



eGauge Configuration Guide

(for firmware v1.1 or newer)

eGauge Systems LLC
1510 28th St, Suite 205
Boulder, CO 80303
<http://egauge.net/>

April 3, 2012

1 Overview

This guide explains how to configure eGauge so it properly reflects the physical reality of an installation. There are three sections to this guide: the first is a brief introduction to the web pages used to configure eGauge, the second is the main section and consists of a list of examples reflecting common installation scenarios. The third section contains tips on how to fix up installation mistakes through the web configuration rather than having to go out to a site and correct the physical mistake.

eGauge establishes a few basic rules. Following these rules is not strictly required, but they help to keep things straight and properly working:

1. The direction in which the Current Transformers (CTs) point matters. **The white sticker on the CTs should always point towards the entity being measured.** For example, towards the utility when measuring power from the power grid, towards the inverter for solar and/or wind generators, towards appliances when measuring loads, or towards the panels when measuring subpanels.
2. Power readings that are **positive** numbers indicate that power is being delivered **from the entity being measured** whereas **negative** numbers indicate power being delivered **to the entity**. For example, when a solar system produces more power than a site uses, the excess power is delivered back into the grid. In this case, the power reading for the grid will be negative, since the grid is consuming the excess power.

To configure eGauge, start a compatible browser on a computer and connect to the device's web page. See the Owner's Manual for details on how to do that. Once connected to the device, click on the "LAN Access" link in the top-right of the page. This redirects the browser to a page ensuring a direct LAN connection to the device. If the page does not load, you will not be able to make changes to the device settings, unless remote administration is enabled. Please contact eGauge technical support for details on how to enable that. Once the page has loaded, click on the "Settings" link in the top-right of the page, then click on "Installation" in the navigation-bar on the left of the new page.

As illustrated in Figure 1, the Installation page has five sections:

1. Potential Transformers (PTs)
2. Current Transformers (CTs)
3. Remote Devices
4. Registers
5. Totals and Virtual Registers

We describe the purpose of each section in more detail below.

After any of the settings have been changed, they need to be saved by clicking on the "Save" button near the bottom of the page. When doing that for the first time, you may be prompted for authorization to make the changes. You can enter "owner" as the user name. By default, the password is "default" (no quotes).

To restore the settings which are currently active on the device, click on the "Reset" button. This will revert any changes you have made to the page since the last save.

1.1 Potential Transformer (PT) Configuration

This section is used to inform the device of any potential-transformers (PTs) that may be installed. Usually, no PTs are installed and the settings here can be left at the default value of "direct (no PT)". However, if PTs have been installed, the voltages that the device will measure at the L1, L2, or L3 pin will be lower than the actual line-voltage and the appropriate voltage-division ratios need to be selected in this section. For example, with PTs that transform 34,500V (34.5kV) down to 120V, the ratio "34.5kV:120V" should be selected.

1.2 Current Transformer (CT) Configuration

This section defines what kind of current-transformer (CT) is connected to each of the twelve CT positions. A blank entry indicates that no CT is connected. When a CT is connected to the device, simply select the appropriate current-rating from the pull-down list for the position that the CT is plugged into. For example, if a 100A CT is plugged into CT position 2, click on the pull-down list for CT2 and select "100A".

It is also possible to select "custom" as the CT rating. In this case, it is possible to manually enter a scaling factor. This is most commonly used when a CT measures only a portion of the total current being carried on a phase. For example, suppose that a large commercial building receives its utility power through four equal sized conductors per phase. Rather than installing a large CT that encompasses all four conductors, it may be more economical to install a smaller CT that encompasses only a single conductor. Assuming the current on the four conductors is balanced, the smaller CT will capture a **fourth** of the total current per phase. To compensate for that, enter a custom scale factor that is a **quarter** of factor that would normally be used. For example, if the smaller CT has a rating of 100A, the scale factor would normally be 12.281 (displayed when "100A" is selected) and we would therefore enter a custom scale factor of 3.0703.

Potential Transformers (PTs):

L1	direct (no PT) ▼	-4.003	L2	direct (no PT) ▼	-4.003	L3	direct (no PT) ▼	-4.003
----	------------------	--------	----	------------------	--------	----	------------------	--------

Current Transformers (CTs):

CT1	100A ▼	12.281	CT2	100A ▼	12.281	CT3	50A ▼	24.509	CT4	▼	
CT5	▼		CT6	▼		CT7	▼		CT8	▼	
CT9	▼		CT10	▼		CT11	▼		CT12	▼	

Remote Devices:

2ndary	×	=	remote eGauge via UDP ▼	proto1	✓	Edit
Add Device						

Registers (7 of 12 in use):

Name:	Recorded value/formula:	
Grid	×	= P ▼ = CT1 ▼ × L1 ▼ × + CT2 ▼ × L2 ▼ × Add Component
Solar	×	= P ▼ =+ CT3 ▼ × L1 ▼ × + -CT3 ▼ × L2 ▼ × Add Component
Grid Leg 1 Current	×	= I ▼ CT1 ▼
Grid Leg 2 Voltage	×	= V ▼ L2 ▼
Grid Frequency	×	= F ▼ L1 ▼
Mech Room	×	= 2ndary ▼ Mech Room ▼
Add Register		

Totals and Virtual Registers:

Usage	= + ▼	Grid ▼	×	+ ▼	Solar+ ▼	×	Add Register	
Generation	= + ▼	Solar ▼	×					Add Register
A.Usage	×	= + ▼	Mech Room ▼	×				Add Register
A.Generation	×	=						Add Register
Add Virtual Register								

Save Reset

Figure 1: Example of eGauge Installation-Settings Page

1.2.1 Rope CTs (Rogowski Coils)

Rope CTs come in two variants: *powered* and *self-powered*. The former come with a hardware-integrator that is a little black box that looks as shown below:



Powered rope CTs are available in various amperage ratings ranging from 250A to 5000A and, as far as the eGauge is concerned, they're configured like any other CT. That is, simply select the appropriate amperage rating from the drop-down menu.

In contrast, *self-powered* rope CTs are wired directly to the eGauge with a green 2-pin plug and look as shown below:



Self-powered rope CTs have a fixed amperage of 4800A. Each has slightly different output characteristics and because of that, each comes labeled with a calibration sticker. For accurate operation, the value printed on the calibration sticker has to be entered into the eGauge configuration. Specifically, to configure a *self-powered* rope CT, select "Rope 6" from the appropriate CT drop-down menu. For example, if we do this for CT1, then the entry area will look like this:

Current Transformers (CTs):

CT1	Rope 6" ▼	1.709	cal: 2.5	%
-----	-----------	-------	----------	---

Note the box label-led "cal: ". In this box, enter the value printed on the calibration label. This is usually a value in the range from -20% to +20%. In our example, we entered a value of 2.5%.

The scale factor displayed in the box before the calibration box should normally read 1.709. However, under special circumstances, for example if you needed to double the value read by the rope CT for some reason, you could enter a custom scale factor here, just like for regular CTs when selecting "custom".

1.3 Remote Devices

This section is used to define remote devices whose data should be recorded. Examples of remote devices are other eGauges, PV inverters, or weather stations. If you are not planning on recording data from a remote device, skip this section.

The details of what data is recorded from a remote device is specified separately (see below). Here, only the basic information required to successfully communicate with the device is needed. Also, each remote device is assigned a unique name.

