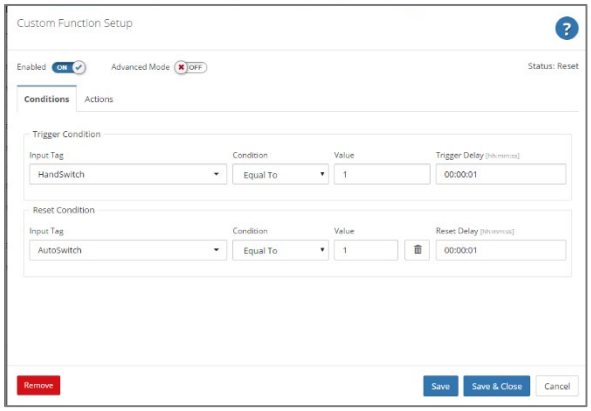
When the **Tubing Pressure** is less than 200 PSI for a duration of 5 seconds then the function resets. **"Tubing Pressure Low!"** will be displayed on the screen and **Digital Output Channel C** will be set to 0 (open).

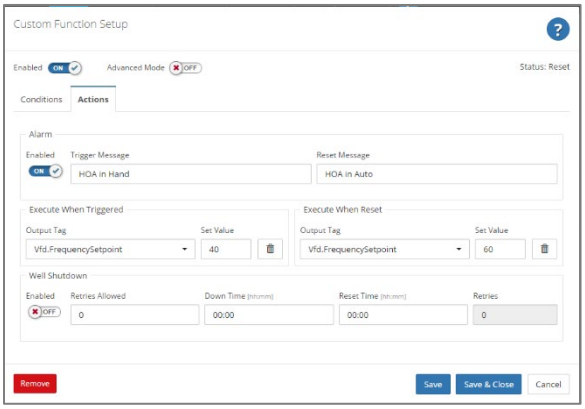
When triggered, a notification will also be given to the right of the **Custom Function**.



4.2.2 Advanced Mode

Switching to Advanced Mode in Custom Functions allows the user to customize the trigger and action conditions and create functions with more than one Trigger Condition or Action. New Custom Functions can be created in Advanced Mode by typing in the logic for the Trigger Conditions and Actions. However, if a Custom Function has already been created, switching to Advanced Mode preserves whatever logic has been entered and converts it to text for further editing. The screenshot below is a Custom Function with Advanced Mode disabled.

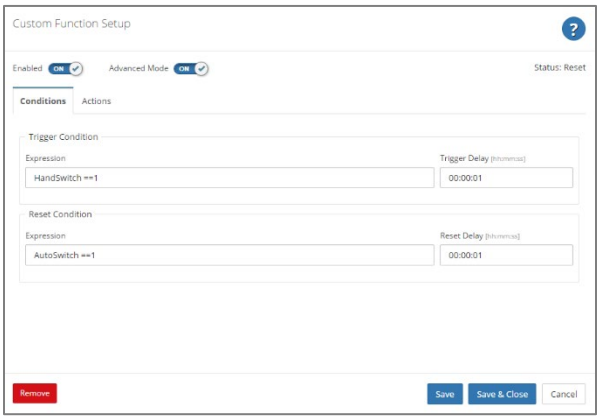


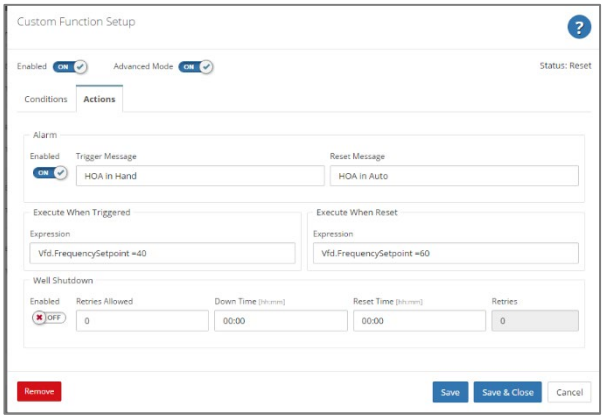


After switching to **Advanced Mode** all input fields change in such a way that logic for each condition must be typed. It is necessary that the text entered matches the format requirements for **Custom Functions**. For example, **"TubingPressure"** or similar for a preset analog or digital input function, **"Custom.NameOfChannel"** for custom analog or digital input functions or **"RodPump.NetStroke"** or similar for calculated values within SMARTEN. When constructing **Custom Functions** in **Advanced Mode** some logic symbols may be necessary. These include **">, greater than"**, **"<, less than"** and **"== Equal to"**. See the table below for logic operators and their meanings:

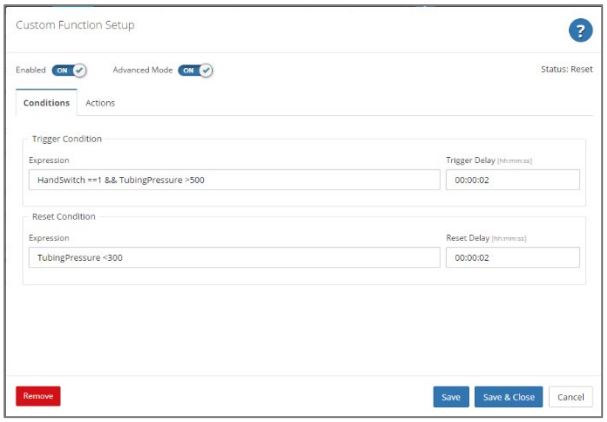
Operator	Symbol	Meaning
Assign	=	Set variable to a value
Equality	==	Two variables have the same value
Not Equal	!=	Set variable to some other value
Addition	+	The sum of two quantities
Subtraction	-	The difference of two quantities
Multiplication	*	The product of two quantities
Division	/	The quotient of two quantities
Greater Than	>	Value is larger than another
Greater Than or Equal To	>=	Value is larger or equal to another
Less Than	<	Value is less than another
Less Than or Equal To	<=	Value is less than or equal to another
And	&&	Evaluates two conditions both of which must be true
Or	||	Evaluates two conditions one of which must be true
Not	!	Reverses a normal expression

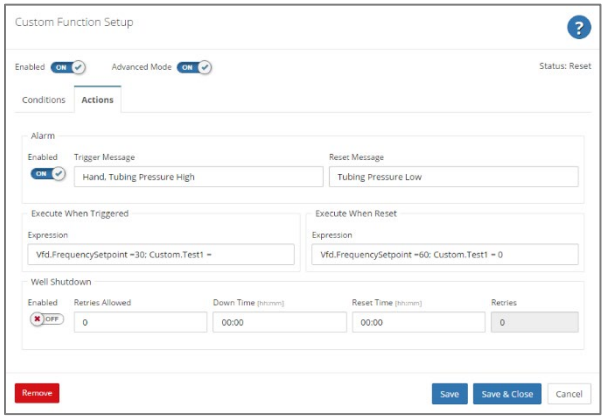
The screenshot below shows the above **Custom Function** in **Advanced Mode**. Notice that all **Expressions** have been converted into editable text.

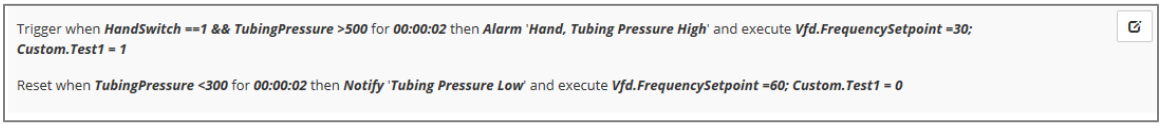




Once in **Advanced Mode** additional **Trigger Conditions** and **Reset Conditions** can be entered. Each **Expression** must be separated by "**&&**" (the AND operator) or "**||**" (the OR operator). Multiple **Actions** can also be set when the condition is triggered or reset. Each **Action Expression** must be separated by a semi-colon ("**;**").







The **Custom Function** in the screenshot above states that when the **HOA switch** is in the **Hand** position (HandSwitch ==1) AND **Tubing Pressure** is greater than 500 PSI for 2 seconds, then the message **"Hand, Tubing Pressure High"** will display on the screen, the **VFD Frequency Setpoint** will be set to 30 Hz and the **Digital Output Channel** labeled **Test1** will close. When **Tubing** Pressure falls below 300 PSI for 2 seconds, the message **"Tubing Pressure Low"** will be displayed on screen, the **VFD Frequency Setpoint** will be set to 60 Hz and the **Digital Output Channel** labeled **Test1** will open.

NOTICE

***NOTE**: When turning off **Advanced Mode**, only the first expression is preserved.*

4.3 Load & Position Signals

The **Load & Position** signals are plotted on the **I/O > Load & Position** tab. The position signal (blue line) should be a sine wave with a range between 0V and 10V with a difference of at least 1.5V between the lowest and highest value of the incoming signal. The position will not calibrate if the change in voltage from the inclinometer (or laser) is less than 1.5V. The scale for the position signal is on the left-hand side of the plot. The actual **Position** voltage of the incoming data points are presented below the signal plot.

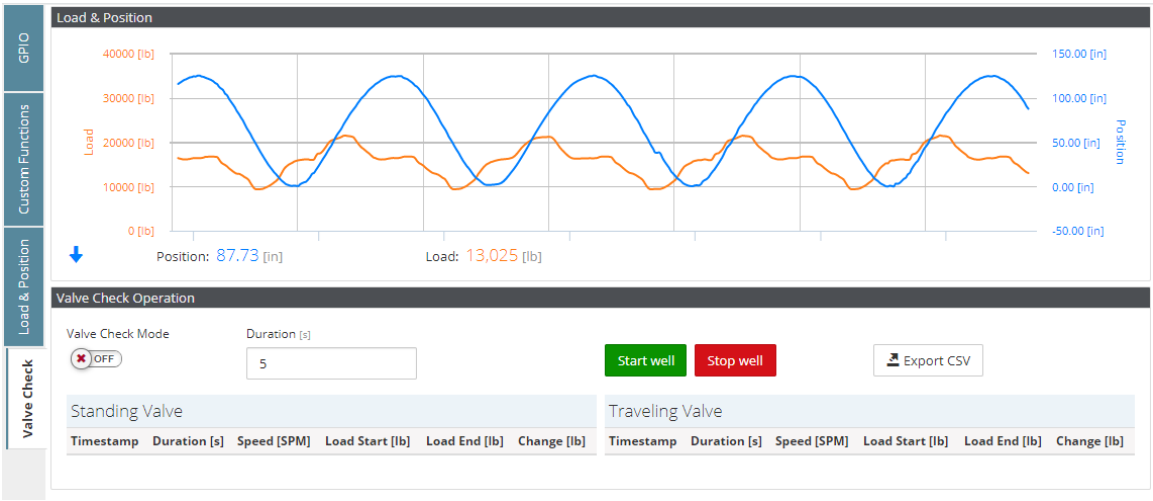
The **Load** signal (red line) will likely not be a perfect sine wave but will contain several distinct load changes throughout the stroke. Although not a perfect sine wave, the load signal should still be periodic and follow a pattern from stroke to stroke. Load values should be contained in a reasonable range considering the depth of the well, rods, fluid load and friction. The scale for the load signal is on the right-hand side of the plot. Load values should not exceed a maximum of 30,000 lb or 50,000 lbs., depending on what type of **Load Cell** is installed.
The vertical lines appearing periodically throughout the signals indicate the start and end of a complete stroke. The blue arrow below the plot under the “Position:” label indicates whether the well is moving through the upstroke or downstroke.
The **Overlay Tag** button allows the user to select an input **Tag** to plot along with the **Load** and **Position** signals. The **Tag** plotted is represented with a green line. Once the **Tag** is selected, the **Tag** title is shown along with the current value. Available tags include **Rod Pump** and **VFD** values in addition to **Custom** values from input channels.

4.4 VFD I/O

A fourth sub-tab will be visible when either the Fuji FRENIC-MEGA or the Schneider ATV630 are selected and enabled as the Variable Frequency Drive Client on the Modbus page. This fourth sub-tab shows the I/O channels for the selected inverter in the same format visible for the SMARTEN RIB found at the beginning of Section 4. The steps for programming the VFD I/O channels in SMARTEN are the same as programming the SMARTEN I/O. The exception is that shutdowns cannot be programmed for the VFD using the SMARTEN user interface.

4.5 Valve Checks

CAUTION: Be sure that the pumping unit has a working brake prior to performing valve checks.



On the **Valve Check** page incoming Load and Position signals can be seen on the graph. The load is represented by the orange line and the position is represented by the blue line.

Enable Valve Checks by turning the Valve Check Mode toggle switch to the ON position. When Valve Checks are enabled, a red banner is shown in the upper right corner of the screen indicating this. The Valve Check alert will also be active as seen when the alerts are clicked in the bottom toolbar. When Valve Checks are enabled, an event is recorded in the Event Log.

The pumping unit must be stopped in order for a Valve Check to completed. The unit can be stopped either by switching the HOA switch to the Off position or pushing the Stop Well button and pulling the brake at the position where the test is to be performed.

The position at which the well stops determines whether a Standing Valve or Traveling Valve Check will be done. If the pumping unit is stopped on the upstroke, then the Traveling Valve will be tested. If stopped on the downstroke, the Standing Valve will be tested. Once the controller determines that the pump is no longer moving the test will begin automatically and will last for time entered in the Duration(s) field. The default value is 5 seconds. The position signal line (blue line) will be flat when a Valve Check is being performed.

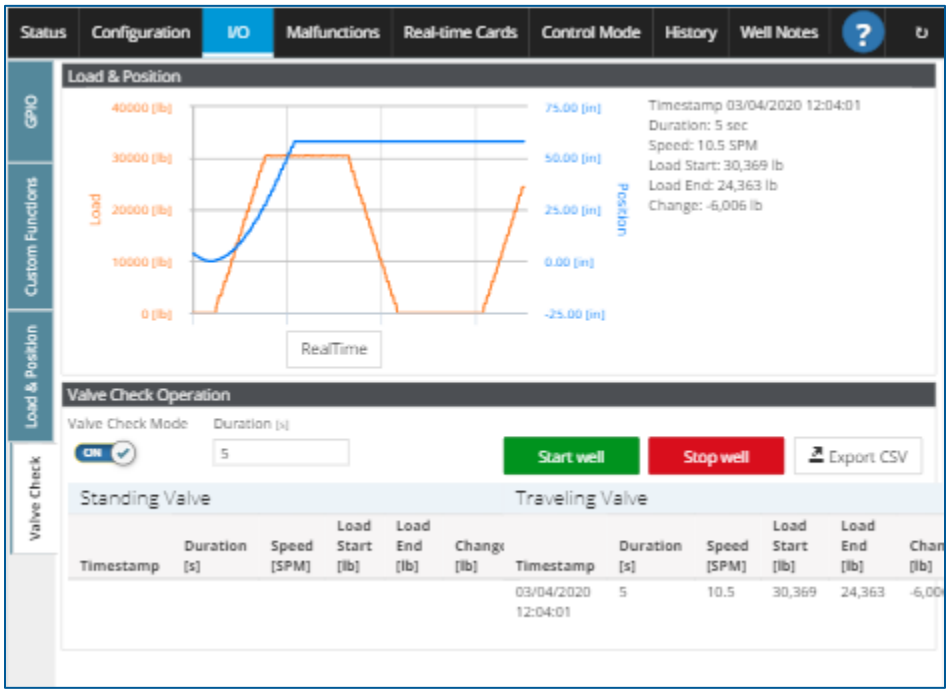
Once the test is complete it, the test results will be stored in the either the Standing Valve or Traveling Valve table at the bottom of the page. The results from each test include the Timestamp, Duration (s) of the test, the Speed (SPM) prior to stopping, the Load (lb) at the Start and End of the test, and the Change in the load value from the start to the end of the test.

If additional Valve Checks are to be completed, turn the pumping unit back on and allow it to run for a few strokes. Additional Valve Check results will be added to the results tables.

CAUTION: Prior to restarting the pumping unit, be sure that the pumping unit brake has been disengaged.

By clicking the Export to CSV button, all Valve Check data in memory will be saved to a flash drive (if inserted) or downloaded to a users' computer.

Clicking on the Valve Check entries in the results tables opens a window with additional information from that particular Valve Check. In particular, the load and position signals can be viewed. Click on the Realtime button to return to the Valve Check page.



After 20 minutes, the Valve Check mode will timeout automatically. If further testing is required, then simply re-enable Valve Checks.

During Valve Checks, all faults are enabled and dynagraph cards will not draw. Therefore, the unit will not be pumping nor will speed be changed if running in Variable Pump Speed mode.

NOTE: *During Valve Checks, all faults are enabled and dynagraph cards will not draw. Therefore, the unit will not pumping nor will speed be changed if running in Variable Pump Speed mode..*

Section 5: Malfunctions

5.1 Malfunction Setup

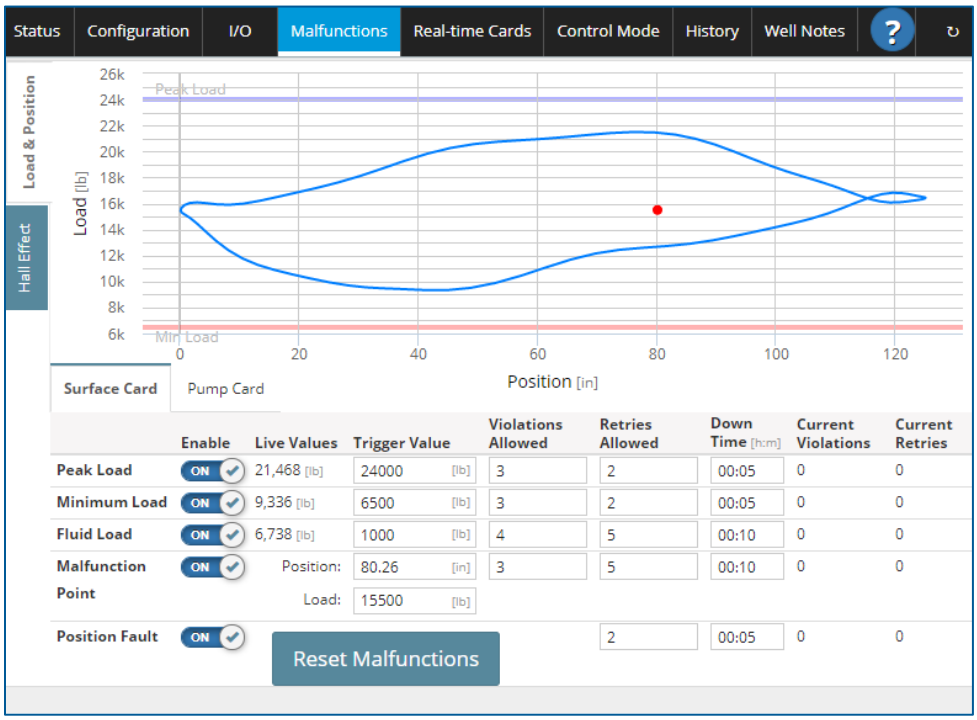
The SMARTEN/SMARTEN Edge **Malfunctions** tab enables the user to set up malfunction conditions on both **Pump** Card and **Surface** Card tabs for five (5) different parameters:

- Peak Load
- Minimum Load
- Fluid Load
- Malfunction Point
- Position Fault

These shutdowns are found on the Load & Position sub-tab.
The Hall Effect sub-tab shows five (5) additional shutdowns and one (1) alert:

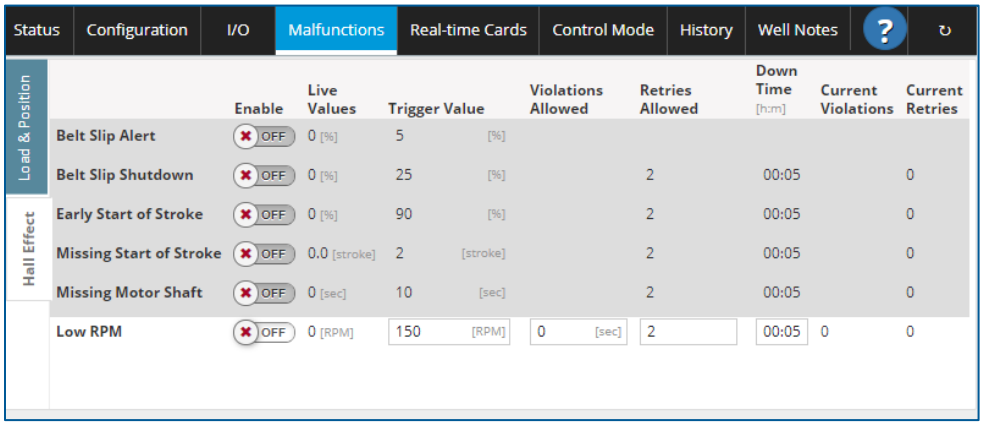
- Belt Slip Alert
- Belt Slip Shutdown
- Early Start of Stroke
- Missing Start of Stroke
- Missing Motor Shaft
- Low RPM

Depending on the number of **Retries Allowed** there could be two types of Shutdowns – **Fault** or **Malfunction**. A **Fault** state is a recoverable fault condition. The well will restart following the expiration of the **Down Time** for that **Malfunction** item. In the **History Pages**, **Fault** entries are highlighted in yellow and are indicated by a "!" surrounded by a yellow triangle. A **Malfunction** state is an unrecoverable fault condition. There are no Retries with a **Malfunction.** In this case the pump remains halted until corrective action is taken by an operator. Often, a **Malfunction** state follows a **Fault** state once all the **Retries** have been used. In the **History Pages**, **Malfunction** entries are highlighted in red and are indicated by a "!" surrounded by a red circle.