To add a remote device, click on the “Add Device” button. The screen will change to this:

Enter the desired name for the new device. You can pick any name here that makes sense to you, provided the name is unique. For this example, we will use “2ndary”. Then click on the “Edit” button. The screen will change to this:

You can now select the communication protocol from the drop-down menu and enter the device’s address in the text-entry box to the right of the drop-down menu. The format of the device address depends on the communication-protocol. The following choices are available:

remote eGauge via UDP: This protocol is suitable for reading data from other eGauge devices. For the device address, enter the device’s IP address or its hostname here. Hostnames are automatically resolved via DNS or, if the hostname contains no dots, an attempt is first made to resolve it via the NetBIOS name service. Example addresses are “192.168.1.155” (IPv4 address), eGauge1234 (hostname resolved via NetBIOS or, if that fails, DNS), or eGauge1234.egaug.es (hostname resolved via DNS).

remote eGauge via TCP: This protocol serves the same purpose as the previous one except that it uses a less compact data format and less efficient transport protocol. However, since it uses standard XML-over-TCP queries, this protocol can read data via the eGauge proxy-service and also can be used with devices running old (pre-v1.00) firmware, which doesn’t support the more efficient UDP protocol. The address-format is the same as for the previous protocol.

RS485: This protocol can be used to read data from a devices with an RS-485 interface. To interface with eGauge, the RS-485 bus needs to be wired to an Ethernet-to-RS485 converter. The recommended converter for this purpose is the Chiyu BF-430. Other Ethernet-to-RS485 converters may work but have not been tested by eGauge Systems LLC.

Device addresses have the form *busprot://devaddr@convaddr*, where *busprot* is the RS-485 bus protocol (see below), *devaddr* is an optional RS-485-device address, and *convaddr* is the IP-address of the Ethernet-to-RS485 converter. The IP-address *convaddr* can be specified in several forms:

Ethernet MAC address: An Ethernet MAC address is six bytes long (12 characters) and is printed on the device label of the Ethernet-to-RS485 converter. Enter the MAC address as 12 characters, without any colons or other punctuation. For example, MAC address 00:20:4a:cd:19:2d would be entered as 00204acd192d. When specified

in this fashion, eGauge will send an Ethernet-broadcast to locate the IP-address of the Ethernet-to-RS485 converter with the specified MAC address. At present, Chiyu BF-430 and GridConnect Net485 converters can be located in this fashion.

IPv4 dotted address: If the Ethernet-to-RS485 converter has been configured to use a static IP address, you can directly enter the IP address in the usual “dotted-quad” format. For example, you could specify `192.168.1.43` if that is the address of the converter.

DNS hostname: If a DNS-hostname has been assigned to the Ethernet-to-RS485 adapter, you can directly specify the hostname. Examples might be `bf430` (unqualified hostname) or `bf430.example.com` (fully-qualified hostname).

For IPv4 and DNS hostnames it may be necessary to specify the port number at which the RS485-data is available. By default, eGauge will use port 50,000, which is the correct value for the Chiyu BF-430 converter. For GridConnect Net485 converters, the port 10,001 would have to be specified. This can be done by appending a colon (:) and then the port-number. The following RS-485 bus protocols are currently supported:

sma: This uses an SMA-proprietary protocol to automatically discover SMANet-capable devices on the RS-485 bus. This can be used, for example, to read out SMA Sunny-Boy inverters or SMA SensorBox weather stations. Since devices are automatically discovered, `devaddr` does not have to be specified. That is, the `devaddr` part of the address must be left empty.

po: This uses a Power-One-proprietary protocol to read data from Power-One Aurora inverters. The `devaddr` part of the address specifies the RS-485 device-address of the inverter. The device-address is a number between 0 and 255. By default, Power-One Aurora inverters ship with a device-address of 2, but other addresses can be configured through the Aurora user-interface.

Some examples of complete RS-485 protocol addresses are:

sma://@00204acd192d: Provides access to all SMANet-devices wired to the Ethernet-to-RS485 converter with MAC address `00204acd192d`.

po://2@192.168.1.43: Provides access to the Power-One Aurora inverter configured for RS-485 device address 2, wired to the Ethernet-to-RS485 converter with IP address `192.168.1.43`.

po://2@192.168.1.43:10001: Like the previous example, but eGauge will connect to port 10,001 of the Ethernet-to-RS485 converter instead of the default-port of 50,000.

Power-One Aurora inverter: Obsolete. For new installations, please use the RS485 protocol instead. The address-format is the same as described there for Power-One devices, except that the `po://` prefix must not be specified. For existing installations, we recommend switching to using the RS-485 protocol instead. Please contact us for details.

Alpha-Innotec Luxtronik 2: This protocol enables the reading of data from the Luxtronik 2 heatpump controller manufactured by Alpha-Innotec. For the device address, enter the device’s IP address or its hostname here. Hostnames are automatically resolved via DNS or, if the hostname contains no dots, an attempt is first made to resolve it via the NetBIOS name service.

For our running example, we will select “remote eGauge via UDP” as the protocol and “`proto1`” as the device’s address. After entering the address, click the “Done” button. For security-reasons, eGauge may prompt you for authentication before this step can be completed. If so, enter username “`owner`” and the matching password (which is “`default`” by default). Assuming proper authorization, the screen will then change to this:

Note that the protocol and address fields have been grayed out, indicating that they are not editable anymore. Should you need to make changes, click the “Edit” button again. Also note that the question-mark after the address field has changed to a green check-mark. This indicates that the eGauge was able to communicate with the remote device and that it has fetched the list of available registers from that device. If this step had failed for some reason, there would be a red cross-mark instead of the green check-mark, as shown below:

There are several reasons why you might get a red cross-mark after clicking “Done”:

- **Wrong address.** Verify that the address you entered is correct and has the proper format.
- **Wrong protocol.** Verify that you selected a protocol suitable for the remote device.
- **Remote device not working.** Verify that the remote device is up and running.
- **Remote device not reachable.** Verify that the remote device can be reached from the eGauge. If the remote device is another eGauge, you can use the `Settings→HomePlug` screen to verify that the remote device can be reached with good signal strength.

You will only be able to define new registers for remote devices listed with a green check-mark. However, eGauge is careful to never delete already configured registers for remote devices, even if the remote devices may be (temporarily) inaccessible.

1.4 Register Configuration

This section defines what data gets recorded in the internal database of the eGauge device. Each register has a unique name that identifies what it is recording. There is a fixed upper limit on the number of registers a device can record. Depending on the generation of the hardware, the limit may be eight, twelve, or sixteen registers. Devices can also be ordered with an optional storage expansion, which increases the limit to 128 registers. To make it easy to keep track of how many registers are in use and how many registers are available in total, the title of this section displays this information in the format “(*N* of *M* in use)”, where *N* is the number of registers in use and *M* is the total number of registers available.

Registers record the data with one minute granularity for the most recent year. For the next 29 years, granularity drops to thirty minutes. Data older than 30 years gets overwritten with newer data, so 30 years of history is the most the device can record. Note that registers record *averages*: for the most recent year, the recorded data consists of one-minute averages. For the next 29 years, the data consists of thirty-minute averages.

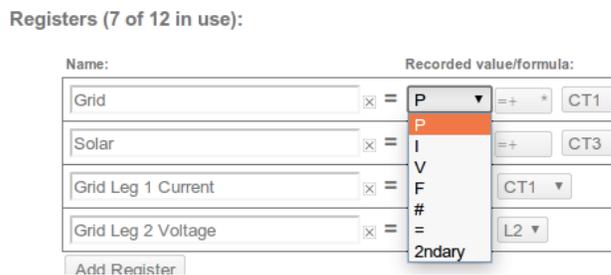
1.4.1 Register Name

Register names may contain any ASCII/UTF-8 characters except for control characters such as backspace, delete, or newline. Most punctuation marks such as slash, backslash, quotes, etc., are all permissible. The exception is that you may not enter a register name that ends with a plus (+), minus (-), vertical-bar (|), or asterisk (*).

Through UTF-8, it is possible to use symbols from non-English character sets. However, note that non-English symbols encoded in UTF-8 occupy up to four bytes of memory. eGauge limits the length of register names to 31 bytes. With English characters, register-names can therefore be up to 31 characters long. With non-English characters, fewer symbols can be stored in a register-name, with the exact maximum length depending on the chosen symbols. As a rule of thumb, non-ASCII Latin characters (e.g., accented characters such as German Umlauts) consume two bytes per symbol and symbols from ideographic languages such as Chinese consume four bytes per symbol.

1.4.2 Register Type

Each register can be configured to record one of several types of data. The type can be selected from the drop-down menu to the right of a register-name. In our example, the drop-down menu looks as follows:



The entries in this popup-menu have the following meaning:

- P**: Records the **power** calculated from one or more current/voltage-pairs.
 - I**: Records the RMS **current** measured by one of the connected CTs (CT1–CT12).
 - V**: Records the RMS **voltage** measured by one of the lines (L1–L3).
 - F**: Records the **frequency** measured on one of the lines (L1–L3).
 - #**: Records numeric data. The only numeric data available at this time is a quantity called “.*excess*”. When there are remote devices, the quantity has a non-zero value only if a remote device was temporarily unavailable and eGauge is catching up with the remote device’s current data. The details of this register are arcane but a non-zero value can be used as an indicator that there were some (temporary) communication problems with remote devices and that the eGauge is now catching up to the current data, which may cause the temporary inflation of up to $\pm 10\%$ of the values read from remote registers.
 - =**: Formula register. Records the value obtained by evaluating the specified formula. See Section 1.4.4 for details.
- remote device name**: Selecting the name of a remote devices (in our example, 2ndary), allows you to record a register from that device. Before adding a remote register, make sure that there is a green check-mark (✓) indicator to the right of the address field of the remote device. If the indicator is a question-mark (?), click on it to fetch the list of registers available from the remote device. If the indicator is a red cross-mark (✗), the eGauge was unable to communicate with the remote device. See the previous section for information on how to resolve the problem.

In the example of Figure 1, we see six rows in the `Registers` section: the first two record power (P). We will discuss those in more detail in the next section. The third row defines a register recording the current

(I) of CT1, the fourth row defines a register recording the voltage (V) of line L2 (e.g., red leg in a split-phase residential installation). The fifth row defines a register that records the frequency (F) of line L1. Finally, the sixth row defines a remote register that records the data from the “Mech Room” register of remote device 2ndary.

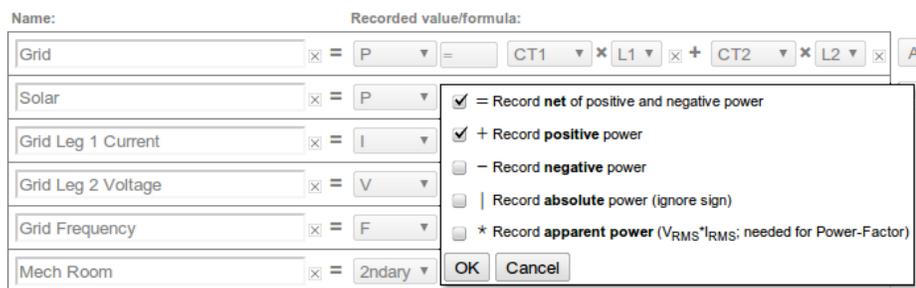
A register can be added by clicking on the “Add Register” button. An existing register can be deleted by clicking on the remove icon  to the right of the register name.

1.4.3 Recording Power

There are two parts to configuring a register to record power: first, the subtype(s) to be recorded need to be selected, second, the power-components that should be used to calculate the power need to be specified.

Power Subtypes The subtypes to record for a power register are selected by clicking on the subtype-selector button to the right of the register-type button. This will pop up the dialog shown below:

Registers (7 of 12 in use):



As shown here, there are five subtypes which can be recorded by turning on the corresponding checkbox:

- = **(net)**: Checking this box ensures that the net flow of power is available as a register-value. The value of such a register increases when the calculated real power is positive and decreases when it is negative. This is equivalent to a utility’s net-meter, for example.
- + **(positive-only)**: Checking this box ensures that a register-value is available that increases only when the calculated real power is positive. When the real power is negative, the register-value does not change. This can be used, for example, to record only the power generated by an inverter or only the power consumed from the utility.
- **(negative-only)**: Checking this box ensures that a register-value is available that increases only when the calculated real power is negative. When the real power is positive, the register-value does not change. This can be used, for example, to record only the power consumed by an inverter when there is no sun or only the power fed back into the grid.
- | **(absolute)**: Checking this box ensures that a register-value is available that counts independent of the sign of the calculated real power. That is, the register-value increases by the absolute value of the real power regardless of whether it is positive or negative. This can be used, for example, when measuring pure loads where the direction of the power-flow is known.

- ★ **(apparent):** Checking this box ensures that apparent power is recorded in a register. Apparent power is the sum of the product of the RMS voltage and current of each power-component. As such, apparent power always has a non-negative value. This can be used, for example, to track the quality of the power as the ratio of apparent power and absolute real power is the power-factor.

When you are done selecting subtypes, click on the `OK` button to save the selection or on the `Cancel` button to revert to the previously existing configuration.

Note that the values of the different register subtypes are dependent on each other, except for apparent power. For example, given the positive-only and the net register values, the negative-only register value can be calculated as the difference of the two. To conserve storage space, eGauge automatically exploits these dependencies and only records the minimum data needed. Because of this, eGauge never uses up more than three registers no matter what combination of subtypes are selected.

Firmware versions older than v1.00 supported only the recording of net real power (=). The other subtypes were added for increased flexibility. For example, the positive-only (+) register can be used to accurately calculate total power usage at a site with a photo-voltaic (PV) solar system. It can also be used to accurately track energy-flow of a utility meter, which can be helpful for cases where a utility charges a different rate for consumed power than it pays for power fed back into the grid. Using the absolute (|) subtype can simplify CT installation for, e.g., pure loads. By ignoring the sign of the calculated power, the measured power is always positive, no matter which way the CT is installed. Finally, the apparent power (|) subtype enables power-factor tracking as the ratio between apparent power and the absolute value of real power is the power-factor.