	Enable	Live Values	Trigger Value	Violations Allowed	Retries Allowed	Down Time [h:m]	Current Violations	Current Retries
Peak Load	ON	21,468 [lb]	24000 [lb]	3	2	00:05	0	0
Minimum Load	ON	9,336 [lb]	6500 [lb]	3	2	00:05	0	0
Fluid Load	ON	6,738 [lb]	1000 [lb]	4	5	00:10	0	0
Malfunction Point	ON	Position:	80.26 [in]	3	5	00:10	0	0
		Load:	15500 [lb]					
Position Fault	ON				2	00:05	0	0

Aside from Position Fault, the Load and Position malfunctions have four (4) fields that can be edited. They are **Trigger Value, Violations Allowed** (number of times a malfunction parameter may be violated before the POC stops the well)**, Retries Allowed** (number of times the POC will try to restart the unit before going into a malfunction state)**, Down Time** (amount of time well will be allowed to be in a violation state before a **Retry** is attempted, in hh:mm format). The remaining values on this page are read only. These include **Live Values**, **Current Violations** (displays the number of consecutive times a parameter has been violated) and **Current Retries** (consecutive times the POC has stopped the well due to a setting violation)**.** The final parameter, **Position Fault,** has fields for **Retries Allowed, Down Time (hh:mm)**, **Current Violations** and **Current Retries.**



With the **Hall Effect** malfunctions, the only value that can be edited for **Belt Slip Alert** is the **Trigger Value**. For **Belt Slip Shutdown**, **Early Start of Stroke**, **Missing Start of Stroke** and **Missing Motor Shaft**, the **Trigger Value**, **Retries** and **Down Time** can be edited. For **Low RPM**, the **Trigger Value**, **Violations Allowed**, **Retries Allowed** and **Down Time** can be edited. With **Hall Effects** enabled, all the **Hall Effects** shutdowns function when enabled. With **Hall Effects** disabled, only **Low RPM** will function.

***NOTE**: Remaining **Down Time** can be viewed on the **Well Status** tab.*

5.1.1 Violations Allowed, Retries and Down Time

The **Violations Allowed** value is the number of times a malfunction parameter may be violated before the POC stops the well. For the **Peak Load, Minimum Load, Fluid Load** and **Malfunction Point,** this value is defaulted to two (2). The number of violations for **Position Fault, Belt Slip Shutdown, Early Start of Stroke, Missing Start of Stroke** and **Missing Motor Shaft** is not a parameter that can be edited by the user.

For **Peak Load** and **Minimum Load** a **Violation** is simply a Surface Card data point. So, if the **Violations Allowed** is set to 3, and 4 Surface Card points in a complete stroke (not necessarily consecutive) exceed the peak or minimum load limits then the well will enter a Fault or Malfunction state depending on the number of **Retries Allowed** and **Current Retries** tallied. For **Fluid Load** and **Malfunction Point** a **Violation** counts as a complete stroke after which the malfunction condition is triggered. Violations are tallied as they occur.

Retries Allowed is the number of times the POC will try to restart the unit before going into a malfunction state. For the **Peak Load, Minimum Load** and all the Hall Effect shutdowns, this value is defaulted to two (2). For **Fluid Load** and **Malfunction Point, Retries Allowed** is defaulted to five (5). For **Position Fault**, this value is defaulted to two (2).

***NOTE**: Recall that if the well violates a parameter more than the permitted number of retries, the well will enter a malfunction state.*

Down Time is the amount of time programmed for each shutdown caused by a violation. **Down Time** can be set in hours and minutes (hh:mm). For **Peak Load, Minimum Load**, **Position Fault** and all the **Hall Effect** shutdowns, the **Down Time** is set for five (5) minutes. **Down Times** for **Fluid Load** and **Malfunction Point** are typically set for 10 minutes.

The **Current Violations** column displays the number of consecutive times a parameter has been violated. The **Current Retries** column shows the consecutive times the POC has stopped the well due to a setting violation. Following a complete stroke in which no violations occur for a specific **Malfunction** (Peak, Min Load, Fluid Load, Malfunction Point), the **Current Violations** and **Current Retries** counts for that **Malfunction** are reset to 0. The **Current Violations** value for the **Hall Effect** shutdowns is reset to 0 at **Gauge-off Time**.

The toggle button on the **Enable** boxes for all five (5) parameters must be switched from **OFF** to **ON** for the function to become active.

Clicking the **Reset Malfunctions** button will restart the well after it has shut down due to a malfunction, violation or "pump off" (see **Control Mode** tab for information regarding "pump off"). This button will also reset the number of violations.

***NOTE**: Any changes made to the parameters in either the **Pump Card** or **Surface Card** tabs are only saved if the **Save** button is clicked. Clicking the **Cancel** button voids any changes. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Saving configuration settings…Success!" if the changes have been saved successfully.*

5.1.2 Surface Card and Pump Card

The **Surface Card** and **Pump Card** tabs both provide a visual representation of where the parameters of the **Malfunctions** have been set and contain the most recent live values for the parameters that have been set. To view the **Surface Card,** click on the **Surface Card** tab. To view the **Pump Card,** click on the **Pump Card** tab.

5.1.3 Peak and Minimum Load

The current **Peak Load** and **Minimum Load** values are shown in the box in the **Live Values** column. These values will change slightly from stroke to stroke and can be used as a reference when setting up the violations for the **Peak** and **Minimum Loads**. In the **Trigger Value** column, enter the desired **Peak** and **Minimum Violation** Load values in pounds.

***NOTE**: The **Peak Load** value should typically be set approximately 15% higher than the live **Peak Load** value. The **Minimum Load** value should typically be set approximately 25% lower that the live **Minimum Load** value.*

5.1.4 Fluid Load

The **Fluid Load** is the weight of the fluid moving through the pump barrel with all buoyancy factors included. This is represented by the calculated area inside the pump card. Set the **Fluid Load** value to approximately 25% of the live **Fluid Load** value.

5.1.5 Malfunction Point

The **Malfunction Point** is an adjustable point that is placed inside the **Surface Card** that is violated when the top of the card (on the upstroke) falls below it. The **Malfunction Point** should be placed at a stable point in the **Surface Card** aligned with a load value equivalent to the **Rod Weight** found on the **Well Config** page. The location of the **Malfunction Point** can be chosen by clicking the mouse at the desired location on the **Surface Card** or by entering the position and load values in the **Malfunction Value** column.

5.1.6 Position Fault

The **Position Fault** is a condition that is caused when the position signal is disrupted or when the position is unable to calibrate. In order to allow the controller to calibrate the change in voltage of the position, the signal should be at least 1.5V from low to high.

5.1.7 Motor Run Detect Timeout

Although the configuration parameters are not visible to the user, the well can violate and malfunction on **Unable to Run, Motor Timeout**. If the controller does not detect a position change within the time specified by the **Run Detect Timeout** on the **Well Config** tab, the well will become **Idle** for a period of 10 minutes. **Motor Run Detect Timeout** is given two (2) **Retries** after which the well will malfunction and will remain shut down until the operator restarts the well.

5.1.8 Belt Slip Alert

The Belt Slip Alert will trigger if the reference revolutions for the current stroke exceeds the reference revolutions value for the previous stroke by the amount of the Trigger Value as a percentage. When enabled and triggered, an orange banner will appear in the upper right corner of the screen stating that the “Belt Slip Alert” has triggered. In addition, an active alert will be visible in the toolbar at the bottom of the screen. Note that this alert will only appear if it is enabled in the toolbar. A value ranging from 1 to 50% can be entered.

***NOTE**: The controller will not shut down on **Belt Slip Alert**. If the unit is to shut down on belt slip then the **Belt Slip Shutdown** must be enabled as seen in section 5.1.8.*

5.1.9 Belt Slip Shutdown

The Belt Slip Shutdown will trigger if the reference revolutions for the current stroke exceeds the reference revolutions value for the previous stroke by the amount of the Trigger Value as a percentage. A value ranging from 1 to 50% can be entered.

5.1.10 Early Start of Stroke

The Early Start of Stroke will trigger if the “Start of Stroke” Hall Effect sensor pulse is received too early compared to the amount of Motor Shaft Pulses received since the previous Start of Stroke pulse. The trigger for Early Start of Stroke is a percentage of the normal reference revolutions value. A value ranging from 80 to 99% can be entered.

5.1.11 Missing Start of Stroke

The Missing Start of Stroke malfunction triggers if a Start of Stroke pulse is not received when expected. The Live Value will increment until the next Start of Stroke pulse is received at which point it will reset to 0. The Trigger Value represents the number of strokes which, once complete, a Start of Stroke pulse must be received otherwise the well will shut down. A value ranging from 2 to 9 must be used.

5.1.12 Missing Motor Shaft

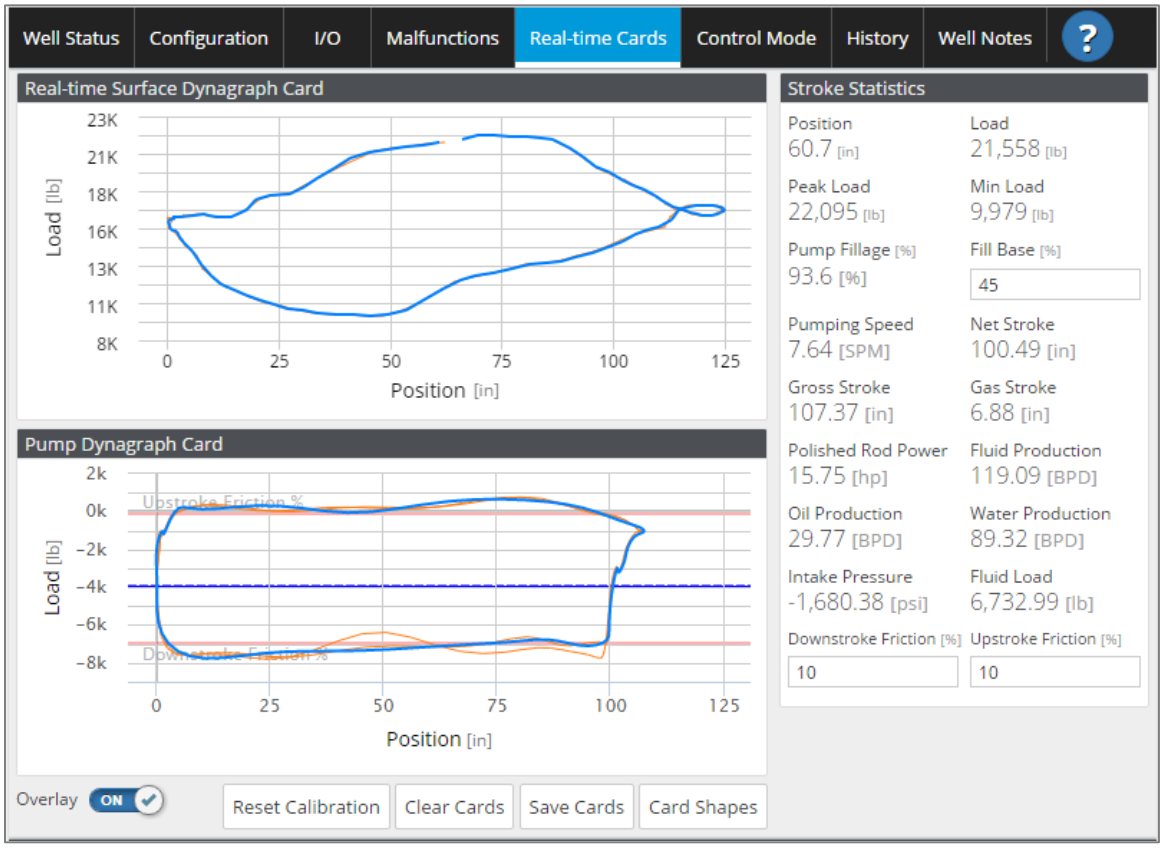
The Missing Motor Shaft malfunction will trigger if the time between Motor Shaft pulses exceeds the time entered for the Trigger Value. A duration of 1 to 20 seconds can be used.

5.1.13 Low RPM

The Low RPM malfunction will trigger if the RPM of the motor as measured by the Hall Effect Motor Shaft Sensor, falls below the trigger value.

Section 6: Real-Time Cards

The SMARTEN/SMARTEN Edge displays live, real-time dynagraph-card information and also, stores historical dynagraph cards.



6.1 Real-Time Surface and Pump Dynagraph Card

The **Real-time Surface Dynagraph Card** is the plot of the point-by-point values gathered for position load. A full card will resemble the shape of an oval or football-like image.

The **Pump Dynagraph Card** is the calculated dynagraph card at the pump. A wealth of well information can be gathered from the card shapes as can be seen from the **Reference Pump Card Shapes** image that appears when the Card Shapes button is pressed. This image displays the 12 basic card shapes that may occur. The ideal card shape is a rectangle; this indicates the well is highly productive and the pump is full. In reality, a combination of the features seen in the basic card shapes will likely be observed. Push the Card Shapes button again to close the image.

The current pump card overlays the previous four (4) pump cards. The **Pump Card** plot can be cleared by clicking the **Clear Cards** button, after which the cards will start to overlay again. The feature of overlaying the **Real-Time Surface Card** and **Pump Dynagraph Card** can be enabled or disabled by toggling the button next to **Overlay** from **OFF** to **ON.** Clicking the **Save** button stores the current card in the **Reference Card Library.** The saved cards can be found by navigating to **History** > **Card Library** > **Reference**.

If the position deviates from its initial calibration point, SMARTEN will automatically recalibrate the position. Recalibrating the position can be done at any time by pushing the **Reset Calibration** button. During the time when the calibration routine is running, the pump card will not be drawn and the scaling on the surface card will vary greatly. The entire recalibration cycle takes four (4) or five (5) strokes.

6.2 Stroke Statistics

There are fifteen (15) fields in the **Stroke Statistics** box that present real-time information about the current operational status of the well. Position and Load provide data that is updated on a point-by-point basis. The remaining items are calculated following the completion of a stroke:

- **Position (in):** The live surface position of the carrier bar scaled according to the stroke length as measured by the position sensing device.
- **Load (lb):** The live surface load weight of the polished rod as measured by the load cell.
- **Peak Load (lb):** The highest surface load value measured in the previous stroke.
- **Min Load (lb):** The lowest surface load value measured in the previous stroke.
- **Pump Fillage (%):** The amount of fluid filling the pump on the last stroke as a percentage of the full pump capacity.
- **Pumping Speed:** The speed of the pump based on the time of the most recent stroke. Measured in strokes per minute (SPM).
- **Net Stroke (in):** The portion of the downhole pump stroke length that produced fluid, calculated from the most recently completed stroke.
- **Gross Stroke (in):** The total downhole pump stroke length calculated from the most recently completed stroke.
- **Gas Stroke (in):** The portion of the downhole pump stroke length that produced gas, calculated from the most recently completed stroke.
- **Polished Rod Power (hp):** The power exerted upon the polished rod during the most recently completed stroke. This is the amount of work per stroke period required to artificially lift the fluid to the surface.
- **Fluid Production (BPD):** The flow rate of all fluid (oil and water) produced by the most recently completed stroke.
- **Oil Production (BPD):** The flow rate of oil produced by the most recently completed stroke.
- **Water Production (BPD):** The flow rate of water produced by the most recently completed stroke.
- **Intake Pressure (PSI):** The pump intake pressure (PIP) exerted on the suction side of the downhole pump, calculated from the most recently completed stroke.
- **Fluid Load (lb):** The weight of the fluid lifted by the downhole pump during the upstroke, calculated from the most recently completed stroke.

Three (3) parameters in the Stroke Statistics box require configuration:

- **Fill Base %:** The location in the **Pump Card** where pump fillage is measured. This is indicated by the dark blue horizontal line intersecting the **Pump Card** whose position is determined as a percentage of the difference between the **Peak** and **Min Load** values measured from the **Min Load** value. This value can be changed by using the arrow keys to select the desired fill-base percentage. Click the **Save** button to preserve the desired value.
- **Downstroke Friction (%):** A measure of the total load differential added to the minimum load of the downstroke. The **Downstroke Friction** is indicated by a light red horizontal line on the **Pump Dynagraph Card** labeled **Downstroke Friction %**. This value can be set from 0% to a maximum of 30%.
- **Upstroke Friction (%):** A measure of the total load differential subtracted from the peak load of the upstroke. The **Upstroke Friction** is indicated by a light red horizontal line on the **Pump Dynagraph Card** labeled **Upstroke Friction %**. This value can be set from 0% to a maximum of 30%.

As an alternative to **Fill Base**, pump fillage can also be measured automatically using **TVO** (traveling value open) **Determination**. The method to measure pump fillage can be selected on the Settings tab found on the Admin page.

NOTE: *The* ***Upstroke Friction*** *and* ***Downstroke Friction*** *values are used as the basis to calculate* ***Fluid Load*** *which also feeds the calculation for* ***Intake Pressure****. As the friction values are adjusted you will notice that the* ***Fluid Load*** *and* ***Intake Pressure*** *values change.*

NOTE*: Any changes made to the* ***Fill Base %*** *are only saved if the* ***Save*** *button is clicked. Clicking the* ***Cancel*** *button voids any changes. If the user attempts to exit this tab before the changes are saved, the message "Your changes have not been saved! If you leave this page, your pending changes will be discarded."*

*Click **Go Back** to save the changes or **Leave** if the changes are to be discarded. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Saving configuration settings…Success!" if the changes have been saved successfully.*

Section 7 Control Mode

There are several options on the **Control Mode** tab that allows the operator to select the mode that will best optimize the well depending on the conditions of the well and available equipment.

On the Mode Setup tab there is a drop-down menu that contains five (5) control options. These include **Host, Pump Fillage, Surface, Timer** and **Variable Pumping Speed.** Each mode is discussed in the sections that follow.

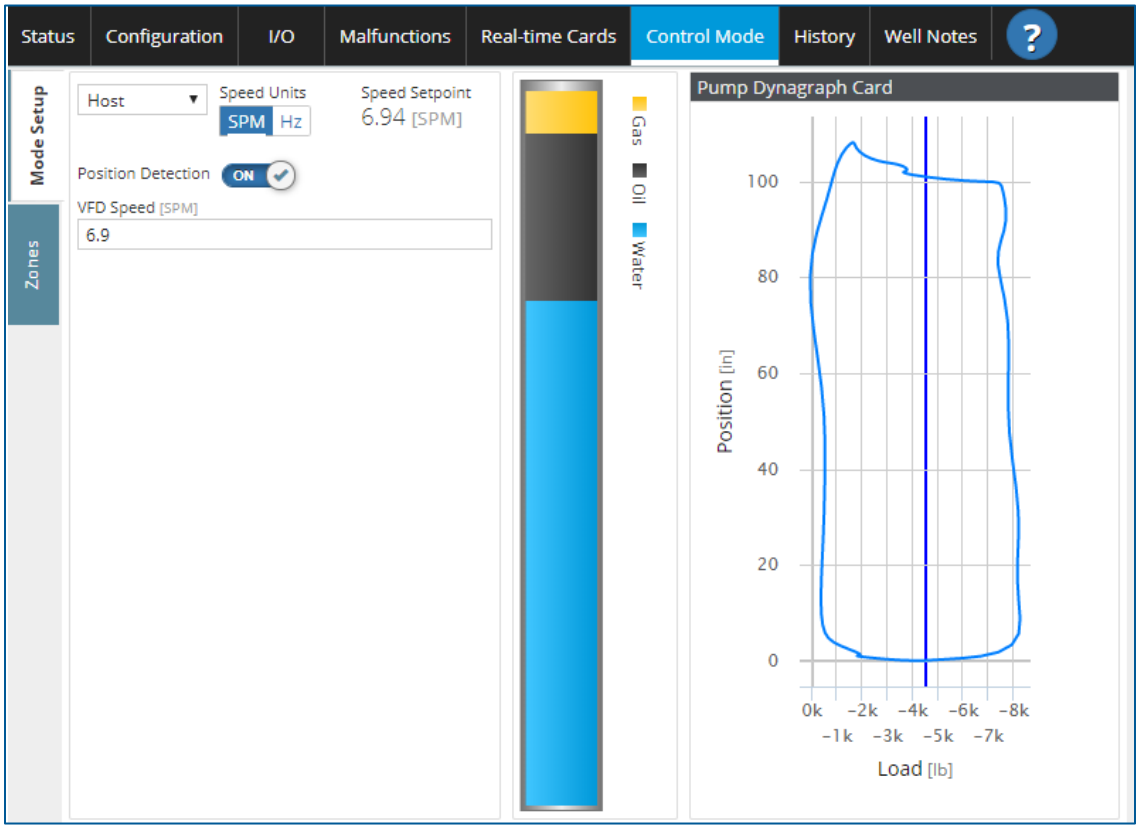
A pump column is visible on the Mode Setup Page which provides a visual for the proportions of fluid (blue = water, black = oil and yellow = gas) in the pump. The Water Cut value entered on the Well Config page determines the proportions of oil and water. Incomplete fillage is represented by yellow and is assumed to be gas. The pump column does not function in Host Mode or Time mode when Position Detection is off. When in Surface Mode the pump column fills with yellow only since fillage is not calculated.

The Pump Dynagraph Card is displayed vertically following the completion of each stroke. The Pump Card is not drawn in Host Mode or Timer Mode when Position Detection is off. When in Surface Mode, the Surface Dynagraph Card is drawn.

Speed units can be chosen to be either SPM or Hz. Selecting SPM or Hz displays the Speed Setpoint in the selected units and also changes the input of VFD Speed accordingly. When in Variable Pumping Speed Mode, all speed settings will be represented in either SPM or Hz depending on what Speed Units have been selected.

Speed Zones can be configured on the Zones tab. This feature is only functional in Variable Pumping Speed mode. See Section 7.5.2 for a full explanation.

7.1 Host



Host mode allows the well to run continuously but will shut down on **Peak** and **Minimum Load** set points and on all analog and digital set points assuming these shutdowns are enabled. The well will *not* pump off in Host Mode.