Power Components The power components define which currents and voltages are to be combined to calculate a register's power figure. In our example, the power components for the `Grid` and `Solar` registers look as follows:

Name:	Recorded value/formula:	
Grid	$\times = P \downarrow =$	$CT1 \downarrow \times L1 \downarrow \times + CT2 \downarrow \times L2 \downarrow \times$ <input type="button" value="Add Component"/>
Solar	$\times = P \downarrow =+$	$CT3 \downarrow \times L1 \downarrow \times + -CT3 \downarrow \times L2 \downarrow \times$ <input type="button" value="Add Component"/>

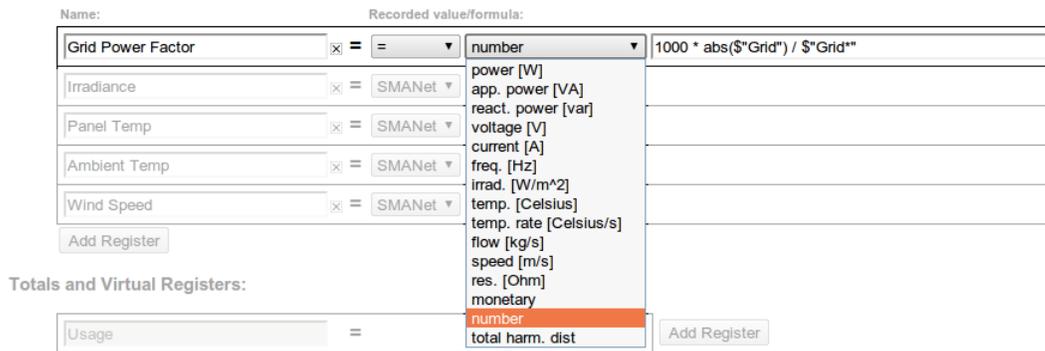
This shows that `Grid` power is calculated as the product of the current measured by CT1 and the voltage measured on line L1 (e.g., black leg) plus the current measured by CT2 and the voltage measured on line L2 (e.g., red leg). In other words, the power coming from the two legs of the split-phase power feed from the utility are combined into a single register. It would of course be possible to record the two legs in separate registers, but that would use up more of the available storage space and would add a level of detail that most customers do not care about.

It is illustrative to look at the power-components for the `Solar` register since it uses `-CT3` in the second component. Naively, a 240Vac solar inverter would have to be measured by two CTs: one per leg. However, provided there is no current flowing on the Neutral wire (usually the case for a single-phase inverter), we know that at any given point in time, the current flowing out of leg 1 of the inverter has to flow back into leg 2 and vice versa (the flow of current reverses 60 times a second assuming a 60Hz power system). Thus, instead of measuring the second leg of the inverter with a fourth CT, we can simply use the negated value of CT3, i.e., `-CT3` to accurately calculate the power delivered from the inverter. This saves the cost of a CT and the time that would be required to install it. Note that the minus-sign in `-CT3` should not be taken too literally in the formula: it causes the polarity of the component to be reversed for real power calculations, but for apparent power calculations, the sign has no effect, since the RMS value of the current measured by CT3 and `-CT3` is by definition always positive.

To add a new power-component to a register, click on the “Add Component” button. To delete a component, click on the remove icon  to the right of the component.

1.4.4 Formula Registers

Formula registers are a powerful tool to record quantities that can be derived from other, directly-measured registers. For example, suppose register `Grid` measures the real power used at a site, then register `Grid*` would measure the apparent power used at the same site. To record the power-factor for the site, we would have to divide the absolute value of `Grid` by `Grid*`. This can be accomplished by defining a formula register as shown below:

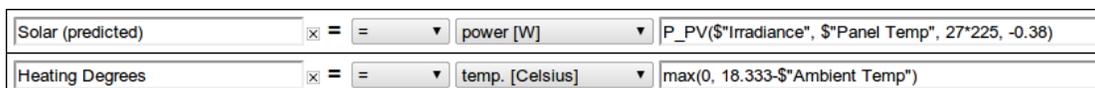


The screenshot shows the configuration for a formula register named "Grid Power Factor". The "Recorded value/formula:" field contains the formula `1000 * abs($"Grid") / $"Grid**"`. A dropdown menu is open, showing various physical quantity types: power [W], app. power [VA], react. power [var], voltage [V], current [A], freq. [Hz], irradi. [W/m^2], temp. [Celsius], temp. rate [Celsius/s], flow [kg/s], speed [m/s], res. [Ohm], monetary, number, and total harm. dist. The "number" option is selected. Below the main configuration, there is a section for "Totals and Virtual Registers" with an entry for "Usage" set to an equals sign (=) and an "Add Register" button.

In this example, we named the register “Grid Power Factor” and selected the equal-sign (formula-register) as the register type (see Section 1.4.2). Next, we selected the type of physical quantity that is being recorded by the register. Various choices are available here: power (recorded in units of Watts), voltage (recorded in units of Volts), irradiance (recorded in units of Watts per square meter), and so on. In our case, power-factor is a unit-less number, so we selected `number` from the drop-down box. Finally, we entered a formula of `1000*abs($"Grid")/$"Grid**"` for calculating the value of the register. Here, `$"regname"` is used to obtain the current (second-by-second) value of register `regname`, so `$"Grid"` will evaluate to the current site-usage (in Watts) and `$"Grid**"` evaluates to the apparent power used by the site. As you might expect, the `abs()` function calculates the absolute value of the value passed to it (i.e., it returns the passed value after dropping its sign). Dividing the value returned by the `abs()` function by the apparent power yields a number between 0 and 1 (the power-factor). Why do we multiply this quotient by 1,000? To understand that, you need to know that eGauge records number-type quantities as signed integer values. Thus, any value between 0 and 1 would get rounded to either 0 or 1, which wouldn’t be very informative. By multiplying it by 1,000, we instead can record the power-factor with a precision of 3 digits. For example, a value of 983 would correspond to a power-factor of 0.983.

A list of functions that are available for use in calculating the value of a formula register can be found in Appendix A. An online-version of this function-list can also be found in the `Help` section of the eGauge web-pages. Apart from basic mathematical functions such as square-root-, exponential-, or min- and max-functions, there are some time-related functions available to read the time-of-day, month of the year, and the weekday. Also, there are some convenience-functions available to calculate, for example, expected output from a solar PV array or to calculate reactive power given measured real and apparent power.

Below are two more examples of useful applications of formula registers.



The first example shows a register named "Solar (predicted)" with the formula `P_PV($"Irradiance", $"Panel Temp", 27*225, -0.38)` and the type `power [W]`. The second example shows a register named "Heating Degrees" with the formula `max(0, 18.333-$"Ambient Temp")` and the type `temp. [Celsius]`.

The first (`Solar (predicted)`) shows how to calculate and record the predicted power of a solar PV array given solar irradiance (`%"Irradiance"`), the panel temperature (`%"Panel Temp"`), the rated power of the PV array (27 panels of 225W each), and the temperature-coefficient of the panels (-0.38%). Note that irradiance and panel temperature would have to be measured by a weather-station that is compatible with eGauge, such as the SMA Sunny SensorBox. Note that predicted PV-output is a physical quantity measured in Watts, so we selected `"power [W]"` as the physical quantity for this register.

The second example (`Heating Degrees`) shows how to record heating degrees given a register called `"Ambient Temp,"` which records the ambient (outside) temperature at a site. Heating degrees is defined to be the average temperature by which a room would have to be heated to keep it at a comfortable temperature of 65° Fahrenheit (18.333° Celsius). If the outside temperature is above 65F (18.333C), no heating is required and the formula is defined to return 0 in that case (the maximum value of 0 and a negative number is 0). If the ambient temperature is any lower than that, the formula returns the difference as 18.333 minus a number smaller than that will be a positive number. Note that we selected `"temp. [Celsius]"` as the physical quantity for this register, as heating degrees is a temperature. This also illustrates the point that formula registers always record physical quantities using the metric system. Any conversions to user-preferred units have to happen when the recorded values are being presented to the user, e.g., through the built-in web-pages.

Several caveats apply to using formula registers:

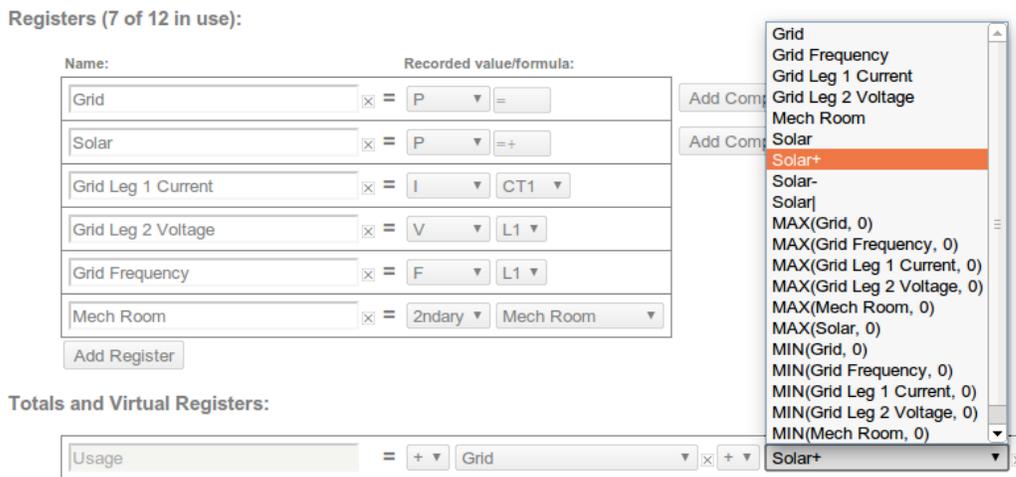
- You might wonder what would happen if a formula attempted to use the value of another formula register. The answer is that this is an undefined operation. It could return the current value of that register, the previous second's value of the register, or any other value. Thus, formulas should refer only to measured (physical) registers.
- Calculating formulas takes time. The more complicated a formula is, the more time it takes to calculate its value. In extreme cases, it might be possible to overload a device by defining lots of complicated calculations, especially if the device is already heavily loaded, e.g., due to lots of power calculations. If this were to happen, the device-response could become sluggish, even to the point where it might seem unresponsive.
- All calculations are performed using single-precision IEEE-754 floating-point numbers. The final value of a formula register is then rounded to a 64-bit signed integer number.

1.5 Totals and Virtual Registers Configuration

Virtual registers are calculated as a sum or difference of real (physical) registers. As such, virtual registers do not consume any storage space and there is no a priori limit on how many of them you can define. A virtual register can be added by clicking on the `"Add Virtual Register"` button. To remove one, click on the remove icon  to the right of the register name. In our example, this section looks as follows:

Usage	=	+ ▼	Grid	▼	x	+ ▼	Solar+	▼	x	Add Register
Generation	=	+ ▼	Solar	▼	x					Add Register
A.Usage	x	=	+ ▼	Mech Room	▼	x				Add Register
A.Generation	x	=								Add Register
Add Virtual Register										

For each virtual register, you can define an arbitrary number of registers which are added or subtracted together when calculating the virtual register's value. A register is added by clicking on the **Add Register** button. A register can be removed by clicking on the remove icon  to the right of the register drop-down menu. You can select whether there register should be added to or subtracted from the virtual registers value by selecting + or - from the drop-down menu to the left of the register name, respectively. The register to be added or subtracted can also be selected from a drop-down menu. In our example, this menu looks as follows:



Each power register will show up in several variations in the menu, namely with one variant for each available subtype. If you look back at the register configuration for *Grid*, only the net (=) subtype is being recorded, so it shows up only once as *Grid* (since net metering is the default for eGauge, the equal-sign is omitted from the name, unlike for any other subtype). However, for *Solar*, both net (=) and positive-only (+) subtypes are being recorded. Because of this, all subtype variants except for apparent power appear in the menu: *Solar* (net), *Solar+* (positive-only), *Solar-* (negative-only), and *Solar|* (absolute). The last two are available because they can be calculated from net and positive-only.

The menu also has entries of the form $\text{MAX}(reg, 0)$ and $\text{MIN}(reg, 0)$. Those are for backwards compatibility with configurations created by older firmware and should no longer be used. Instead of $\text{MAX}(reg, 0)$, use the positive-only variant of a register (i.e., *reg+*) and instead of $\text{MIN}(reg, 0)$, use the negative-only variant of a register (i.e., *reg-*).

1.5.1 Totals

There are two special virtual registers called *Usage* and *Generation*. These are called *totals* and their value is used to represent *total site usage* and *total site generation*. In the dashboard graph, total usage is represented by a thick red line, and total generation is represented as a thick green line. The totals are always present (cannot be deleted), but if a site does not measure usage or if there is no site-local power generation, the respective total can be left blank.

1.5.2 Defining Views

Views can be used to define a restricted or alternate view of the data recorded by an eGauge device. For example, views could be used to view the usage/generation data for an individual condo when a single eGauge device is used to meter several condos.

A view is defined by pre-pending the view-name and a dot in front of a register name. In our example, the virtual-register rows shown below define a view called **A**:

A.Usage	x	=	+ ▼	Mech Room	▼	x	Add Register
A.Generation	x	=					Add Register

With this setup, selecting view **A** in the dash-board will display register `Mech Room` as the total site usage and nothing (zero) as the total site generation. That is, within a view, the register-names `Usage` and `Generation` serve as the totals for that view. You can define an arbitrary number of other register names within a view to display additional information in that view.

2 Configuration Examples

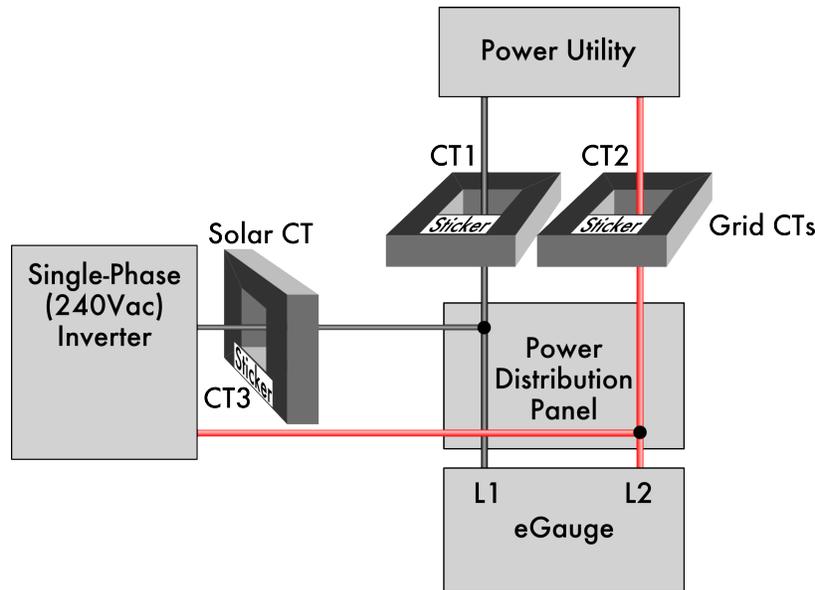
The following pages illustrate various common installation scenarios and matching configurations. For clarity, the diagrams have been simplified in the following manner:

- No circuit breakers are shown.
- The CT wires are not shown.
- The Neutral and Ground wiring is not shown.
- Most examples are partial configurations. For a complete system, the configurations from various examples may have to be combined.

Please review the Owner's Manual for detailed installation requirements. For safety, the eGauge device always must be wired to a breaker and the breaker should be labeled "eGauge Disconnect."