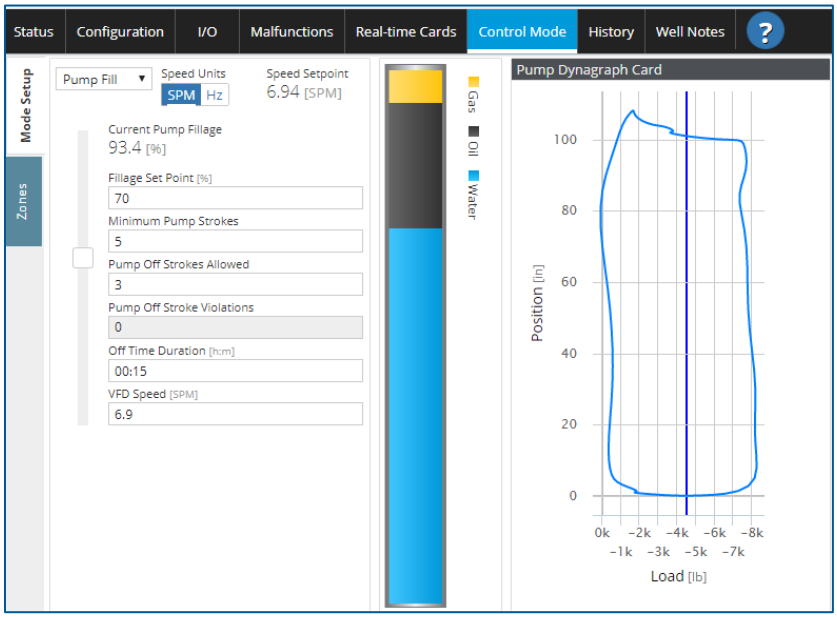
Toggling the button from **OFF** to **ON** next to **Position Detection** allows the controller to collect position data and draw surface and pump cards. If the **Position Detection** is **ON**, all shutdowns will function. Hall Effect shutdowns will only function if Hall Effects are used for position. If **Position Detection** is OFF then only Peak and Minimum Load shut downs will function.

If the controller is connected to a VFD, the value entered for VFD Speed is the speed (SPM or Hz) at which the VFD will run while in this mode. The VFD.Frequency Setpoint tag also outputs this value when assigned to an AOUT channel. Click **Save** once all desired changes have been made.

***NOTE**: If the Control Mode is changed in SMARTEN, the controller will enter the system state **Idle, Operator Stop**. The operator will then have to push the **Start** button on the **Well Status** page to start the well in the new control mode.*

***NOTE:** Any changes made to the **Host** operational parameter are only saved if the **Save** button is clicked. Clicking the **Cancel** button voids any changes. If the user attempts to exit this tab before the changes are saved, the message "Your changes have not been saved! If you leave this page, your pending changes will be discarded." Click **Go Back** to save the changes or **Leave** if the changes are to be discarded. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Saving configuration settings…Success!" if the changes have been saved successfully.*

7.2 Pump Fillage



Pump Fillage mode allows the user to set a **Fillage Set Point (%)** and the conditions if the fillage falls below this value. If the fillage falls below the **Fillage Set Point (%)**, the well will continue to run until it has exceeded the number of **Pump-Off Strokes Allowed.** When this occurs, the well will become idle for the amount of **Off Time Duration** (in hh:mm format) that is specified. The **Fillage Set Point** can be entered using the keyboard, the arrow keys or by dragging the **Fillage Set Point** slider located on the left side of the box to the desired location.

The number of **Minimum Pump Strokes** can also be set on this page. The **Minimum Pump Strokes** state operates once SMARTEN has detected adequate movement from the pumping unit. During **Minimum Pump Strokes** state, **Pump Fillage**, **Fluid Load** and **Malfunction Point** settings are ignored.

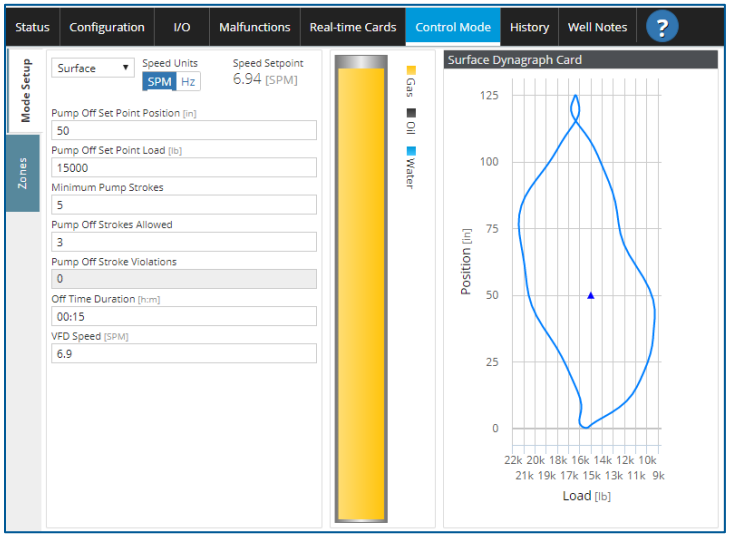
If the controller is connected to a VFD, the value entered for VFD Speed is the speed (SPM or Hz) at which the VFD will run while in this mode. The VFD.Frequency Setpoint tag also outputs this value when assigned to an AOUT channel.

All shutdowns function while running in Pump Fillage mode. Hall Effect shutdowns will only function if Hall Effects are used for position.

***NOTE**: If the Control Mode is changed in SMARTEN, the controller will enter the system state **Idle, Operator Stop**. The operator will then have to push the **Start** button on the **Well Status** page to start the well in the new control mode.*

***NOTE**: Any changes made to the **Pump Fillage** operational parameter are only saved if the **Save** button is clicked. Clicking the **Cancel** button voids any changes. If the user attempts to exit this tab before the changes are saved, the message "Your changes have not been saved! If you leave this page, your pending changes will be discarded." Click **Go Back** to save the changes or **Leave** if the changes are to be discarded. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Saving configuration settings…Success!" if the changes have been saved successfully.*

7.3 Surface



Surface Mode allows the controller to operate based on surface load and position values. This mode may be used when the rod string is unknown or believed to be incorrect. When in **Surface Mode**, the **Surface Dynagraph Card** appears vertically on the **Control Mode** page. Inside the surface card is a triangle symbol that represents the **Pumpoff Setpoint.** If the **Pumpoff Setpoint** falls outside of the downstroke side of the surface card a **Pump Off Stroke Violation** is tallied. If the number of **Pump Off Strokes Violations** exceeds the **Pump Off Strokes Allowed** then the well will shutdown for the **Off Time Duration (hh:mm)**. Following the **Off Time Duration (hh:mm)**, the well will restart and will continue to evaluate the location of the **Pumpoff Setpoint** with regard to the surface card.

The location of the **Pumpoff Setpoint** can be adjusted by clicking the mouse in the desired location only for **Pump Off Set Point Position [in]** and **Pump Off Set Point Load [lb].** These values can be edited by either typing in the desired values or by using the up and down arrows to reach the desired values.

The number of **Minimum Pump Strokes** can also be set on this page. The **Minimum Pump Strokes** state operates immediately when SMARTEN sends the signal to start the pumping unit. During **Minimum Pump Strokes** state, the location of the **Pump Off Set Point** is ignored. The **Fluid Load** and **Malfunction Point** settings are not used in this mode.

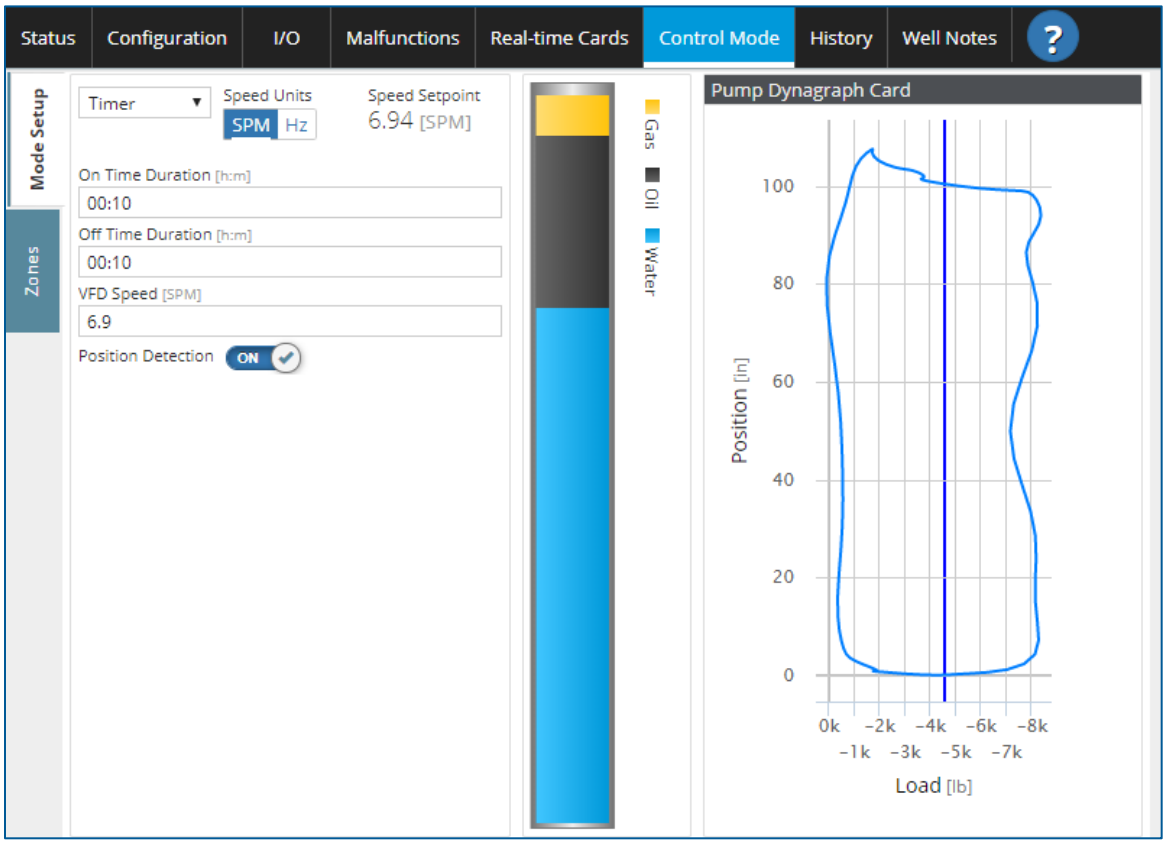
If the controller is connected to a VFD, the value entered for VFD Speed is the speed (SPM or Hz) at which the VFD will run while in this mode. The VFD.Frequency Setpoint tag also outputs this value when assigned to an AOUT channel. While in Surface Mode, all shutdowns will function with the exception of Fluid Load. Hall Effect shutdowns will only function if Hall Effects are used for position.

Click **Save** once all desired changes have been made.

***NOTE**: If the Control Mode is changed in SMARTEN, the controller will enter the system state **Idle, Operator Stop**. The operator will then have to push the **Start** button on the **Well Status** page to start the well in the new control mode.*

***NOTE**: Any changes made to the **Surface** operational parameter are only saved if the **Save** button is clicked. Clicking the **Cancel** button voids any changes. If the user attempts to exit this tab before the changes are saved, the message "Your changes have not been saved! If you leave this page, your pending changes will be discarded." Click **Go Back** to save the changes or **Leave** if the changes are to be discarded. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Saving configuration settings…Success!" if the changes have been saved successfully.*

7.4 Timer



Timer mode allows the user to run the well on a time clock. After selecting **Timer** from the dropdown menu enter values in the **On Time Duration (hh:mm)** and the **Off Time Duration (hh:mm)** fields.

Toggling the button from **OFF** to **ON** next to **Position Detection** allows the controller to collect position data and draw surface and pump cards. If the **Position Detection** is **ON**, all shutdowns will function. Hall Effect shutdowns will only function if Hall Effects are used for position. If **Position Detection** is OFF then only Peak and Minimum Load shut downs will function.

If the controller is connected to a VFD, the value entered for VFD Speed is the speed (SPM or Hz) at which the VFD will run while in this mode. The VFD.Frequency Setpoint tag also outputs this value when assigned to an AOUT channel.

Click **Save** once all desired changes have been made.

***NOTE**: If the Control Mode is changed in SMARTEN, the controller will enter the System State "Idle, Operator Stop." The operator will then have to push the Start button on the Well Status page to start the well in the new control mode.*

***NOTE:** Any changes made to the **Timer** operational parameter are only saved if the **Save** button is clicked. Clicking the **Cancel** button voids any changes. If the user attempts to exit this tab before the changes are saved, the message "Your changes have not been saved! If you leave this page, your pending changes will*

*be discarded." Click **Go Back** to save the changes or **Leave** if the changes are to be discarded. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Saving configuration settings…Success!" if the changes have been saved successfully.*

7.5 Variable Pumping Speed

Several settings are required in order for SMARTEN to effectively control a variable frequency drive. Depending on how the drive is to be controlled hardware and software changes may be necessary. This section describes how to configure the Variable Pumping Speed control mode and assumes that a variable frequency drive has previously been wired and configured to communicate with SMARTEN controller. *Instructions for wiring and configuration for communication with a VFD can be found in section 3.5.*

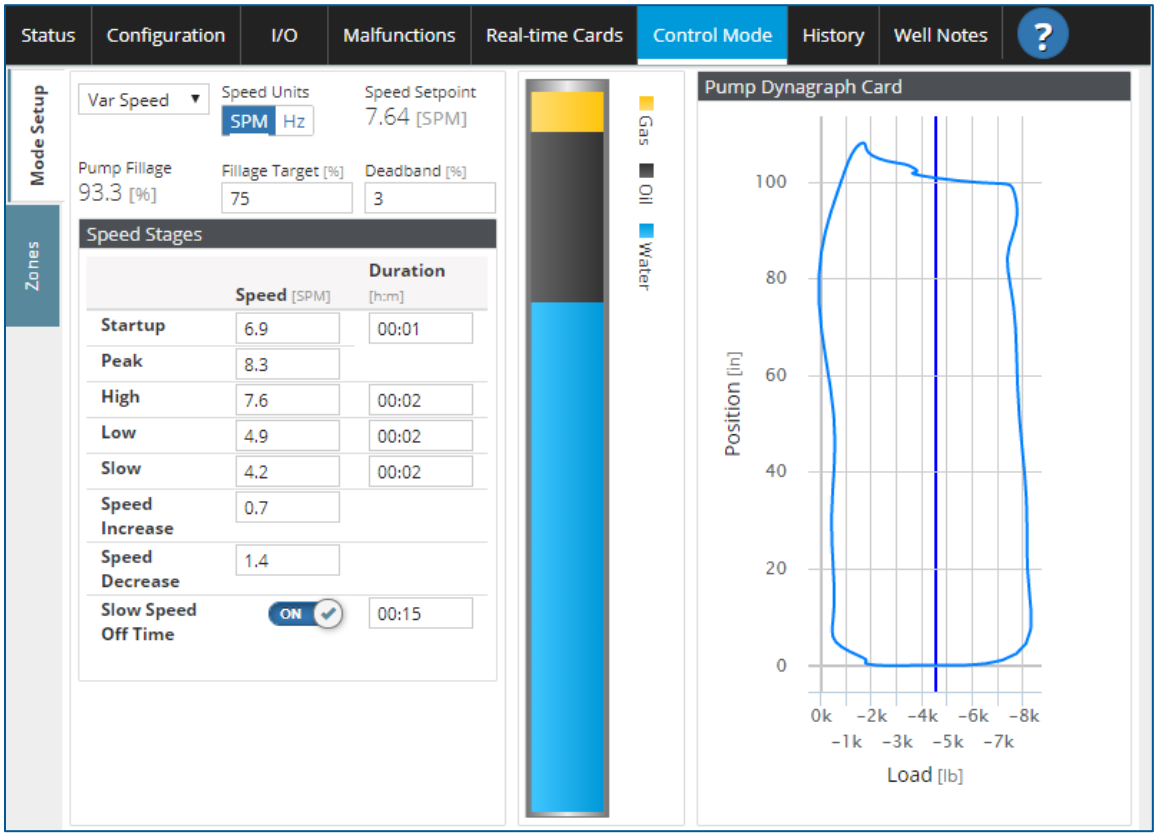
7.5.1 Variable Pumping Speed Configuration

To configure the settings for the drive, select **Variable Pumping Speed** from the dropdown menu on the **Control Mode** tab.

***NOTE**: If the Control Mode is changed in SMARTEN, the controller will enter the system state **Idle, Operator Stop**. The operator will then have to push the **Start** button on the **Well Status** page to start the well in the new control mode.*

Some informational parameters are visible on this page including:

- **Current Pump Fillage (%):** A measure of how full the pump is.
- **Frequency Setpoint (Hz):** The switching frequency of the simulated AC signal sent to the motor by the drive, measured in hertz (Hz).



While operating in the **Variable Pumping Speed** control mode, the **Current Pump Fillage** is assessed following each stroke to determine whether the drive should speed up, slow down or maintain speed. The following settings influence this decision:

- **Pump Fillage Target (%):** The pump-fillage condition that must be met in order to increase drive frequency. If it is not met, the drive frequency is decreased, or the drive is shut down.
- **Deadband (%):** The tolerance of the **Pump Fillage Target** in which no action will be taken. For example, with a **Pump Fillage Target** of 75% and a **Deadband** of 3, no action will be taken between the values of 72% and 78%.

Several other parameters must be configured on this page including:

- **Startup Speed (Hz):** The initial frequency of the VFD at the beginning of the pump ON cycle.
- **Startup Duration (hh:mm):** The length of time the VFD will operate at its **Startup Speed,** measured in hours and minutes.
- **Peak Speed (Hz):** The maximum frequency level the VFD will be allowed to operate at if the pump fillage remains above the **Pump Fillage Target** for the specified **High Speed Duration**, measured in hertz (Hz).
- **High Speed (Hz):** The highest frequency that the VFD will be allowed to operate at as long as the **Pump Fillage Target** is met and the **High Speed Duration** has not expired, measured in hertz (Hz).
- **High Speed Duration (hh:mm):** The amount of time the VFD must successfully operate at its **High Speed** before increasing the speed to the **Peak Speed,** measured in hours and minutes.
- **Low Speed (Hz):** The lowest frequency the VFD will be allowed to operate at as long as the **Pump Fillage Target** has not been met and the **Low Speed Duration** has not expired, measured in hertz (Hz).
- **Low Speed Duration (min):** The amount of time the VFD must maintain the **Low Speed** before reducing the frequency to the **Slow Speed**.
- **Slow Speed (Hz):** The minimum frequency the VFD will operate at if the **Pump Fillage Target** is repeatedly not achieved**,** measured in hertz (Hz).

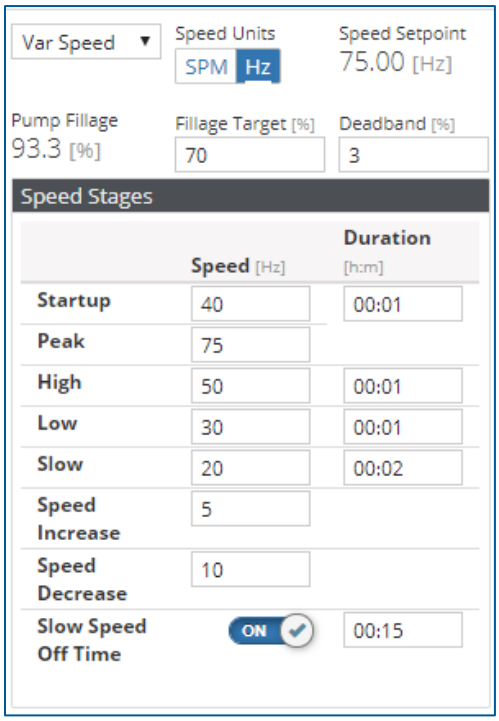
- **Speed Increase (Hz):** The maximum amount the VFD will be allowed to increase its operational speed, measured in hertz (Hz).
- **Speed Decrease (Hz):** The maximum amount the VFD will be allowed to decrease its operational frequency if the **Pump Fillage Target** is not met, measured in hertz (Hz).
- **Slow Speed Duration (hh:mm):** The amount of time the VFD must operate at the **Slow Speed** without achieving the **Pump Fillage Target** before the well will shut down and enter the **Slow Speed Shutdown** state.
- **Slow Speed Offtime (hh:mm):** The duration that the well will remain in the **Slow Speed Shutdown** state measured in hours and minutes.

Slow Speed Shutdown can be enabled by toggling the button from **OFF** to **ON**. If in the **OFF** position, the well will continue to run at the **Slow Speed** indefinitely until the well achieves the **Pump Fillage Target**.

Once all values have been entered, click the **Save** button.

***NOTICE**: Any changes made in the* Configuration *tab are only saved if the **Save** button is clicked. Clicking the **Cancel** button voids any changes. If the user attempts to exit this tab before the changes are saved, the message "Your changes have not been saved! If you leave this page, your pending changes will be discarded." Click **Go Back** to save the changes or **Leave** if the changes are to be discarded. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Well configuration updated by "User!" if the changes have been saved successfully.*

7.5.1.1 VFD Setup and Operation Example



Suppose the drive is setup as shown above. When starting up, the drive is going to operate at its **Startup Speed** for the duration of the **Startup Time**. In this case the **Startup Speed** is 40 Hz and the **Startup Time** is 1 minute (00:01). During this time, the **Well Status** will read **"Running, VFD Startup."**

After the **Startup Time** has expired the well will enter the state **"Running, VFD."** At this point, **Pump Fillage** will be evaluated which will lead to changes in pumping speed. The current operating frequency is indicated on the **Fill Target Tab** and is labeled **Frequency Setpoint**. This can be seen in the image below. If the **Pump Fillage** is above the **Pump Fillage Target**, which in this case 70% and outside the **Deadband** of 3%, the drive speed will increase. Note that with the Deadband of 3%, no speed changes will take place when the Pump Fillage ranges from 70% ± 3% or 67% - 73%. The speed will increase by the amount entered for the **Speed Increase** for every stroke that the **Pump Fillage** exceeds the **Pump Fillage Target**. Therefore, starting at 40 Hz, the speed will increase to 45 Hz then to 50 Hz. The speed will remain at the **High Speed** value for the amount of time entered for the **High Speed Duration**, which in this case is 1 minute (00:01).