2.1 Standard Split-Phase

Basic installation measuring power coming from a power utility (grid) and from a single-phase solar-system inverter.



Registers

$$\begin{aligned} \text{Grid} &= [\text{P}] [=] \text{CT1} \cdot \text{L1} + \text{CT2} \cdot \text{L2} \\ \text{Solar} &= [\text{P}] [=+] \text{CT3} \cdot \text{L1} + -\text{CT3} \cdot \text{L2} \end{aligned}$$

Totals and Virtual Registers

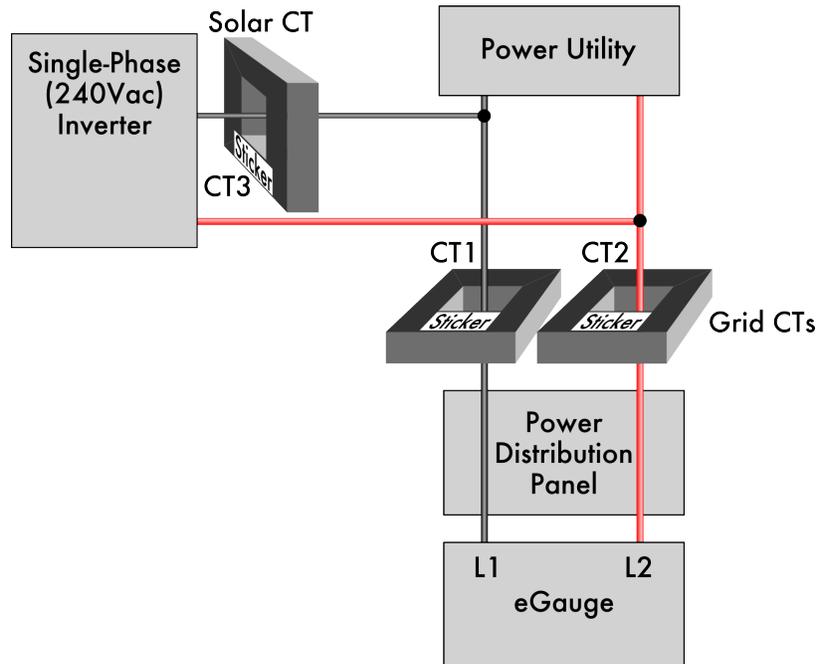
$$\begin{aligned} \text{Usage} &= \text{Grid} + \text{Solar} + \\ \text{Generation} &= \text{Solar} \end{aligned}$$

Notes:

- White stickers on CTs should point in the direction indicated in above diagram.
- Register definitions must be consistent with the wiring. CT1 and CT3 are on leg L1, so they must be multiplied by L1; CT2 is on leg L2, so it must be multiplied by L2.
- With single-phase inverter, the current flowing at any given instant on leg L2 is the negative of the current flowing on leg L1. Hence, rather than using a fourth CT, simply multiply the negated value of CT3 with L2 to calculate the power on that leg.
- The totaling rules indicate that total usage (consumption) is calculated as the sum of the power reported for register `Grid` and, the positive-only register `Solar+`. If the power reported for `Solar` is negative (indicating that the inverter is consuming power, e.g., during the night), then total usage is simply equal to the power reported for register `Grid`. It would be (slightly) wrong to define the `Usage` totaling rule as `Grid + Solar` because in this case, the inverter's consumption would be canceled out of the usage, giving a lower than real consumption figure.

2.2 Direct-Feed Solar

Same as Standard Split-Phase installation, except that the inverter feeds directly into the power utility's grid. That is, the Solar CT is closer to the utility than the Grid CTs. This situation often arises when solar power is delivered via a line-side tap.



Registers

$$\begin{aligned} \text{Grid} &= [\text{P}] [=] \text{CT1} \cdot \text{L1} + \text{CT2} \cdot \text{L2} \\ \text{Solar} &= [\text{P}] [=] \text{CT3} \cdot \text{L1} + -\text{CT3} \cdot \text{L2} \end{aligned}$$

Totals and Virtual Registers

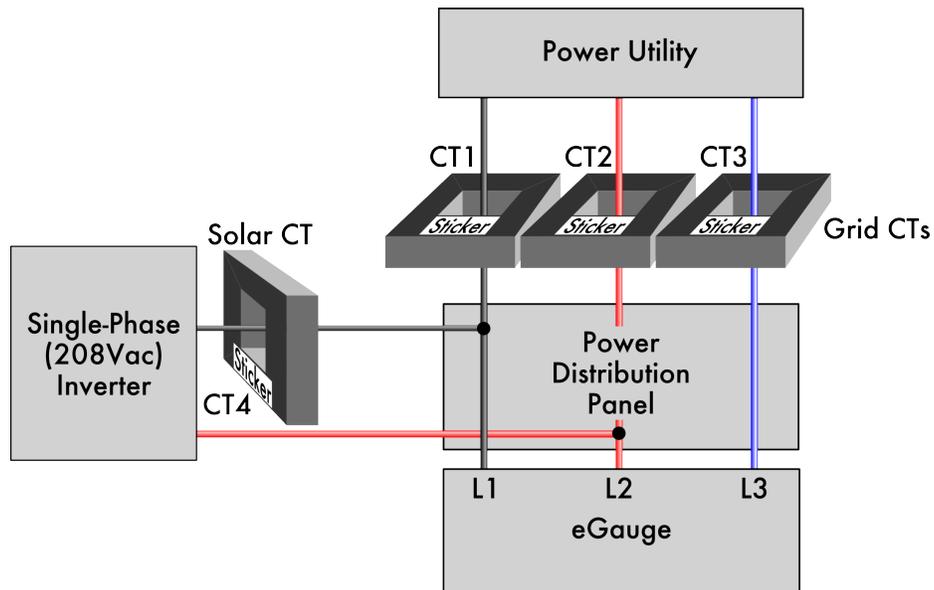
$$\begin{aligned} \text{Usage} &= \text{Grid} + \text{Solar} \\ \text{Generation} &= \text{Solar} \end{aligned}$$

Notes:

- The only difference compared to the standard installation is that `Solar+` was replaced by `Solar-` in the totaling rule for `Usage`. This is because the Grid CTs already capture total consumption, including any power coming from the solar system. The only exception is that when the inverter is consuming power (e.g., at night), that consumption is *not* captured by the Grid CTs. Adding `Solar-` corrects that because it will be equal to the amount of power consumed by the inverter, or zero when the inverter is producing power.

2.3 Three-Phase 120/208Y

Standard three-phase installation measuring power coming from a power utility (grid) and from a single-phase solar-system inverter.