If after the **High Speed Duration** has expired and the **Pump Fillage** still exceeds the **Pump Fillage Target**, the speed will continue to increase after every stroke by the amount entered for the **Speed Increase**. In this case, the speed will increase to 55 Hz, to 60 Hz, then 65 Hz, 70 Hz and finally 75 Hz. In this case, 75 Hz is the **Peak Speed**. This is the fastest the drive will go and will remain running at this speed until the **Pump Fillage** drops below the **Pump Fillage Target** value and out of the **Deadband**.

While in the **"Running, VFD"** state, **if** the **Pump Fillage** falls below the **Pump Fillage Target** value and below the **Deadband**, the speed will decrease by the amount set for the **Speed Decrease** value for every stroke that the **Pump Fillage Target** is not met. If the drive is operating at its **Peak Speed** of 75 Hz and then the **Pump Fillage** drops below the **Pump Fillage Target** (70% in this case), and out of the **Deadband**, the drive speed will decrease to 65, 55, 45, 35 and finally the **Low Speed** of 30 Hz. The drive will continue to run at this speed for the **Low Speed Duration** (in this case 1 minute, 00:01).

If the **Pump Fillage** continues to fall below the **Pump Fillage Target** for the **Low Speed Duration**, the speed will be further reduced by the **Speed Decrease** value until the **Slow Speed** has been reached. In this case there will be two steps from the **Low Speed** value of 30 Hz to the **Slow Speed** of 20 Hz. If the **Pump Fillage** continues to fall below

the **Pump Fillage Target** value (70% in this case) for the duration of the **Slow Speed Duration** (2 minutes, 00:02) then the option exists for the well to shut down.

If **Slow Speed Off Time** is not enabled, then the well will continue to run at the **Slow Speed** indefinitely until the **Pump Fillage** value exceeds the **Pump Fillage Target** value at which point the speed will once again increase by the amount entered for the **Speed Increase**. If the **Slow Speed Off Time** is enabled, then the well will shutdown for the amount of time entered, which in this case is 15 minutes (00:15). After the **Slow Speed Off Time** has expired the well will once again startup and run at the **Startup Speed** for the **Startup Duration** and the cycle will continue.

***NOTE**: For information regarding how to enable and configure the SMARTEN controller to communicate via Modbus with the Fuji Frenic Mega, Toshiba AS1 or AS3 inverters, please see section 3.5.*

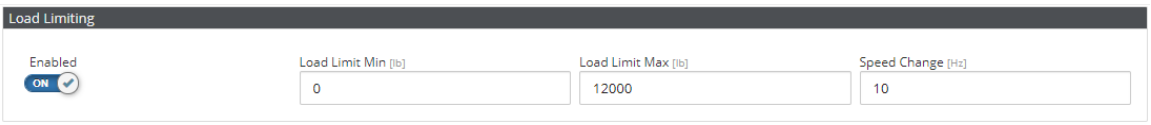
7.5.2 Load Mitigation

There are three features associated with **Load Mitigation**; **Load Limiting, Rod Float Mitigation, and Pump Tag/Fluid Pound Detect**

7.5.2.1 Load Limiting

To use this feature **Load Limit Max** should be set below the **Peak Load** set point, and **Load Limit Min** should be set above the **Minimum Load** set point. When the current stroke peak load exceeds the value entered for **Load Limit Max** the controller will reduce command speed to the VFD in increments specified in **Speed Change [Hz]** per stroke, until it reaches **Slow** speed. The command speed will remain at **Slow** speed until the current stroke peak load no longer exceeds the value entered for **Load Limit Max.**

A similar logic is used for **Load Limit Min**. When the current stroke min load is lower than the value entered for **Load Limit Min** the controller will reduce command speed to the VFD in increments specified in **Speed Change [Hz]** per stroke, until it reaches **Slow** speed. The command speed will remain at **Slow** speed until the current stroke min load is no longer lower than the value entered for **Load Limit Min.**

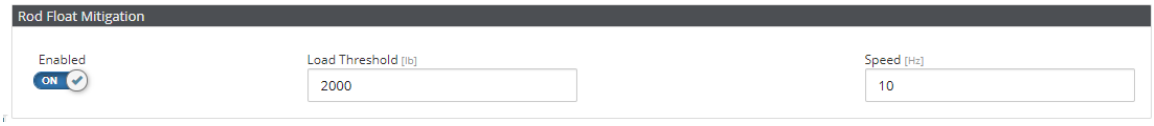


For example, if **Load Limit Max** is set to 12000 lbs and Speed Change is set to 10 Hz, and if the current stroke peak load exceeds 12000 lbs then the controller command speed will reduce VFD speed by 10 Hz per stroke until the speed reaches Slow speed. Once the current stroke peak load no longer exceeds 12000 lbs, then the controller command speed will increase VFD speed in increments specified by **Speed Increase** (Refer to section 7.5.1 Speed Increase)

7.5.2.2 Rod Float Mitigation

This feature is designed to dynamically operate a pumping unit to minimize or eliminate rod float. If rod floating is not a problem for your well it is suggested that you disable this parameter.
There are two fields used with this feature. **Load Threshold [lb]** is the value in load during the down stroke at which the controller will reduce speed. **Speed [Hz]** is the speed at which the controller will slow the drive to, once surface load drops below the **Load Threshold**.

For example, if **Load Threshold** is set to 2000 lbs and **Speed** is set to 10 Hz and surface load drops below 2000 then speed is reduced to 10 Hz during the duration of the stroke which is below 2000 lbs.



7.5.2.3 Pump Tag/Fluid Pound Detect

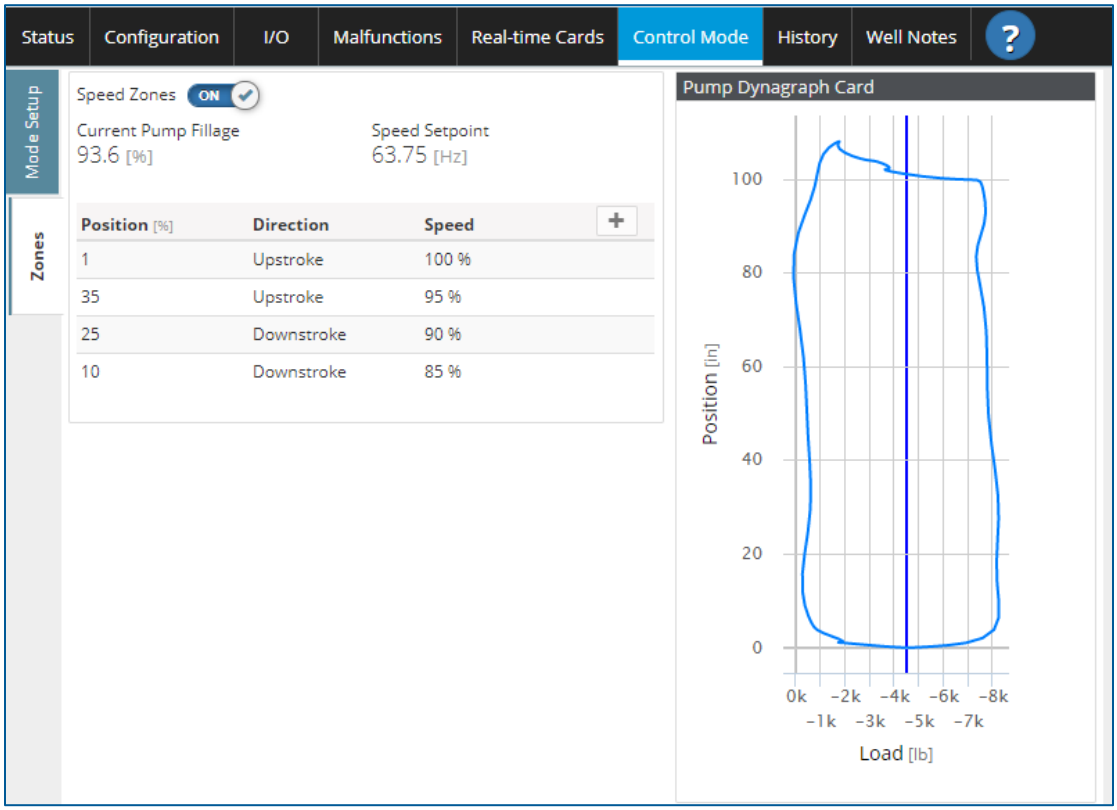
This feature is designed to detect a pump tag and fluid pound. The **Load Change Threshold [lb]** is the value in which the user determines there could potentially be a pump tag and is referring to the delta between two load values of the surface card.

SMARTEN determines *fluid pound* if the delta between the last two load values of the surface card is greater than the **Load Change Threshold** and the surface position is between 5% and 95% of the total stroke length of the downstroke

SMARTEN determines *pump tag* if the delta between the last two load values of the surface card is greater than the **Load Change Threshold** and the surface position is less than 5% or greater than 95% on the downstroke and upstroke respectively.

7.5.3 VFD Speed Zones

***NOTE**: The Speed Zones feature is available when running in Variable Pumping Speed mode.*



On the **Zones** tab, up to 4 **Speed Zones** can be set throughout the stroke which results in the VFD changing speed at defined positions. Click the "+" button to add up to 4 zones. If zones are enabled, at least 2 must be entered.

To set up a speed zone, the **Position** is entered as a percentage of the **Stroke Length**. Position percentages must differ by at least 10% of the stroke length otherwise a warning message will appear stating "Too Close!"

The **Direction** for where in the stroke the speed change must occur is selected as either the Upstroke or Downstroke. Finally, the speed must be entered. The **Speed** is entered either as a percentage of the maximum speed for the current stage, a frequency value or a speed measured in SPM.

In the above image, 4 speed zones have been set. The first zone begins at 1% of the position in the upstroke. The speed for this zone is 100%. At the 35% of the position point in the upstroke, the speed will decrease to 95% of the current speed, followed by 90% speed at the 25% of the position in the downstroke followed by a final reduction to 85% of the speed at 10% of the position in the downstroke. Following the completion of the stroke, this cycle will repeat.

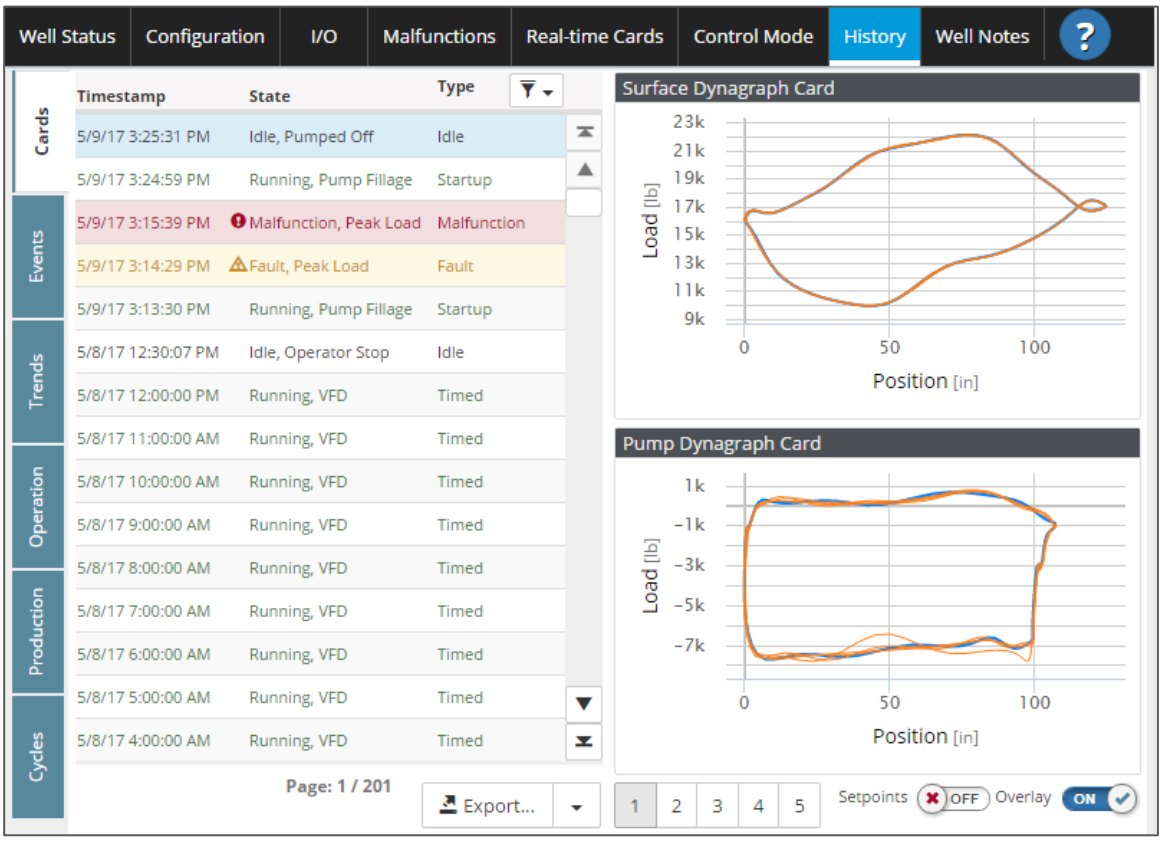
Clicking on each speed zone entry allows for editing of the position, direction, or speed. Click the "X" to the right of the speed zone will delete that particular speed zone entry.

Section 8: History

The **History** tab contains six (6) sub-tabs:

- Cards
- Events
- Trends
- Operation
- Production
- Cycles

8.1 Cards



The SMARTEN controller saves a 5-card set for every significant event including:

- **Startup Card** saved following pump-off down time, HOA set to “Auto” or following a violation
- **Shutdown Card** saved for idle, pump off, fault, malfunction conditions
- **Timed Card** saved every hour
- **Reference Card** saved when the Save button is pushed on the Real-time Cards page.

The Operator can filter the cards using seven (7) different card types. To do so, click on the filter button and then select the desired **Type** from the dropdown menu: **All, Idle, Startup, Timed**, **Reference, Fault** and **Malfunction.** Clicking **Apply** filters the cards according to whatever types have been selected.

Clicking on any line in the Cards history table will display the **Surface** and **Pump Dynagraph Cards** for that time. If the well shutdown due to a load violation or other input violation, a partial surface card will be visible. This partial card represents the surface card data collected prior to the violation.

Use the arrows or scroll bar to view older data. The **Page** indicator will show how many pages of information there are in total (e.g., 1/1, 1/10, 1/20, etc.).

The **Cards** are organized by **Timestamp** (time and date), the **State** that triggered saving the card (Malfunction, Startup, Idle, etc.), or the **Type** of card. Entries are colorized based on the type of card. Green text represents a card collected during normal operation. Blue represents a **Reference** card saved from when the Save button is clicked on the **Real-time Cards** page. Black represents when the well is **Idle** (Pumped Off, Operator Stop). Yellow is used to represent a **Fault** state (Recoverable fault condition. Well will restart following downtime) which is also indicated by a "!" surrounded by a yellow triangle. Red represents a **Malfunction** state (Unrecoverable fault condition. No retries, pump remains halted) which is also indicated by a "!" surrounded by a red circle.

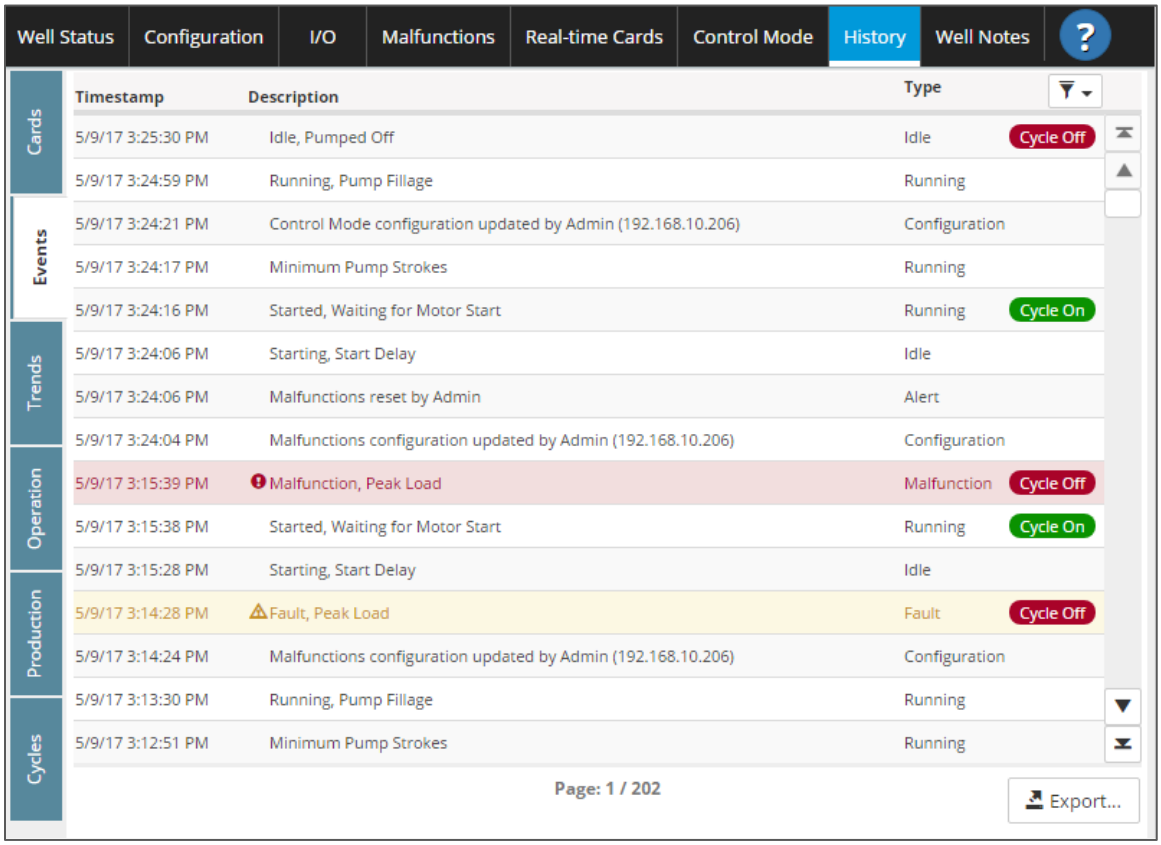
Surface and Pump Dynagraph Card data can be exported for further analysis. Clicking down-arrow next to the **Export** button allows the user to select the format in which to export the card data. Available formats are CSV, JSON and DYN.

For every saved card, the four (4) previous cards are saved as well. The individual cards from the 5-card series can be viewed by clicking on 1, 2, 3, 4, or 5. Card 1 is the oldest and card 5 is the most recent.

The feature of overlaying the **Real-Time Surface** and **Pump Dynagraph Cards** can be enabled or disabled by toggling the button next to **Overlay** from OFF to ON.

The peak and minimum load setpoint lines can also be toggled on and off using the button next to **Setpoints**. These lines indicate the location of the load setpoints at current time, not when the card was collected.

8.2 Events



The **Events** tab shows the Timestamp date and time of any startup, shutdown, violation, malfunction, parameter change, well state, and change in power or user login/logout. Information in the Event Log can be sorted by selecting **All**, **Access, Configuration, Idle, Fault, Malfunction, Power, Running, Alert, Gauge-off** or **Cycle** from the **Type** dropdown menu and clicking **Apply.** The beginning of a cycle is indicated by a green "**Cycle On**" button on right side of the event in which the well has started. The end of a cycle is indicated by a red "**Cycle Off**" button on the right side of the event in which the well has stopped. **Fault** and **Malfunction** events are indicated by yellow and red text respectively.

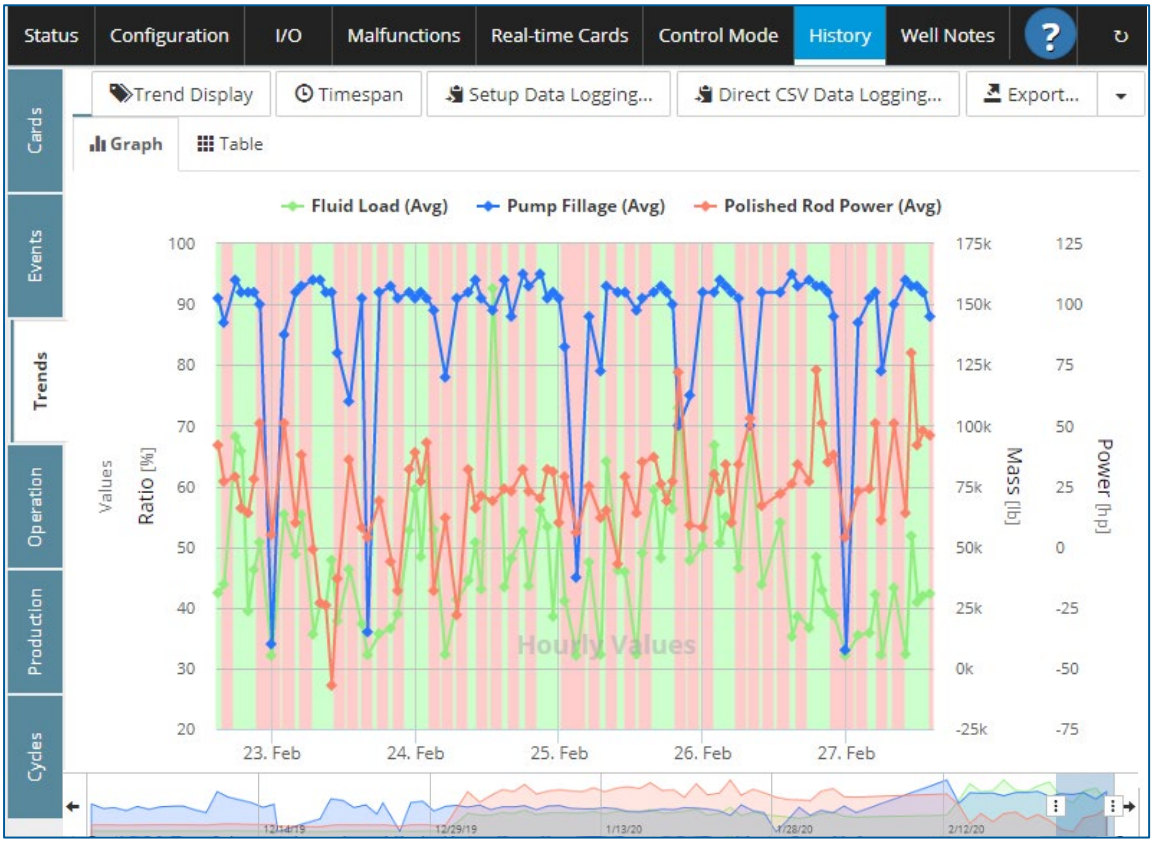
Use the arrows or scroll bar to view older data. The **Page** indicator will show how many pages of information there are in total (e.g., 1/1, 1/10, 1/20, etc.)

Clicking on an event listed in the **Events** log open a window which gives additional details of the event. If the well shuts down on a VFD fault, the fault code will be deciphered in this window.

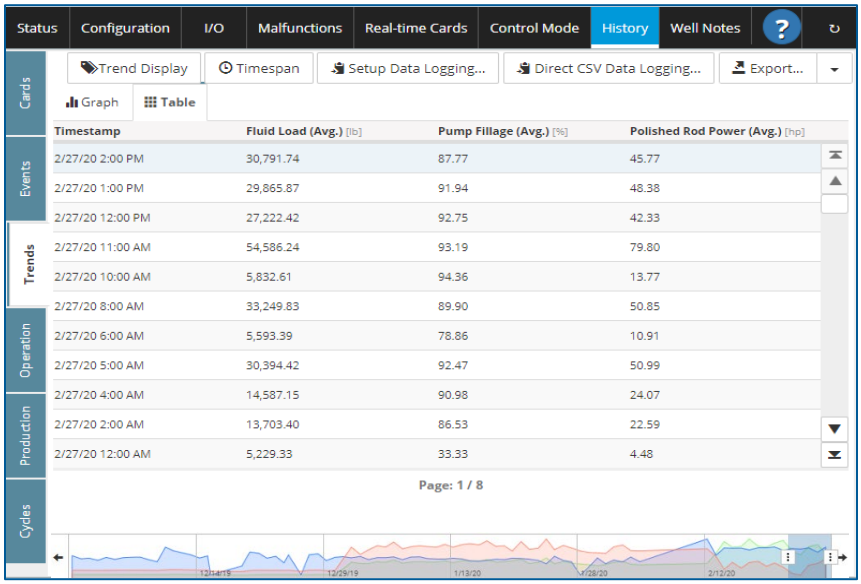
Event Log data can be exported to a CSV file for further analysis by clicking the **Export** button.

8.3 Trends

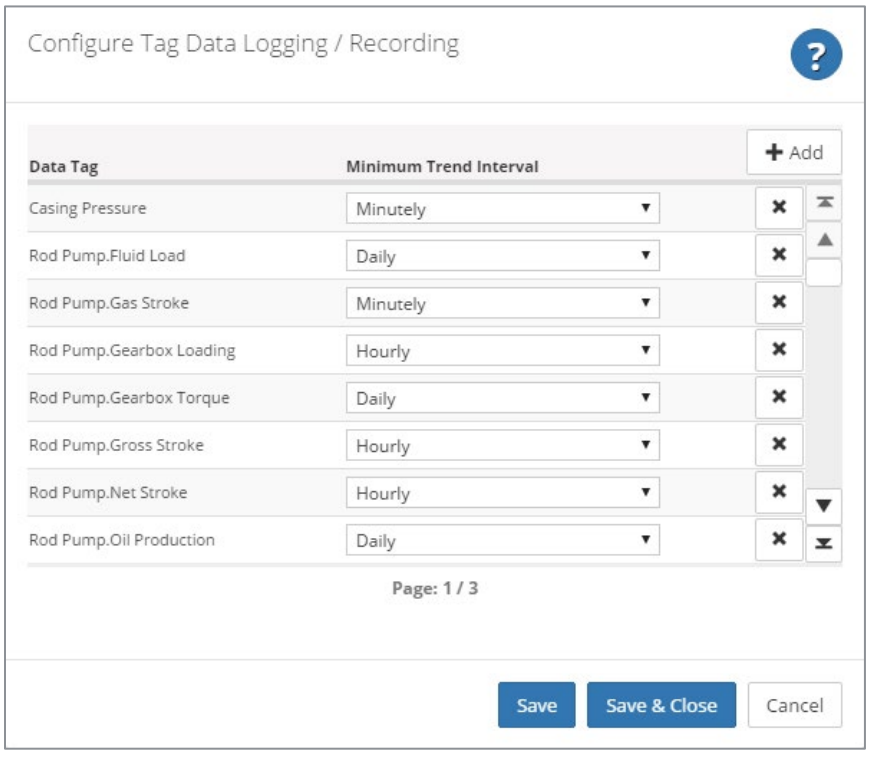
The Trends feature allows for any **Tag** to be set up for **Data Logging**. These **Tags** can then be plotted with respect to time on several different time scales.



The logged data can be display in a graph shown above or a table as seen below. Click the **Graph** or **Table** tabs in the upper left corner of the screen to switch between the graph or table views. Note that only the data visible on the graph will be available in the table.



8.3.1 Setup Data Logging



Clicking on the **Setup Data Logging** button opens the **Configure Tag Data Logging/Recording** window. This is where the tags are chosen to record in the data logger. To setup a **Tag** for data logging, click on the **+Add** button in the upper right corner of the screen. This opens up a menu in which a **Tag** can be selected for logging. **Tags** can be selected from the analog or digital input devices in the **Custom** folder, **Rod Pump** based values, **VFD** parameters or other functions such as **Casing Pressure, Tubing Pressure, Flowline Pressure** and **Commands**. After a **Tag** is selected it will be added to the table of **Tags** being logged.

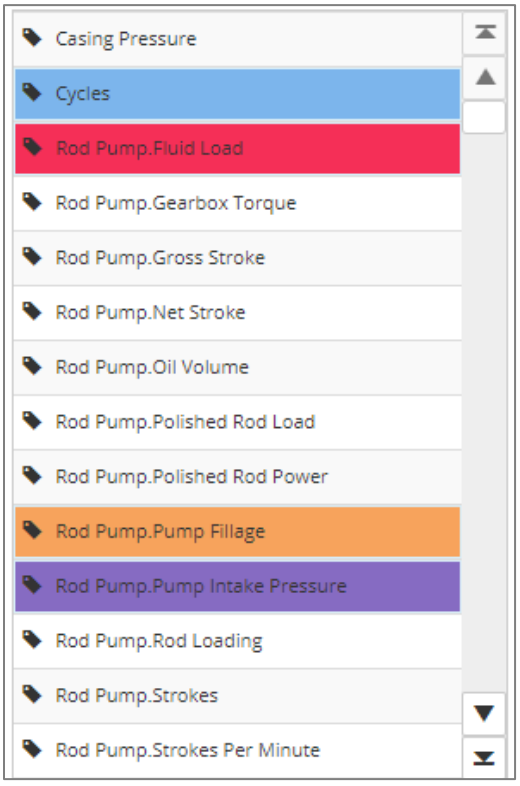
The **Minimum Trend Interval** must be selected before any logging occurs. Options include **Minutely Hourly** or **Daily** trend intervals. Up to six (6) Tags can be trended **Minutely**, fourteen (14) can be trended **Hourly** and twenty-four (24) can be trended **Daily**. After the **Tag** and **Trend Interval** have been selected click **Save & Close** after which the **Tag** will start to be logged. Once setup, the recorded trend history data will then be available to plot in "**Trend Display**" as it becomes available.

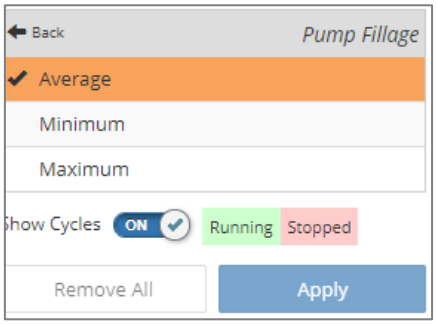
Clicking the **Save** button preserves all changes made and keeps the **Configure Tag Data Logging/Recording** window open. Clicking the **Cancel** button discards all changes made prior to clicking **Save** and closes the **Configure Tag Data Logging/Recording** window.

To remove a **Tag** from the data logging list, click the **"X"** on the row to the right of the **Tag** name. Clicking the **"X"** next to the Tag name does not delete all recorded data it simply stops recording data. So, if the same **Tag** were to be set up for logging again at a later time all previous data would be available up to 90 days prior.

8.3.2 Trend Display

Clicking on the **Trend Display** button opens the list of **Tags** that are currently setup for logging. From this list the tag trend data series (**Average/Minimum/Maximum**) can be selected to display on the graph. Up to ten (10) data series items may be selected to plot simultaneously. If you do not see a tag in this list that you wish to plot, it must be added to the **"Data Logging"** so that its data is recorded and can be plotted later. Once the data series is selected and the **Apply** button is pushed, the data will be plotted on the graph.





Any or all of the tag trend data series (**Average, Minimum, Maximum**) can be plotted simultaneously.

Click the **"← Back"** banner at the top of the current menu to return to the previous **Tag** list. When the **"Remove All"** button is pushed, the user is prompted to confirm to clear all graph selections. Clicking **Yes** turns off all **Trend Displays** and clicking **No** preserves all currently plotted trends.

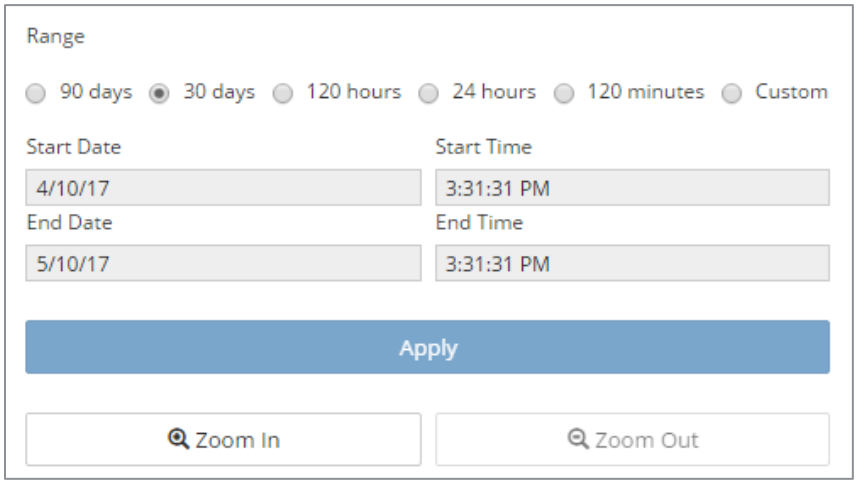
The names of the currently plotted **Tags** are listed above the graph along with a color indicator used to plot each series. Each data series is further described as **Average (Avg), Minimum (Min)** or **Maximum (Max).** The data points for the **Average** plot are indicated by diamond-shaped markers. The data points for the **Minimum** plot are indicated by downward pointing triangles. The color used to represent the **Minimum** values plot is a lighter shade of the color used to represent the **Average** plot. The data points for the **Maximum** plot are indicated by upward pointing triangles. The color used to represent the **Maximum** values plot is a darker shade of the color used to represent the **Average** plot.

Below the selection for **Average, Minimum** or **Maximum** of each **Tag** there is a **Show Cycles** toggle button. When ON, the Running/Stopped cycles will appear as green and red bands on the **Trends** plot. See section 8.3.4 for more details.

Clicking on the **Tag** names at the top of the graph temporarily turns the plots for the **Tags** on and off. Doing so does not affect the **Trends** enabled in the **Trend Display** menu.

8.3.3 Timespan

As data series are added to the graph, axes with the appropriate scale and units are added to the plot. The horizontal axis always represents time. The scale of the horizontal axis can be changed by clicking the **Timespan** button. **Timespans** of **90 days**, **30 days**, **120 hours**, **24 hours,** and **120 minutes** are available. A **Custom** timespan can also be set by choosing the start date and time and the end date and time. Click **Apply** to save the **Timespan** settings and return to the plot.

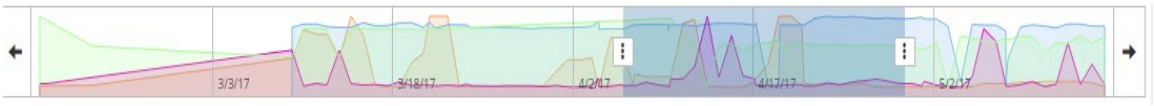


Some detail will be lost as the timespan changes. For example, tags that are trended daily will not appear on the 120-minute scale. On the flip side of that, tags that are trended minutely will lose a great amount of detail when plotted on the 90-day timespan scale when compared to the 120 minute timespan.

The **Zoom** feature on the **Timespan** window allows the user to zoom in or out depending on what time scale is currently being viewed. Zooming in changes the time scale to the next finer scale (days → hours, hours → minutes) while

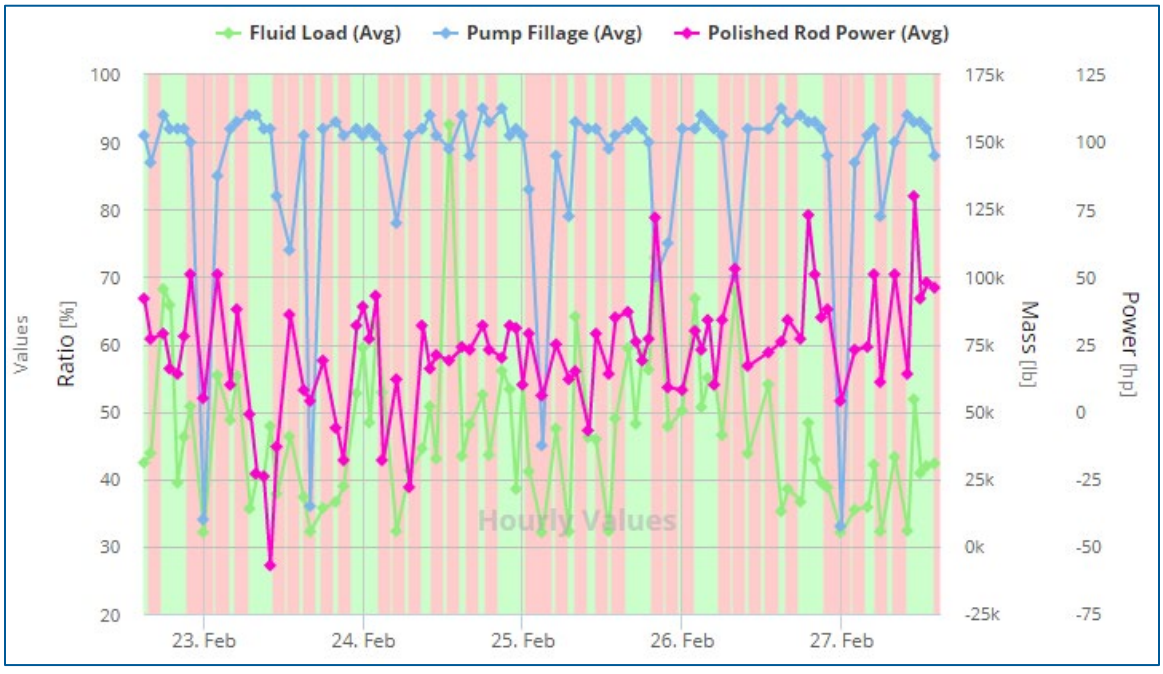
zooming out changes the time scale to the next coarser scale (minutes → hours → days). Zooming in or out centers the plot on the data in the middle of the graph.

Below the main trends graph is a narrow Preview plot which shows other data available on the current time scale. The data displayed on the main plot is represented by the shaded region on the preview plot. When viewed remotely (on a computer for example), the preview can be resized by clicking and dragging the edges of the shaded region. This creates a "zooming" effect but will not change the time scale. Therefore, the size of the preview slice is limited to the data available on the currently selected time scale. The preview slice can be positioned to view other data by clicking and dragging the shaded region to another position on the preview plot. Clicking the arrows to the right and to the left also reposition the preview slice accordingly.



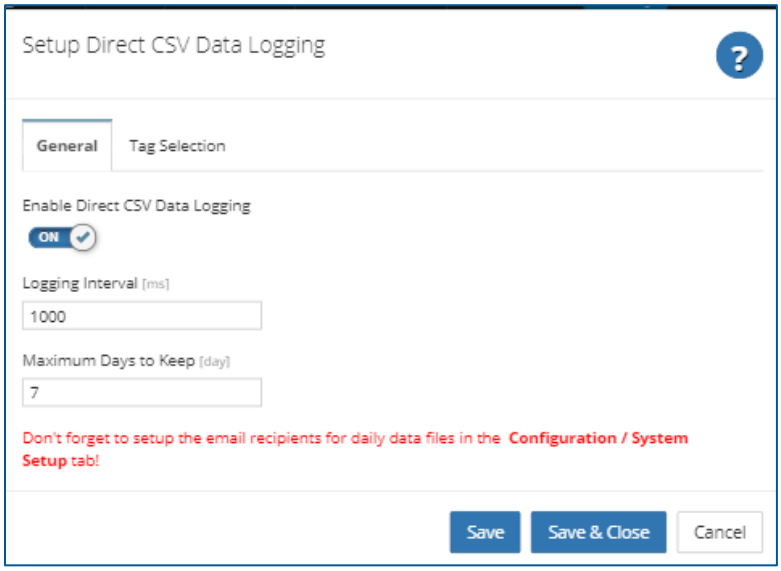
8.3.4 Overlay Cycles

On/Off Cycles can also be plotted on the trends graph by turning on the **Overlay Cycles** feature. When enabled, pump on/off cycles are represented by shaded regions on the background of the graph. Red regions indicate the time spans where the pump was off/stopped and green regions indicate those periods where the pump was on/running. On some time, scales there may be too much cycle data to represent on the graph in which case a warning banner will appear recommending changing to a shorter time range.



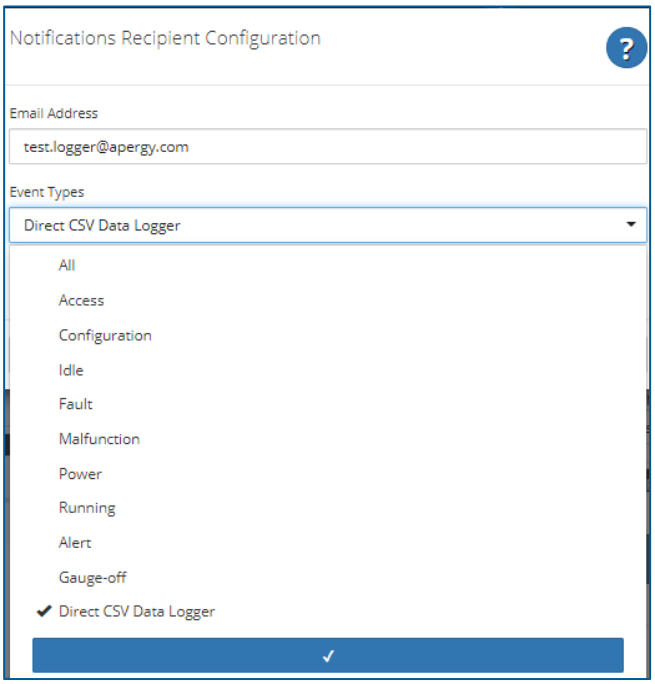
8.3.5 Direct CSV Data Logging

Select tags can be logged as fast as once per second using the **Direct CSV Data Logging** feature. When enabled, the data is saved directly to the controller's memory. The data acquired from this feature can either be exported to a USB flash drive, downloaded to a computer, or emailed to a recipient at Gauge-off Time.



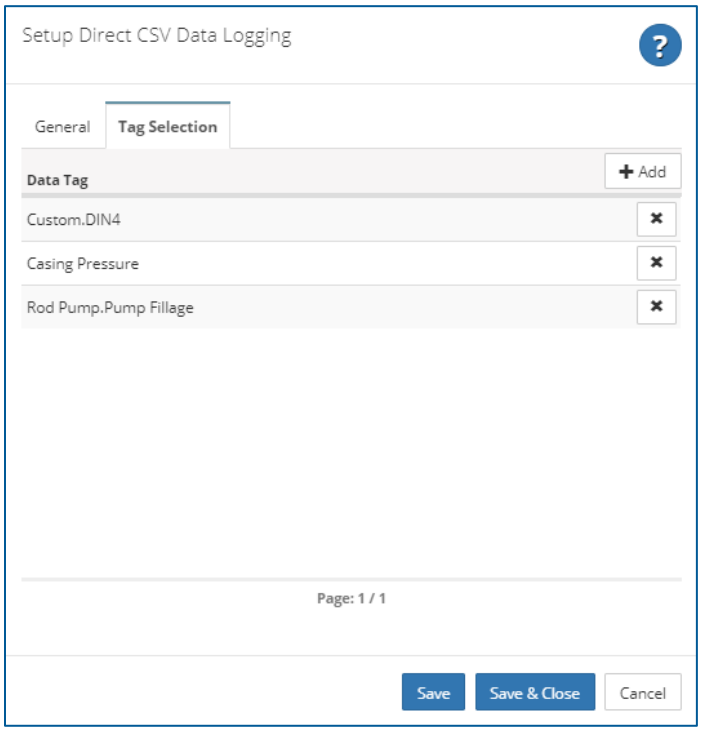
Clicking on the **Direct CSV Data Logging** button on the **History/Trends** page allows for configuration of this feature. Turn the enable button to the On position to allow for **CSV Data Logging**. The logging interval can be chosen for any time between 1000 ms (1 sec) and 60000 ms (60 sec). The Maximum Days to keep is the amount of time that the data will remain on the device. This value can range from 1 day up to 30 days.