Registers

```
Grid    = [P] [= ] CT1*L1 + CT2*L2 + CT3*L3
Solar   = [P] [=+] CT4*L1 + -CT4*L2
```

Totals and Virtual Registers

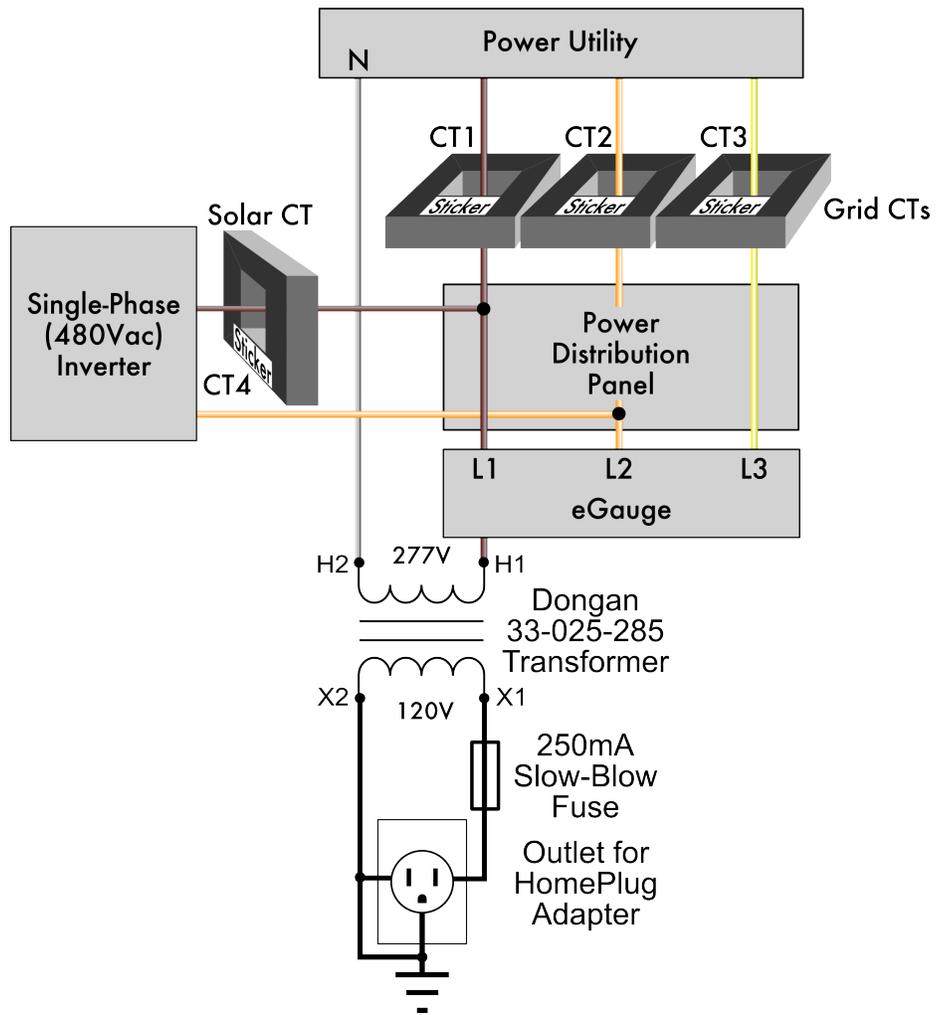
```
Usage      = Grid + Solar+
Generation = Solar
```

Notes:

- Three-phase installations are set up the same as split-phase systems, except that a third voltage-tap (L3) and a third Grid CT is required to measure power flow on phase 3.
- With multiple inverters, add one Solar CT per inverter and define a separate register for each inverter (e.g., `Solar 1` and `Solar 2`). Adjust the register definition according to the CT that is measuring the current and the phases that the inverter feeds onto. For example, CT5 measuring current onto L2 and also feeding onto L3: `Solar 2 = CT5*L2 + -CT5*L3`.
- If there are more than three single-phase inverters, it is more economical to measure the total solar output with one CT per phase.

2.4 Three-Phase 277/480Y

Three-phase 277/480V installation measuring power coming from a power utility (grid) and from a single-phase solar-system inverter.



Registers

$$\begin{aligned} \text{Grid} &= [\text{P}] [=] \text{CT1} \cdot \text{L1} + \text{CT2} \cdot \text{L2} + \text{CT3} \cdot \text{L3} \\ \text{Solar} &= [\text{P}] [=+] \text{CT4} \cdot \text{L1} + -\text{CT4} \cdot \text{L2} \end{aligned}$$

Totals and Virtual Registers

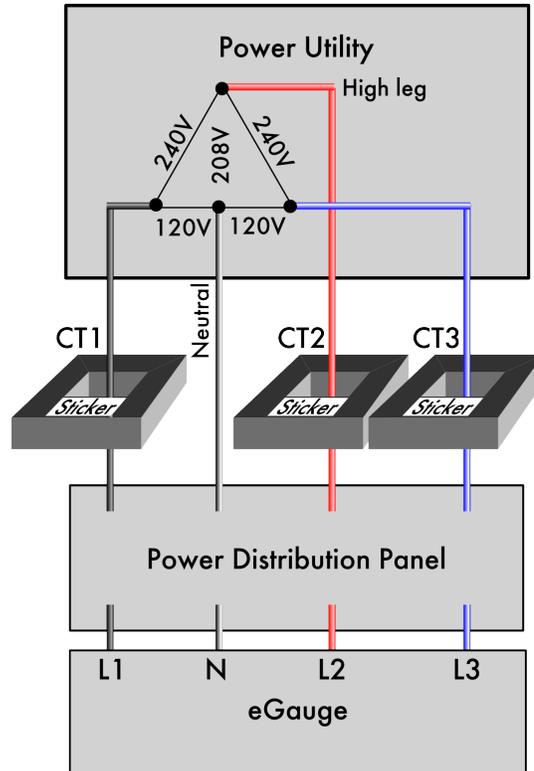
$$\begin{aligned} \text{Usage} &= \text{Grid} + \text{Solar} + \\ \text{Generation} &= \text{Solar} \end{aligned}$$

Notes:

- Same setup as for 120/208Y installation, except that a 277V transformer kit is needed to power the HomePlug adapter.

2.5 Three-Phase High-leg Delta

Three-phase high-leg delta installation measuring power coming from a power utility (grid).



Registers

$$\text{Grid} = [\text{P}] [=] \text{CT1} * \text{L1} + \text{CT2} * \text{L2} + \text{CT3} * \text{L3}$$

Totals and Virtual Registers

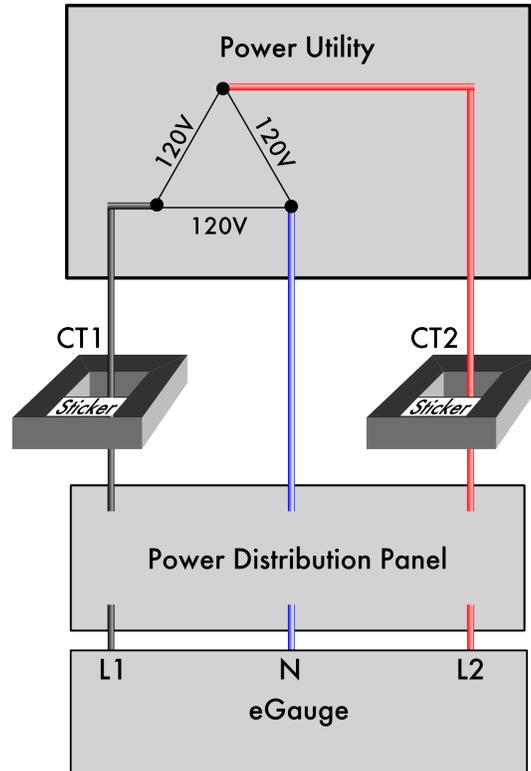
$$\text{Usage} = \text{Grid}$$

Notes:

- Wiring and configuration is identical to a standard three-phase site. The only difference is in the voltages measured on L1, L2, and L3:
 - L1 and L3 are 120Vac to neutral.
 - L2 is 208Vac to neutral.
- It does not matter whether the high-leg is wired to L1, L2, or L3, as long as all three phases are measured.

2.6 Three-Phase Delta

Three-phase delta installation measuring power coming from a power utility (grid).