There is a message in red stating *"Don't forget to setup the email recipients for the daily data files in the Configuration/System Setup tab."* If internet access is available at the controller, the CSV data file can be emailed to a recipient at Gauge-off Time. This must be set up in the Email Notifications section on the System Setup page. Ensure that the recipients email address is entered correctly, and that Direct CSV Data Logger is selected. For more information on how to configure Email Notifications, please see section 3.2.6.



Back in the **Setup Direct CSV Data Logging** window, click on the **Tag Selection** tab and then the +Add button to select the tags you wish to log. Several folders including Chemical Injection, Commands, Custom, Downhole Gauge, Faults, Rod Pump, State, System and VFD all contain tags available for logging. Other tags available include Auto Switch, Casing Pressure, Cycles, Flowline Pressure, Hand Switch, Production Flow Rate, Runtime, Runtime Display, Runtime Percentage Display, Stroke Calibrated and Tubing Pressure. Click on the tags you wish to log.

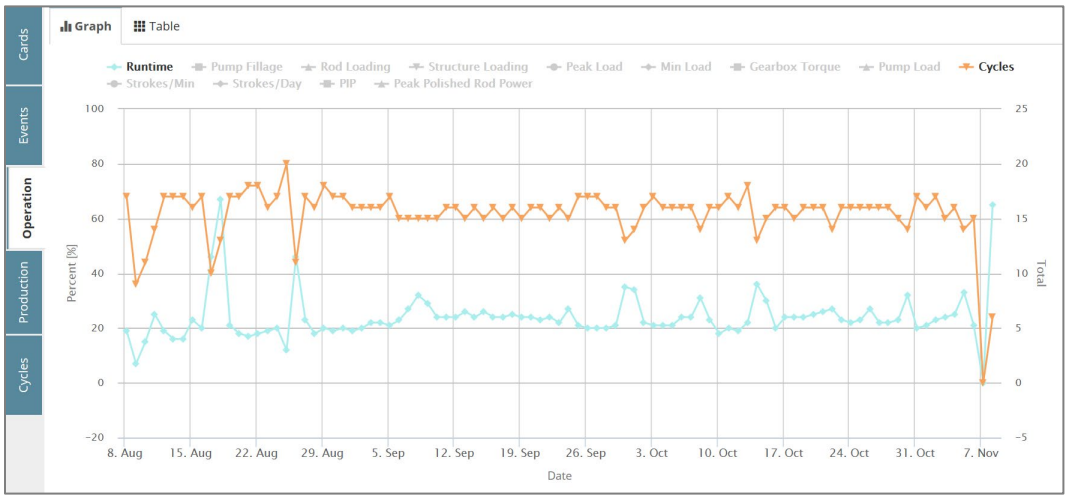
To remove any unwanted tags click the X to the right of the tag name. Note that deleting the tag also deletes all stored data for this tag. Click the Save or Save & Close button to preserve your selections. Clicking the Cancel button discards all changes made since the Save button was last pushed and returns to the Trends page.



In the upper-right corner of the Trends page clicking the downward facing arrow (**v**) gives the option for downloading Direct CSV Data. Selecting this option when logged into the controller remotely or locally downloads the data to your computer. Selecting this option on the display saves the data to a flash drive inserted into a USB port on the controller. When using a computer, the Export – Direct CSV button downloads a zip file to your computer that contains daily CSV files with all tags in one file for a given day. Similarly, when the Export – Direct CSV button is pressed on the display, the data will export to a flash drive.

***NOTE**: In order for the data to export to a flash drive, the flash must be formatted to work with the SMARTEN controller.*

8.4 Operation



Graph | Table

Timestamp	Cycles	Peak Gearbox Torque [in-lbf]	Peak Load [lb]	Min Load [lb]	Avg Fluid Load [lb]	Avg Speed [SPM]	Avg Pump Fillage [%]	Peak Rod Loading [%]	Runtime [%]	Strokes	Peak PIP [psi]	Peak Polished Rod Power [hp]
11/8/16 6:00 AM	6	-95,337	14,719	7,427	4,029	5.5	88.8	28.6	65	5,192	2,092	6
11/7/16 6:00 AM	0	0	0	0	0	0.0	0.0	0.0	0	0	0	0
11/6/16 6:00 AM	15	0	14,707	7,742	0	0.0	0.0	0.0	21	0	0	0
11/5/16 6:00 AM	14	-97,334	14,760	7,632	4,125	5.5	78.8	26.6	33	2,562	1,963	6
11/4/16 6:00 AM	16	-91,030	15,196	6,699	4,770	5.3	73.5	31.1	25	1,927	1,884	7
11/3/16 6:00 AM	15	-97,245	14,829	7,706	4,078	5.4	74.1	35.7	24	1,892	2,027	5
11/2/16 6:00 AM	17	-100,983	14,658	7,639	4,026	5.4	68.2	26.4	23	1,810	2,029	5
11/1/16 6:00 AM	16	-99,946	14,627	7,645	4,039	5.4	69.0	26.6	21	1,646	2,002	5
10/31/16 6:00 AM	17	-99,726	14,692	7,707	4,061	5.4	68.7	26.4	20	1,557	1,971	5
10/30/16 6:00 AM	14	-102,273	14,673	7,578	4,178	5.5	78.5	30.5	32	2,503	1,954	5
10/29/16 6:00 AM	15	-102,635	14,623	7,661	4,056	5.4	73.0	26.2	23	1,816	2,012	5
10/28/16 6:00 AM	16	-102,457	14,638	7,790	4,027	5.4	70.0	26.0	22	1,739	1,982	5
10/27/16 6:00 AM	16	-95,965	14,697	7,602	4,077	5.4	72.5	26.0	22	1,734	1,962	5

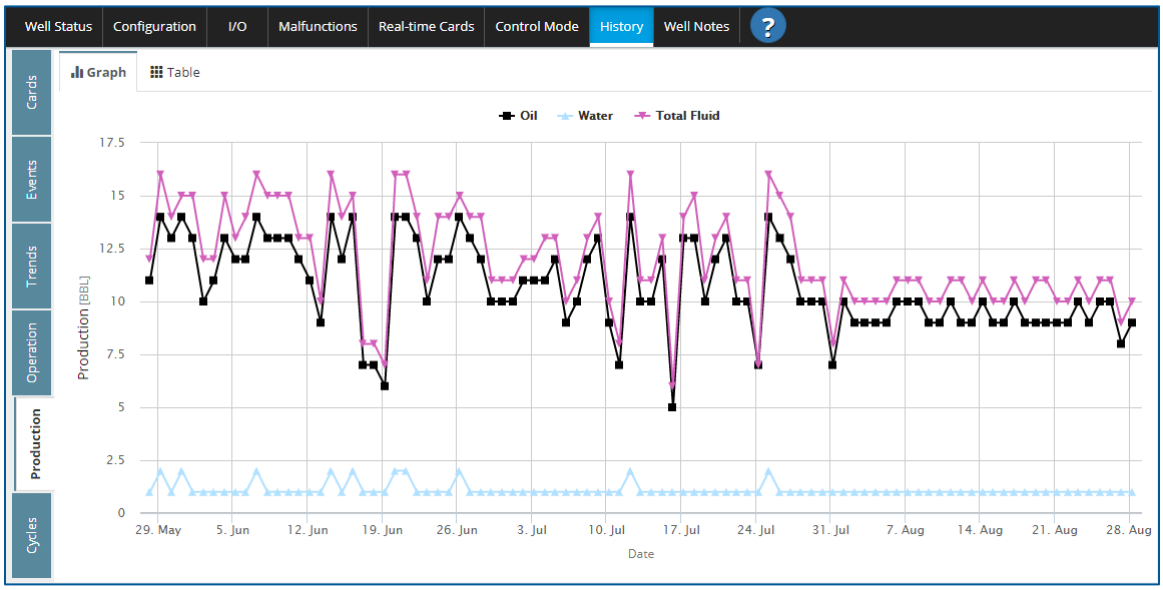
Page: 1 / 8

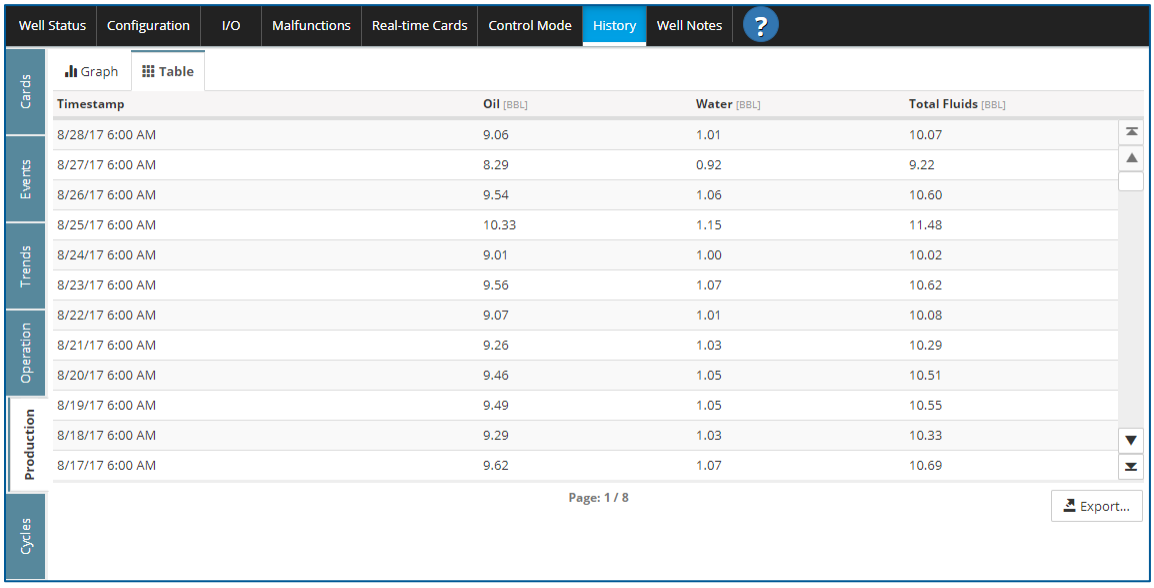
The **Operation History** tab shows the well's operational history as it relates to a number of parameters, including **Runtime, Average Pump Fillage, Peak Rod Loading, Peak Structure Loading, Peak Load, Min Load, Peak Gearbox Torque, Pump Load, Cycles, Average Strokes/Min, Strokes/Day Peak PIP** and **Peak Polished Rod Power.** Click the **Graph** or **Table** tabs to see the information either plotted on a graph or presented in table. When viewing the **Graph**, clicking the parameter buttons at the top of the graph will turn the plots for these parameters on or off. In the **Table** view, use the arrows or scroll bar to view older data. The **Page** indicator will show how many pages of information there are in total (e.g., 1/1, 1/10, 1/20, etc.)

Note that the data for the parameters mentioned previously will only be populated if they setup for trending in the **Data Logger** described in Section 8.3.

On the table view of Operation History, data can be exported to a CSV file for further analysis by clicking the **Export** button.

8.5 Production



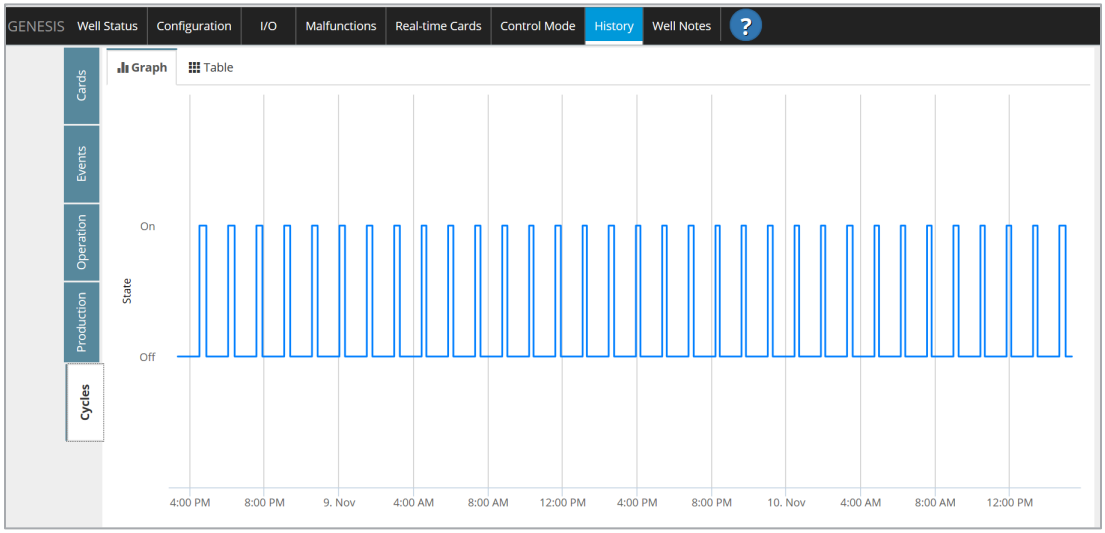


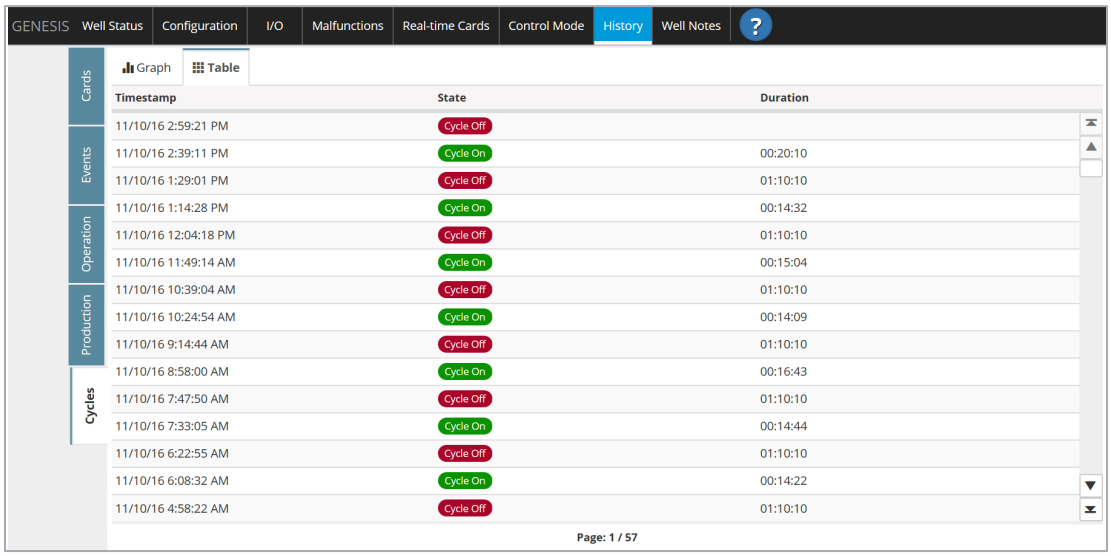
The **Production History** tab shows the well's production of water, oil and total fluids broken down by **Barrels/Day** (b/day) produced and the date and time of day (**Time**). Click the **Graph** or **Table** tabs to see the information presented in either a graphic or table format. When viewing the **Graph** click on **Water, Total Fluid,** and **Oil** buttons along the top of the graph to turn the plots on or off.

In the **Table** view, use the arrows or scroll bar to view older data. The **Page** indicator will show how many pages of information there are in total (e.g., 1/1, 1/10, 1/20, etc.)

On the table view of Production History, data can be exported to a CSV file for further analysis by clicking the **Export** button.

8.6 Cycles





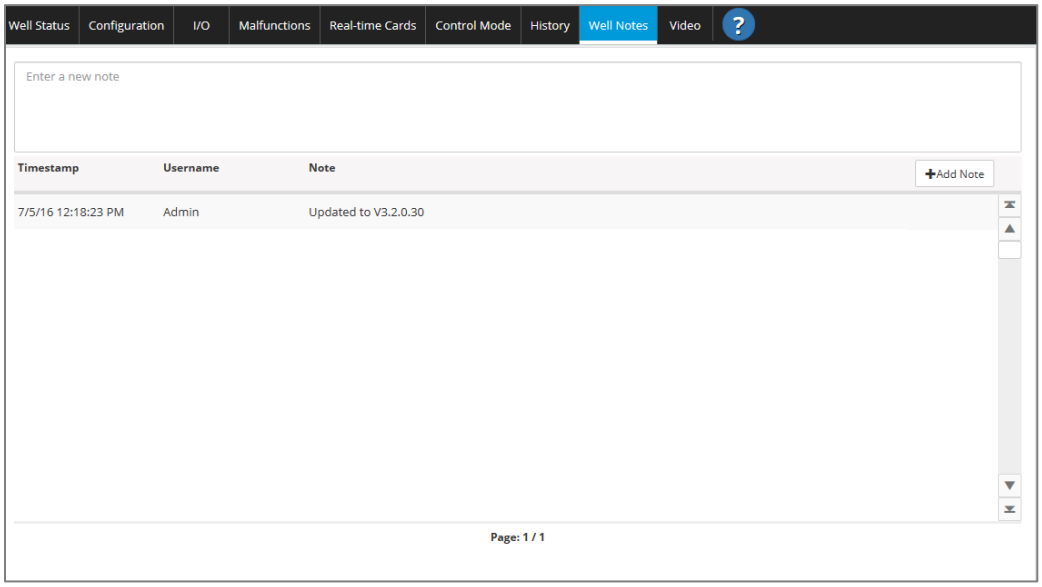
The graph on the **Cycles** tab provides a pictorial view of the on/off cycles for the past 48 hours. When the well is in a **Running** state the plot line will be in the **On** state. When the well is in an **Idle, Fault, Malfunction** or **HOA Off** state the plot line will be in the **Off** state. The time of the cycle is represented by the time axis along the bottom of the graph.

When logged in remotely, hovering over a data point on the plot will show the time/date of that point and the state. Also, when logged in remotely, highlighting a portion of the graph will zoom into that region for a more detailed look at a smaller section of runtime.

Depending on the size of the selected region, the zoom feature can be used multiple times. Click the **Reset zoom** button to return to the full cycle plot.

The table view on the **Cycles** tab lists all **On** and **Off** cycles in the controller's history. Unlike the graphical view, the table view is not limited to the last 48 hours. Every cycle is time-stamped with the duration of each cycle listed on the right side of the table. In the middle column of the table is the **State**. A green "**Cycle On**" button represents the time during which the well was running. A red "**Cycle Off**" button represents the time during which the well was in an **Idle** or **Malfunction** state.

Section 9: Well Notes



The **Well Notes** tab allows the operator to record notes that may be helpful in the future regarding the well's operation or of the SMARTEN controller itself. Users can write notes and reminders that other users of the system can reference.

Once a note has been entered into the field that contains "Enter a new note", click the **Save** button to save the note. Once saved, the note will be listed in the table below. Clicking on the note in the table allows it to be edited. A note can be deleted by clicking on it and then clicking the "X" to the right of the note.

NOTICE

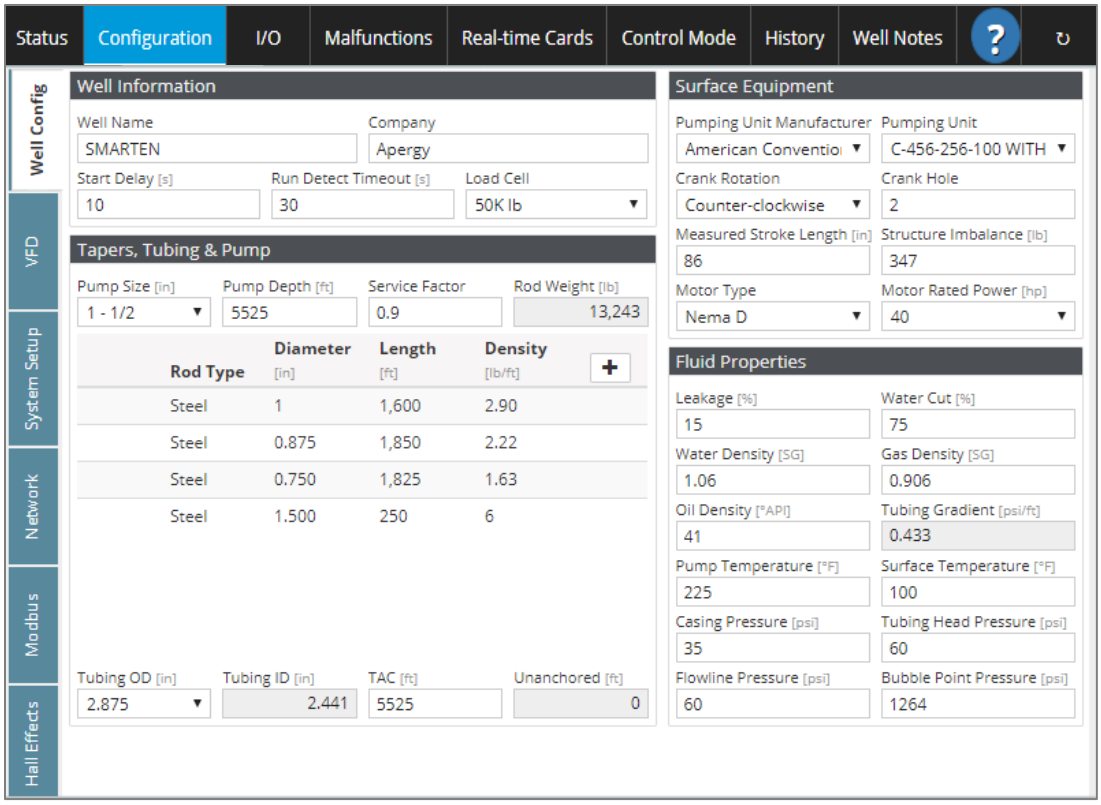
NOTE: *Any changes made to the **Well Notes** tab are only saved if the **Save** button is clicked. Clicking the **Cancel** button voids any changes. If the user attempts to exit this tab before the changes are saved, the message "Your changes have not been saved! If you leave this page, your pending changes will be discarded." Click **Go Back** to save the changes or **Leave** if the changes are to be discarded.*

Appendix A: A Quick Start Guide

The **Quick-Start Guide** gives the operator a quick-and-easy way to start operating the SMARTEN/SMARTEN Edge system. Quick-start instructions follow for two (2) critical operations:

- Well Configuration
- Malfunction Setup

A.1 Well Configuration



Beginning in the Configuration tab, in the **Well Information** box, enter a **Well Name** and **Company** name, as well as the **Start Delay(s)** and **Run Detect Timeout(s)** parameters, both of which are measured in seconds.

In the **Tapers, Tubing & Pump** box, enter the information (use dropdown menus where available) for **Pump Size (in), Pump Depth (ft), Service Factor, Rod Type, Diameter (in), Length (ft), WPF (lb/ft), Tubing OD (in), Tubing ID (in), TAC (ft)** and **Unanchored (ft)**, keeping in mind that the value for **Pump Depth (ft)** should be the same as the combined values for the rod **Lengths (ft).**

In the **Surface Equipment** box, select the **Pumping Unit Manufacturer** and **Pumping Unit** from the available dropdown menus. Also enter the information or use the dropdown menus to select the values/parameters for **Crank Rotation, Crank Hole, Measured Stroke Length (in), Structure Imbalance (lb), Motor Type** and **Motor Full Load (hp).**

In the **Fluid Properties** box, enter the appropriate values for **Leakage (%), Water Cut (%), H_2O Density (SG), Gas Density (SG), Oil Density (API), Tubing Gradient (psi/ft), Pump Temperature (ºF), Surface Temperature (ºF), Casing Pressure (psi), Tubing Head Pressure (psi), Flowline Pressure (psi)** and **Bubble Point Pressure (psi).**

***NOTE**: If any of the previous information is entered incorrectly then inaccurate card shapes, production values and load values will result.*

Click the **Save** button to save all recorded information.

***NOTE**: Any changes made in the* Configuration *tab are only saved if the **Save** button is clicked. Clicking the **Cancel** button voids any changes. If the user attempts to exit this tab before the changes are saved, the message "Your changes have not been saved! If you leave this page, your pending changes will be discarded." Click **Go Back** to save the changes or **Leave** if the changes are to be discarded. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving configuration settings…" followed by a ghosted green box with the message, "Saving configuration settings…Success!" if the changes have been saved successfully.*

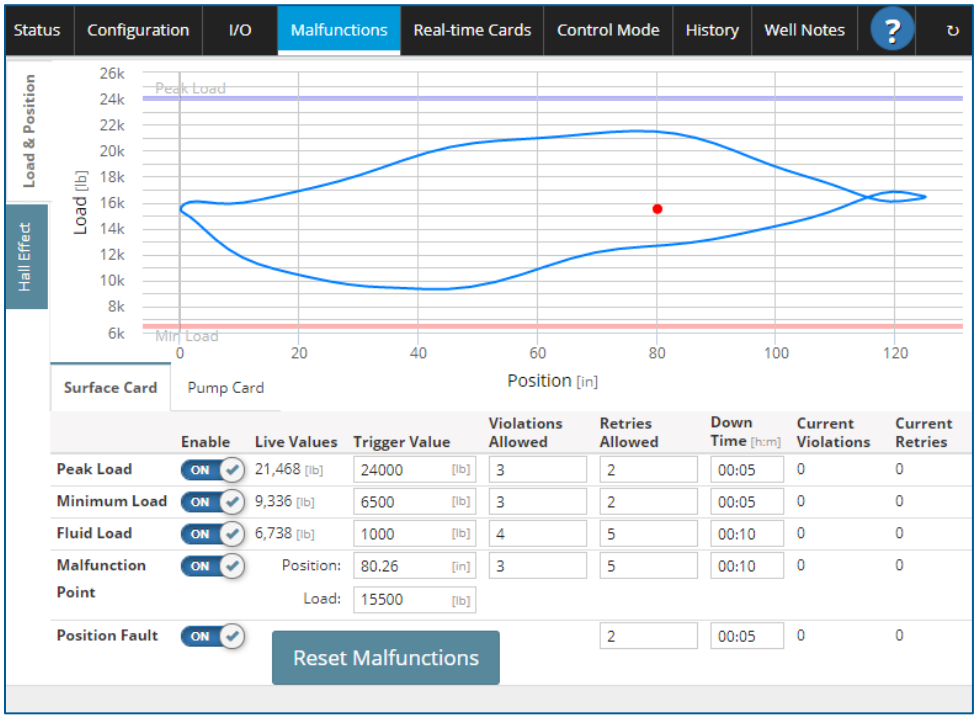
A.2 Position

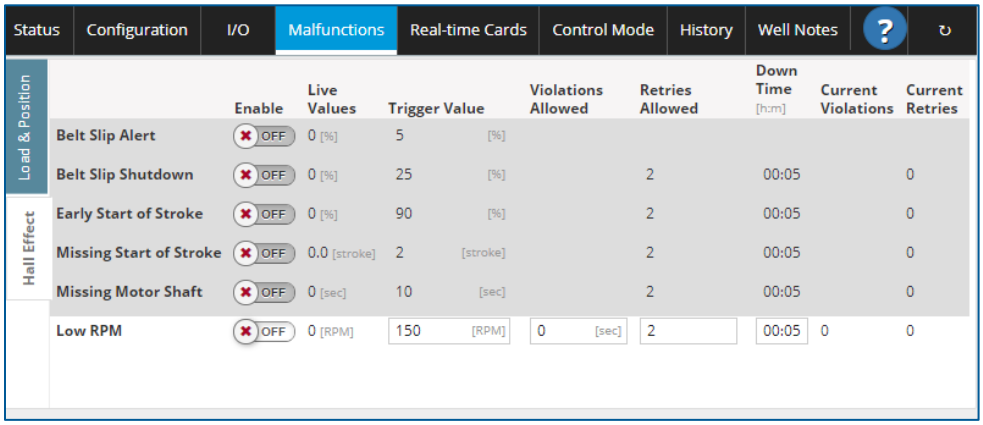
It is essential that position is configured on an analog input channel when using the inclinometer for two digital input channels when using Hall Effects. Please see sections 4.1.1.4 for analog position configuration or section 3.6 for Hall Effect set up.

A.3 Malfunction Setup

The **Malfunction Setup** tab enables the user to individually set up malfunction conditions for five (5) different load and position parameters and an additional five (5) Hall Effect related parameters and 1 alert:

- Peak Load
- Minimum Load
- Fluid Load
- Malfunction Point
- Position Fault
- Belt Slip Alert (Hall Effect)
- Belt Slip Shutdown (Hall Effect)
- Early Start of Stroke (Hall Effect)
- Missing Start of Stroke (Hall Effect)
- Missing Motor Shaft (Hall Effect)
- Low RPM





Use the live values to assist you in determining the appropriate value(s) to enter in the malfunction value box(es). Then enter the desired number of **Violations, Retries Allowed** and **Down Time** (hh:mm). Click the **Save** button to save all recorded information.

If the malfunction parameters need to be edited, click in the appropriate text box to make edits, and click **Save** when finished.

Clicking the **Reset Malfunctions** button resets all violations, malfunctions, and retries to zero (0) and restarts the well.

NOTICE

***NOTE**: Any changes made in the* Malfunctions *tab are only saved if the **Save** button is clicked. Clicking the **Cancel** button voids any changes. If the user attempts to exit this tab before the changes are saved, the message "Your changes have not been saved! If you leave this page, your pending changes will be discarded." Click **Go Back** to save the changes or **Leave** if the changes are to be discarded. Additionally, when the **Save** button is clicked, a ghosted blue box will appear in the upper-right corner of the page with the message, "Saving*

configuration settings…" followed by a ghosted green box with the message, "Saving configurations settings…Success!" if the changes have been saved successfully.

Appendix B: System States

The chart below catalogs all the possible system states of the SMARTEN controller.

Status Text	Description of State
Null	No Data
Invalid State	Undetermined Conditions
Powered Off	No Power to Controller
System Power On	Scheduled Start-Up Delay
Starting, Start Delay	Alarm Sounding, Well Preparing to Start
Stroke Calibration	Calibration of Load and Position
Minimum Pump Strokes	Well Starting, Running Through Min. Strokes
Running, Pump Fillage	Running, Controlled by Pump Fillage on Pump Card
Running, Host	Well Running in Host Mode
Running, Timer	Running, Controlled by Timer
Running, HOA in Hand	Well Running with HOA in Hand Position
Running, Surface Mode	Running, Controlled by Surface Card Pump-Off Set Point
Fault, Unable to Run, Motor Timeout	Downtime due to Insufficient Change in Position
Malf, Unable to Run, Motor Timeout	Stopped due to Insufficient Change in Position
Malfunction, Unable to Stop	Controller Receiving Adequate Position Signals When It Shouldn't
Idle, Pumped Off	Downtime due to Insufficient Pump Fillage
Fault, Setpoint	Downtime due to Violation of Set Point In Surface Card
Fault, Peak Load	Downtime due to Violation of Peak Load
Fault, Min Load	Downtime due to Violation of Min Load
Idle, HOA in Off	Controller On, HOA In Off Position
Idle, Host	Host Mode, Off
Idle, Timer	Downtime due to Timer Mode
Idle, Surface Pumpoff Setpoint	Downtime due to Surface Card Pump-Off Set Point
Fault, Low Fluid Load	Downtime due to Violation of Fluid Load
Fault, Position Fault	Downtime due to Insufficient Position Signal
Idle, Operator Stop	Stop Button Pushed by Operator on Display, Remote or SCADA
Malfunction, Peak Load	Stopped due to Violation of Peak Load Value
Malfunction, Min Load	Stopped due to Violation of Min Load Value
Malfunction, Setpoint	Stopped due to Violation of Set Point in Surface Card
Malfunction, Position Fault	Stopped due to Insufficient Position Signal
Malfunction, Low Fluid Load	Stopped due to Low Fluid Load
Running, VFD	Running, Controlled by VFD Parameters
Idle, VFD Slow Speed	Downtime due to VFD Slow-Speed Shutdown, Insufficient Pump Fillage
Fault, {{ChannelLegend}} {{ChannelLabel}} Minimum	Downtime due to Analog Input Channel Minimum

Fault, {{ChannelLegend}} {{ChannelLabel}} Maximum	Downtime due to Analog Input Channel Maximum
Malfunction, {{ChannelLegend}} {{ChannelLabel}} Minimum	Stopped due to Analog Input Channel Minimum
Malfunction, {{ChannelLegend}} {{ChannelLabel}} Maximum	Stopped due to Analog Input Channel Maximum
Malfunction, Invalid HOA State	Stopped due to Invalid HOA Status
Fault, {{ChannelLegend}} {{ChannelLabel}} Fault	Downtime due to Digital Input Channel Violation
Malfunction, {{ChannelLegend}} {{ChannelLabel}} Fault	Stopped due to Digital Input Channel Violation
Started, Waiting for Motor Start	Start Signal Set to Motor, Waiting For Movement
Running, VFD Startup	Well Starting Up, Running in VFD Mode
Fault, Low Frequency	Downtime due to Low Frequency of Incoming AC Power
Malfunction, Low Frequency	Stopped due to Low Frequency of Incoming AC Power
Fault, Underload	Downtime due to Low Current Load on Drive
Malfunction, Underload	Stopped due to Low Current Load on Drive
Fault, Overload	Downtime due to High Current Load On Drive
Malfunction, Overload	Stopped due to High Current Load on Drive
Fault, VFD Fault ({{TriggerValue}})	Downtime due to VFD Fault
Malfunction, VFD Fault ({{TriggerValue}})	Stopped due to VFD Fault
Fault, VFD Comm Fault	Downtime due to VFD Communication Fault
Malfunction, VFD Comm Fault	Stopped due to VFD Communication Fault
Fault, Custom Function	Downtime due to Custom Function Violation
Malfunction, Custom Function	Stopped due to Custom Function Violation
Idle, Master Restart Delay	Downtime due to Master Restart Delay
Fault, Acquisition Error	Downtime due to Data Acquisition Error
Malfunction, Acquisition Error	Stopped due to Data Acquisition Error
Running, ESP Gas Lock Recovery	Running, controlled by Gas Lock Recovery parameters
Running, ESP Rocking Start	Running, controlled by Rocking Start parameters
Idle, ESP Rocking Start	Downtime, due to Rocking Start parameters
System Shutting Down	System shutting down/restarting
Halt, VFD Emergency Stop	Stopped due to stop command from VFD
Running, PCP	Running, controlled by PCP parameters
Fault, High Rod Torque	Downtime due to high rod torque
Malfunction, High Rod Torque	Stopped due to high rod torque
Fault, Low Rod Torque	Downtime due to low rod torque
Malfunction, Low Rod Torque	Stopped due to low rod torque
Fault, Low Production Flow	Downtime due to low production
Malfunction, Low Production Flow	Stopped due to low production
Fault, High Flow Line Pressure	Downtime due to high flow line pressure
Malfunction, High Flow Line Pressure	Stopped due to high flow line pressure

Fault, Low Flow Line Pressure	Downtime due to low flow line pressure
Malfunction, Low Flow Line Pressure	Stopped due to low flow line pressure
Fault, High Stuffing Box Pressure	Downtime due to high stuffing box pressure
Malfunction, High Stuffing Box Pressure	Stopped due to high stuffing box pressure
Fault, Low Stuffing Box Pressure	Downtime due to low stuffing box pressure
Malfunction, Low Stuffing Box Pressure	Stopped due to low stuffing box pressure
Running, ESP PID	Running, controlled by PID parameters
Running, Low Rod Torque	Running, controlled by low rod torque parameters
Running, PCP Startup	Well Starting Up, Running in PCP Mode
Running, High Rod Torque	Running, controlled by high rod torque parameters
Running, PCP PID	Running, controlled by PCP PID parameters
Fault, No Motor Shaft Pulses	Downtime due to no motor shaft pulses
Malfunction, No Motor Shaft Pulses	Stopped due to no motor shaft pulses.
Fault, No Start of Stroke Pulses	Downtime due to no start of stroke pulses
Malfunction, No Start of Stroke Pulses	Stopped due to no start of stroke pulses
Fault, Belt Slip	Downtime due to belt slip
Malfunction, Belt Slip	Stopped due to belt slip
Fault, Early Start of Stroke Pulse	Downtime due to early start of stroke pulse
Malfunction, Early Start of Stroke Pulse	Stopped due to early start of stroke pulse
Fault, AIN1 High	Fault due to high value trip on AIN1
Fault, AIN1 Low	Fault due to low value trip on AIN1
Fault, AIN2 High	Fault due to high value trip on AIN2
Fault, AIN2 Low	Fault due to low value trip on AIN2
Fault, AIN3 High	Fault due to high value trip on AIN3
Fault, AIN3 Low	Fault due to low value trip on AIN3
Fault, AIN4 High	Fault due to high value trip on AIN4
Fault, AIN4 Low	Fault due to low value trip on AIN4
Fault, AIN5 High	Fault due to high value trip on AIN5
Fault, AIN5 Low	Fault due to low value trip on AIN5
Fault, AIN6 High	Fault due to high value trip on AIN6
Fault, AIN6 Low	Fault due to low value trip on AIN6
Fault, AIN7 High	Fault due to high value trip on AIN7
Fault, AIN7 Low	Fault due to low value trip on AIN7
Fault, AIN8 High	Fault due to high value trip on AIN8
Fault, AIN8 Low	Fault due to low value trip on AIN8
Malfunction, AIN1 High	Stopped due to high value trip on AIN1
Malfunction, AIN1 Low	Stopped due to low value trip on AIN1
Malfunction, AIN2 High	Stopped due to high value trip on AIN2
Malfunction, AIN2 Low	Stopped due to low value trip on AIN2
Malfunction, AIN3 High	Stopped due to high value trip on AIN3

Malfunction, AIN3 Low	Stopped due to low value trip on AIN3
Malfunction, AIN4 High	Stopped due to high value trip on AIN4
Malfunction, AIN4 Low	Stopped due to low value trip on AIN4
Malfunction, AIN5 High	Stopped due to high value trip on AIN5
Malfunction, AIN5 Low	Stopped due to low value trip on AIN5
Malfunction, AIN6 High	Stopped due to high value trip on AIN6
Malfunction, AIN6 Low	Stopped due to low value trip on AIN6
Malfunction, AIN7 High	Stopped due to high value trip on AIN7
Malfunction, AIN7 Low	Stopped due to low value trip on AIN7
Malfunction, AIN8 High	Stopped due to high value trip on AIN8
Malfunction, AIN8 Low	Stopped due to low value trip on AIN8
Fault, DIN1	Downtime due to fault condition on DIN1
Fault, DIN2	Downtime due to fault condition on DIN2
Fault, DIN3	Downtime due to fault condition on DIN3
Fault, DIN4	Downtime due to fault condition on DIN4
Fault, DIN5	Downtime due to fault condition on DIN5
Fault, DIN6	Downtime due to fault condition on DIN6
Fault, DIN7	Downtime due to fault condition on DIN7
Fault, DIN8	Downtime due to fault condition on DIN8
Fault, DIN9	Downtime due to fault condition on DIN9
Fault, DIN10	Downtime due to fault condition on DIN10
Fault, DIN11	Downtime due to fault condition on DIN11
Fault, DIN12	Downtime due to fault condition on DIN12
Fault, DIN13	Downtime due to fault condition on DIN13
Fault, DIN14	Downtime due to fault condition on DIN14
Malfunction, DIN1	Stopped due to fault condition on DIN1
Malfunction, DIN2	Stopped due to fault condition on DIN2
Malfunction, DIN3	Stopped due to fault condition on DIN3
Malfunction, DIN4	Stopped due to fault condition on DIN4
Malfunction, DIN5	Stopped due to fault condition on DIN5
Malfunction, DIN6	Stopped due to fault condition on DIN6
Malfunction, DIN7	Stopped due to fault condition on DIN7
Malfunction, DIN8	Stopped due to fault condition on DIN8
Malfunction, DIN9	Stopped due to fault condition on DIN9
Malfunction, DIN10	Stopped due to fault condition on DIN10
Malfunction, DIN11	Stopped due to fault condition on DIN11
Malfunction, DIN12	Stopped due to fault condition on DIN12
Malfunction, DIN13	Stopped due to fault condition on DIN13
Malfunction, DIN14	Stopped due to fault condition on DIN14
Running, Valve Check	Running with valve checks enabled

Idle, Valve Check	Well stopped with valve checks enabled
Idle, Valve Check Timeout	Well stopped due to no activity with valve checks
Fault, Low RPM	Downtime due to low motor RPM
Malfunction, Low RPM	Stopped due to low motor RPM
Running, Calibrating Nrevs	Running while calculating reference revolutions
Shutdown, Remote Lockout	Stopped remotely from SCADA. Restart by SCADA or Admin access.

Appendix C: Logging into SMARTEN

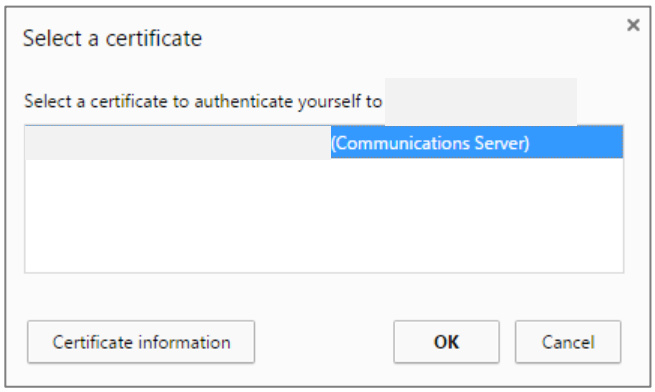
C.1 On Site

Operators can login on site to SMARTEN by connecting to the SMARTEN Wi-Fi signal if equipped with Wi-Fi module device. The name of the Wi-Fi signal will be the same as the Well Name as entered on the Well Configuration screen. Once connected, open a Web browser, enter https://192.168.1.1:8080 (or whatever IP address is entered on the **Network** page for **Wi-Fi Settings**) and hit the Enter or Return key. When prompted, enter the username and password then click **Login**.

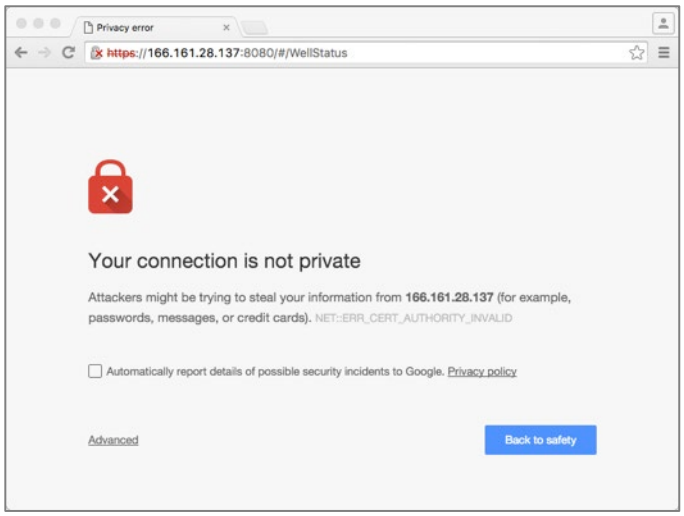
NOTE:** Since this is a secure website, the address must contain **https**, not **http.

Using Google Chrome

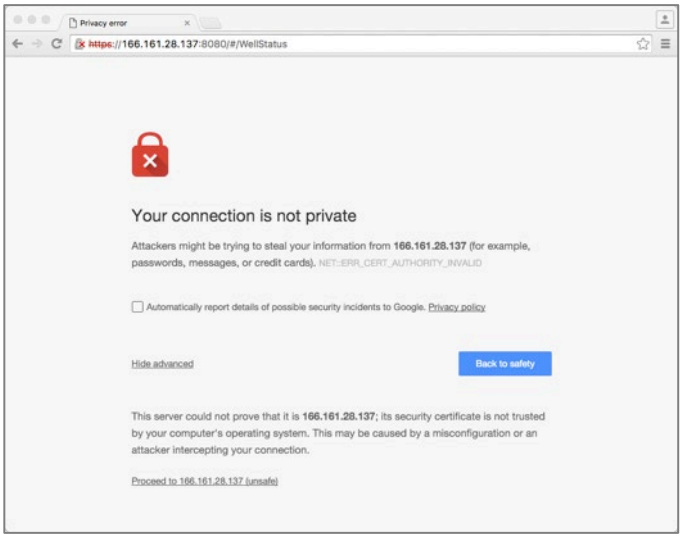
1. Once on the SMARTEN website, the following screen will appear. Click **OK**.



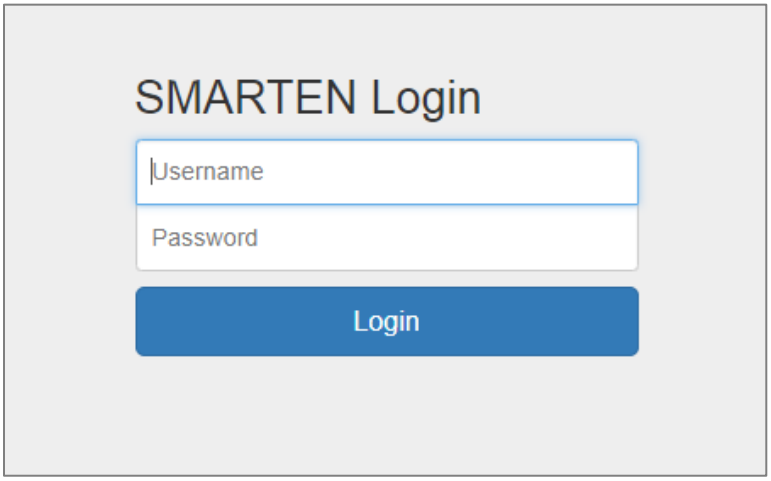
2. Next, the screen will indicate, “Your connection is not private.” Click **Advanced**.



3. Click on the link that says, “Proceed to xxx.xxx.xxx.xxx (unsafe).”



4. The screen will redirect to the SMARTEN Login page. Enter the **Username** and **Password** (provided by ChampionX) to log in.

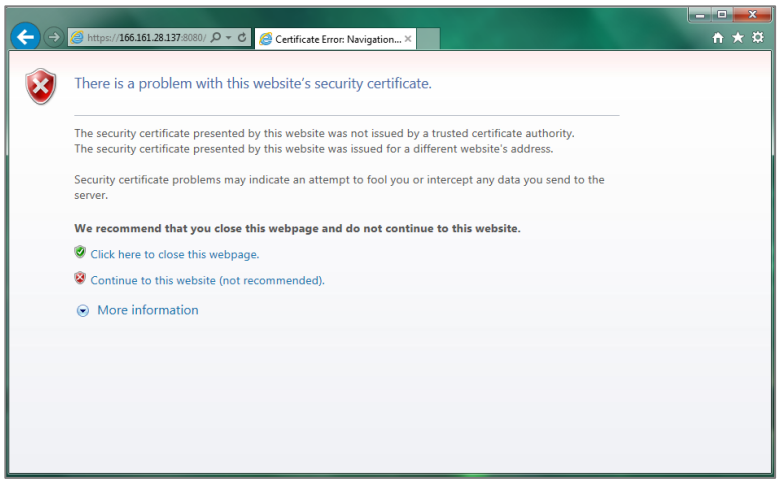


Using Internet Explorer

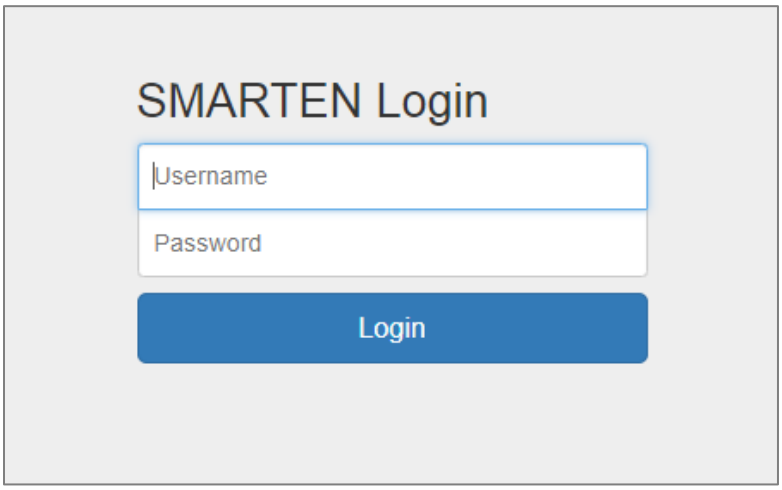
1. Open Internet Explorer and enter the address: https://192.168.1.1:8080 (or whatever IP address is entered on the **Network** page for **Wi-Fi Settings**).

NOTE:** Since this is a secure website, the address must contain **https**, not **http.

2. Press the “Enter” key. The screen will say, “There is a problem with this website’s security certificate.”
3. Click the link “Continue to this website (not recommended).”



4. The screen will redirect to the SMARTEN Login page. Enter the **Username** and P**assword** (provided by ChampionX) to login.



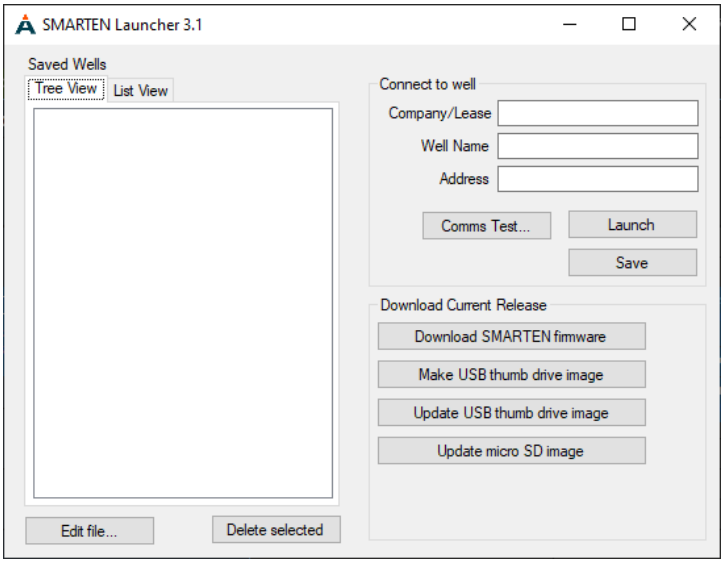
C.2 SMARTEN Launcher 3.1

The SMARTEN **Launcher** 3.1 is an *optional* desktop application used for storing **Well Names** and **IP Addresses** and conveniently launching remote access to the SMARTEN controller. Launcher is also a tool used to download current firmware releases, and to create USB and/or micro-SD card images.

***NOTE**: Please see an CHampionX representative to obtain the SMARTEN Launcher 3.1 installer.*

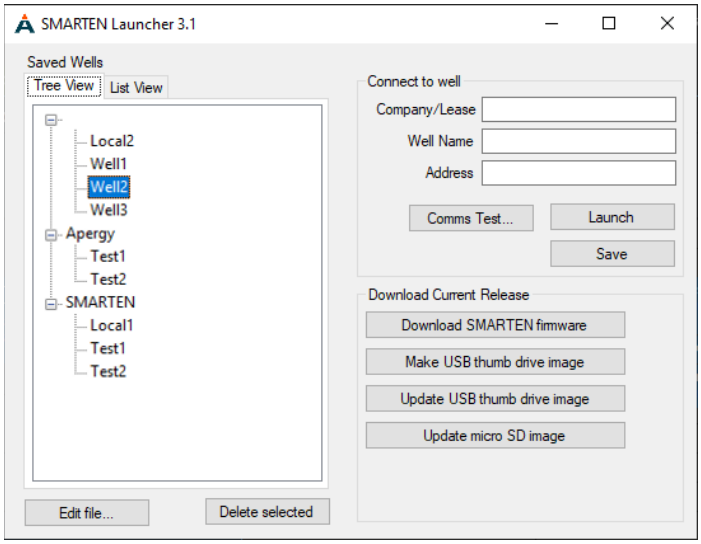
C.2.1 Using the SMARTEN Launcher 3.1

Double-click the SMARTEN Launcher icon to open the launcher. Once opened, the following screen will appear:



The **Saved Wells** in the column on the left side of the screen is the **Well List** that has been imported from a previous version of the SMARTEN remote software if available, or these are the wells that have been entered and saved by the user.

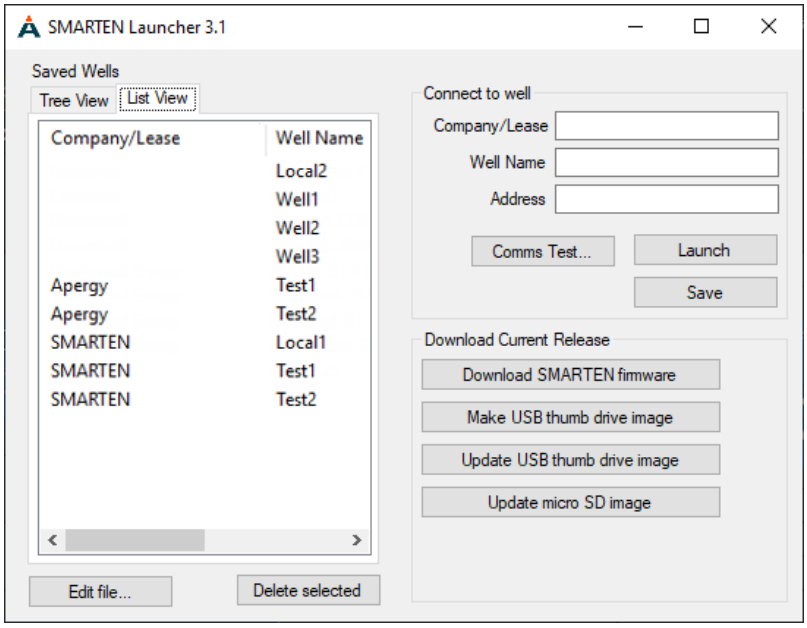
To add a well to this list, enter an optional **Company/Lease** name, a **Well Name** and the IP address, along with the port if different than 8080 and click **Save.** For example, to enter the local IP address for connecting to SMARTEN, enter **Local** for the **Well Name** and 192.168.1.1 for the **Address.** Click **Save** and the well will be stored in the **Saved Wells** list. Note, the address 192.168.1.1 is the default address for the Wi-Fi connection.



To open remote access to a well in the **Saved Well** list, click on the desired well and click **Launch.** You can also double-click the **Well Name** to launch the well. This will open a browser with the well's IP address loaded into the address bar. The user will then be taken to the SMARTEN **Login** screen.
While in **Tree View**, the well names will be arranged alphabetically by **Company/Lease** name. The + next to each **Company/Lease** expands the list to show all well names that are part of that **Company/Lease**.
If two or more wells share the same IP address then a port number must be included with the IP address. For example, as seen above Well2 has the same IP address as Well1. The IP address for Well1 is 10.10.10.10 with the default port of 8080 assumed. The IP address and port for Well2 is entered as 10.10.10.10:8081.

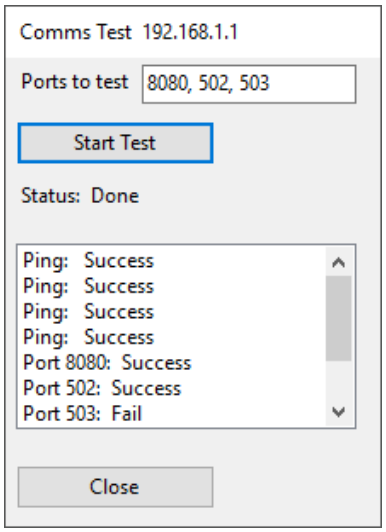
To delete a well, click on the **Well Name** to highlight it and then click the **Delete Selected** button.

Click on the **List View** tab to see all units listed. By default, the wells will be arranged alphabetically by **Company/Lease**. The well list can be arranged by **Company/Lease**, **Well Name** or **IP Address** by clicking the column header at the top of the list.



A text file opens when the **Edit file…**button is pushed. This file contains all well name information. The names and IP addresses of each well can be edited as needed in this file. This well list can also be saved and shared as needed. Also, well names can be copied from other well lists and pasted into your well list. When doing so, be sure to follow the formatting of the existing well list.

Clicking the **Ping Test** allows for testing the connection to the modem or radio on site and the ports required by SMARTEN. Ports 8080 (webserver) and 502 (Modbus) are loaded by default. If a different port is included with the IP address then it will be loaded instead of 8080. Any number of ports can be tested at once provided they are separated by a comma. Push the Start button when you are ready to perform the test. Test results will be indicated by either “Success” or “Fail”.



Appendix D: Communications Setup

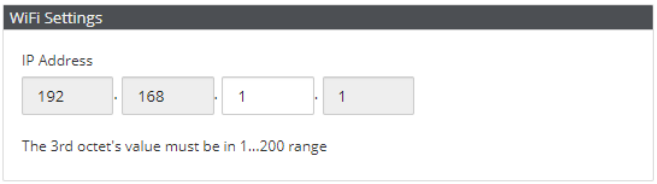
D.1 SMARTEN Wi-Fi Setup

Prior to logging into SMARTEN wirelessly, the Wi-Fi card must be installed. Following the installation of the Wi-Fi card (see SMARTEN Installation Guide) with the controller powered on, verify that the Wi-Fi board is also powered on indicated by illuminated LEDs on the Wi-Fi board.

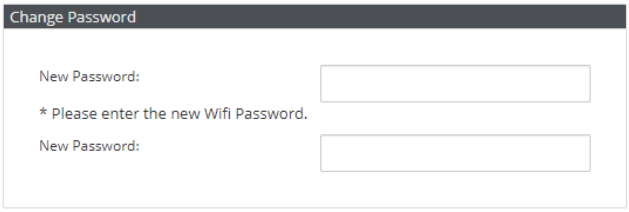
Ensure Wi-Fi card is installed in slot 3 on the RIB2 board. If it is not installed on slot 3 remove it and install it into slot 3. On the display, navigate to the Admin pages of SMARTEN and click on the Admin tab. Click on **Mfg: Set Wi-Fi in slot 3**. Reboot the controller and the Wi-Fi will then broadcast the well's name as the name of the Wi-Fi network.

On the SMARTEN Edge, the Wi-Fi card works immediately once the controller is fully booted. No further configuration is required. If the name of the well is changed, the controller must be rebooted in order for the Wi-Fi signal to show the new well name.

To view and/or change the Wi-Fi Settings in SMARTEN or SMARTEN Edge, navigate to **Setup** tab and select **Network**. Wi-Fi Settings will be located on the bottom right.



The Wi-Fi password can be changed by entering a new password, then re-entering that same new password in the field just below Wi-Fi Settings. Once new passwords have been entered remember to select save.



Once connected to the SMARTEN Wi-Fi network open a browser and enter the IP address https://192.168.1.1:8080 (or whatever IP address is entered on the **Network** page for **Wi-Fi Settings**).

See the SMARTEN Installation Guide for complete instructions on how to install the SMARTEN Wi-Fi card.

NOTE: *The IP address https://192.168.1.1:8080 will only work onsite while connected to the controller's Wi-Fi signal. If logging in remotely, the IP address of the modem or radio on site must be entered instead of 192.168.1.1 along with*

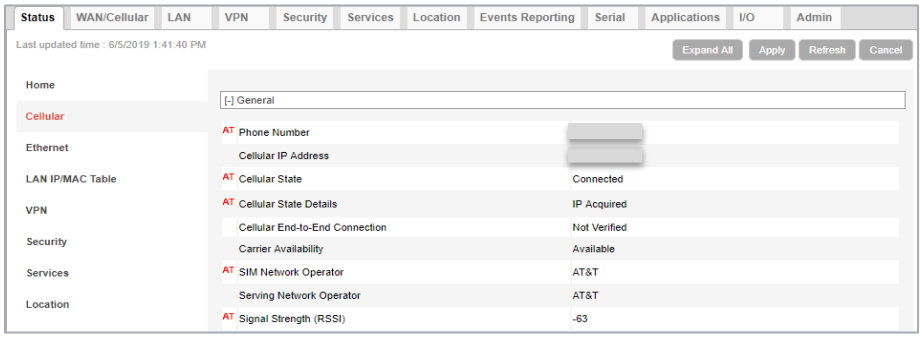
the correct port (8080, 8081, 8082, 8083 etc. when multiple wells share the same modem.)

D.2 SMARTEN Cell Modem Configuration

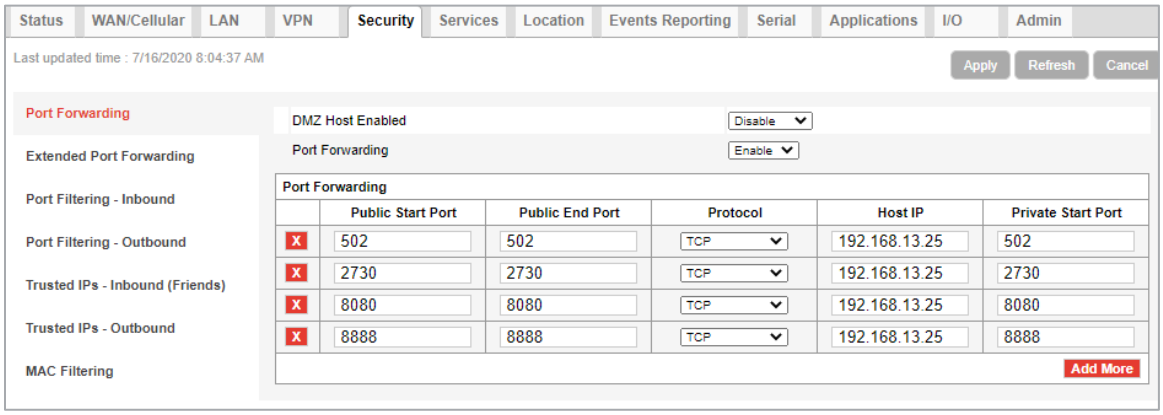
A cell modem provided by ChampionX/SPIRIT will have the settings as seen below. The cell modem can be configured by logging in via a web browser. The modem can be accessed locally (connected directly) at http://192.168.13.31:9191 or remotely at the external IP address and port 9191 (e.g., http://xxx.xxx.xxx.xxx:9191).

Once successfully connected to the modem, a username and password will have to be entered which will be provided by ChampionX/SPIRIT.

The status screen of the modem indicates whether the modem is connected to a network and operating properly.



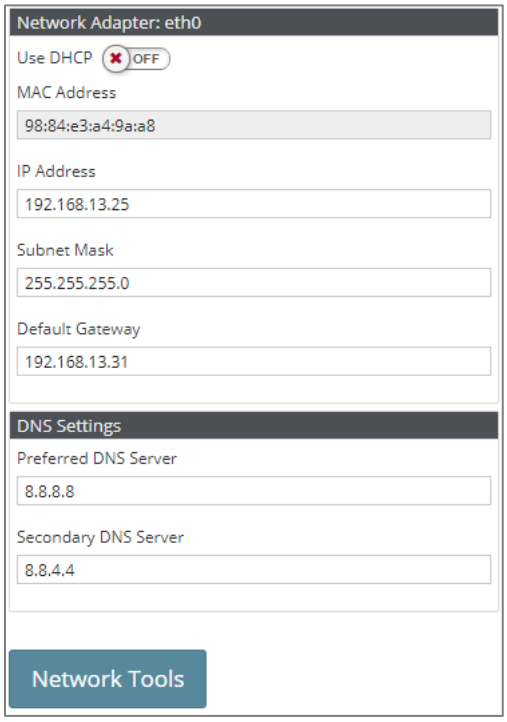
The information present in the screen shot above should be similar to other working modems. Without a valid IP address (provided by the service provider), the modem will not function. The modem must be set up to forward the ports to the controller. The screen shot below shows the ports forwarding to the IP address 192.168.13.25 which is the IP address of the controller. On the security tab, ports should be set up as follows:



In a communication network with multiple units, the ports for all units must be forwarded through the modem to the appropriate IP address of the controller or router at the desired well.

D.3 Network Configuration in SMARTEN/SMARTEN Edge

To communicate with the modem described in the previous section, the network settings in SMARTEN/SMARTEN Edge must be configured. On the **Network** tab, the user can configure the Network Adapter for the Ethernet port on the processor board. The default **IP Address** of the Ethernet port is 192.168.13.25, **Subnet Mask** 255.255.255.0, and **Default Gateway** 192.168.13.31. These settings, together with a modem from ChampionX, will enable remote communication to the controller. In order to set the IP Addresses for the network adapters, **Uses DHCP** must be turned off. These exact settings, in addition to the modem settings in the previous section will allow for remote connection to the controller's webpage or to a SCADA system. However, the Network settings can be configured to work with any existing Ethernet-based communication infrastructure.



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