Registers

$$\text{Grid} = [\text{P}] [=] \text{CT1} * \text{L1} + \text{CT2} * \text{L2}$$

Totals and Virtual Registers

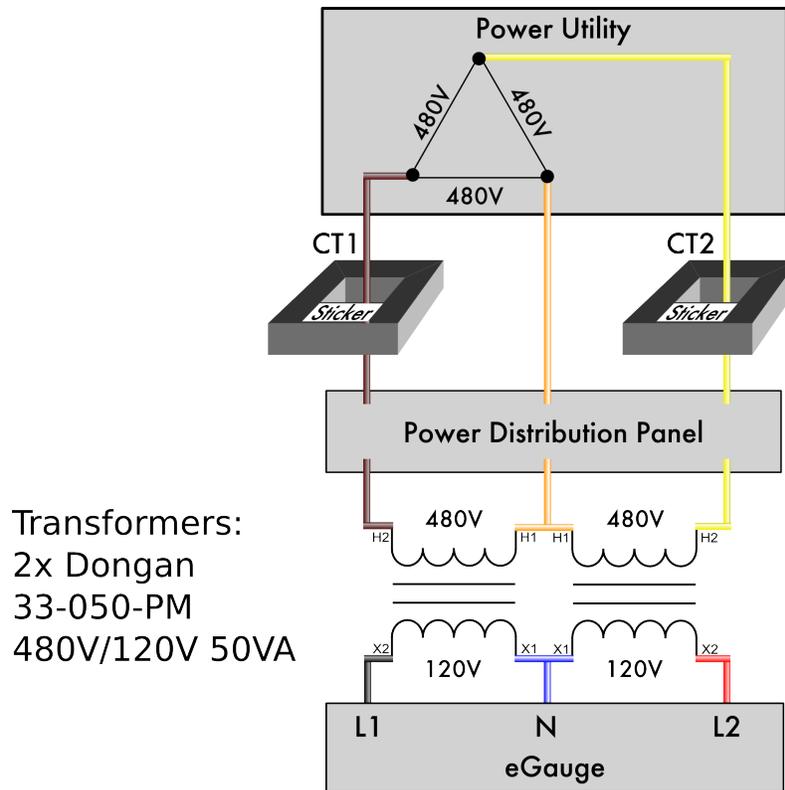
$$\text{Usage} = \text{Grid}$$

Notes:

- **CAUTION:** Since there is no neutral and none of the phases may be grounded, all conductive/metallic parts, including CT-plug screws and CT wiring should be considered live and hazardous!
- If one of the phases is grounded, wire that phase to the Neutral (N) pin on the eGauge.
- For best communication-performance, ensure that phases wired to L1 and N are the ones that are wired to the HomePlug adapter outlet.

2.7 Three-Phase Delta 480V

High-voltage (480V) three-phase delta installation measuring power coming from a power utility (grid).



Potential Transformers (PTs)

L1 = 480V:120V
L2 = 480V:120V

Registers

Grid = [P] [=] CT1*L1+ CT2*L2

Totals and Virtual Registers

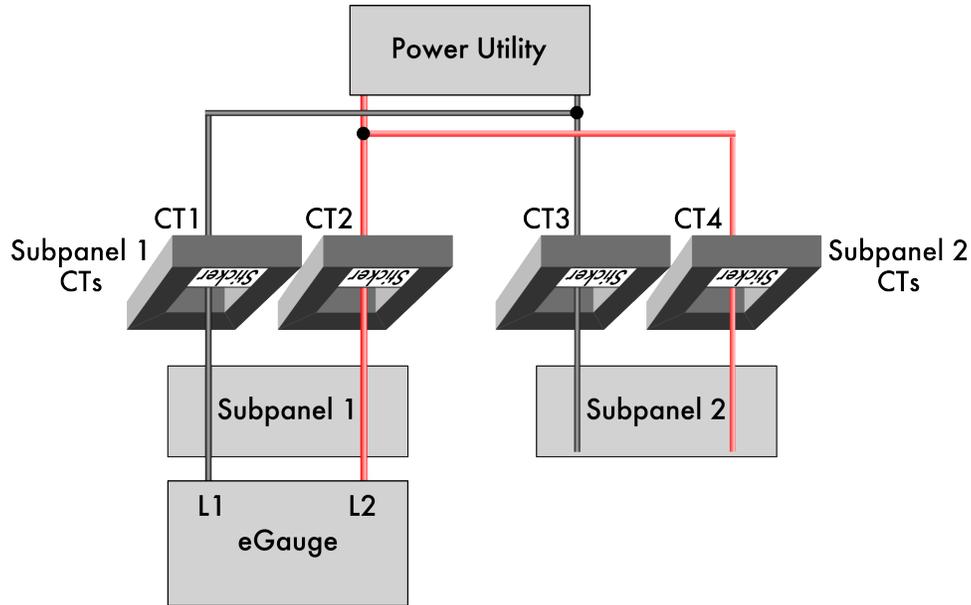
Usage = Grid

Notes:

- **CAUTION:** Since there is no neutral and none of the phases may be grounded, all conductive/metallic parts, including CT-plug screws and CT wiring should be considered live and hazardous!
- If one of the phases is grounded, wire that phase to the Neutral (N) pin on the eGauge.
- The HomePlug adapter should be plugged into an outlet wired in parallel with L1 and N of the eGauge and the outlet should be protected with a 0.5A Slow-Blow fuse.

2.8 Subpanels

This example illustrates how to measure subpanels.



Registers

$$\begin{aligned} \text{Subpanel 1} &= [\text{P}] [=] \text{CT1} \cdot \text{L1} + \text{CT2} \cdot \text{L2} \\ \text{Subpanel 2} &= [\text{P}] [=] \text{CT3} \cdot \text{L1} + \text{CT4} \cdot \text{L2} \end{aligned}$$

Totals and Virtual Registers

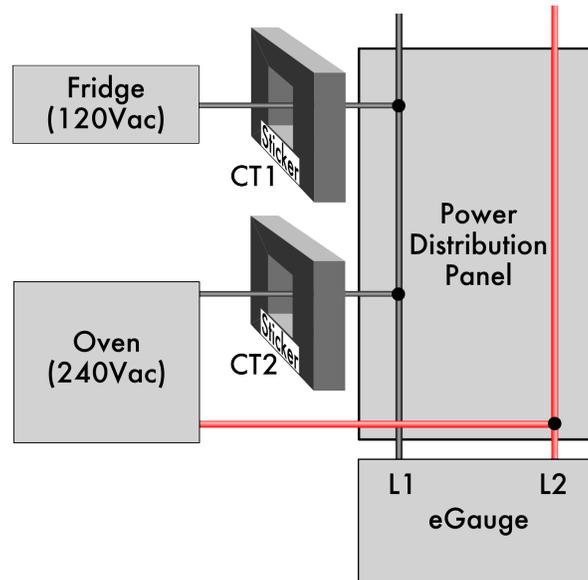
$$\text{Usage} = - \text{Subpanel 1} - \text{Subpanel 2}$$

Notes:

- The stickers on the CTs should point towards what is being measured, i.e., the subpanels.
- When properly installed, the subpanel registers will record negative power figures when power is being drawn on a subpanel, indicating a consumption.
- In the totaling rules, add together the *negative* value of each subpanel.
- It does not matter which subpanel eGauge is installed in.

2.9 Appliances

This example illustrates how to configure 120Vac (single leg) and 240Vac (two leg) appliances.



Registers

```
Fridge = [P] [= ] CT1*L1
Oven   = [P] [= ] CT2*L1 + -CT2*L2
```

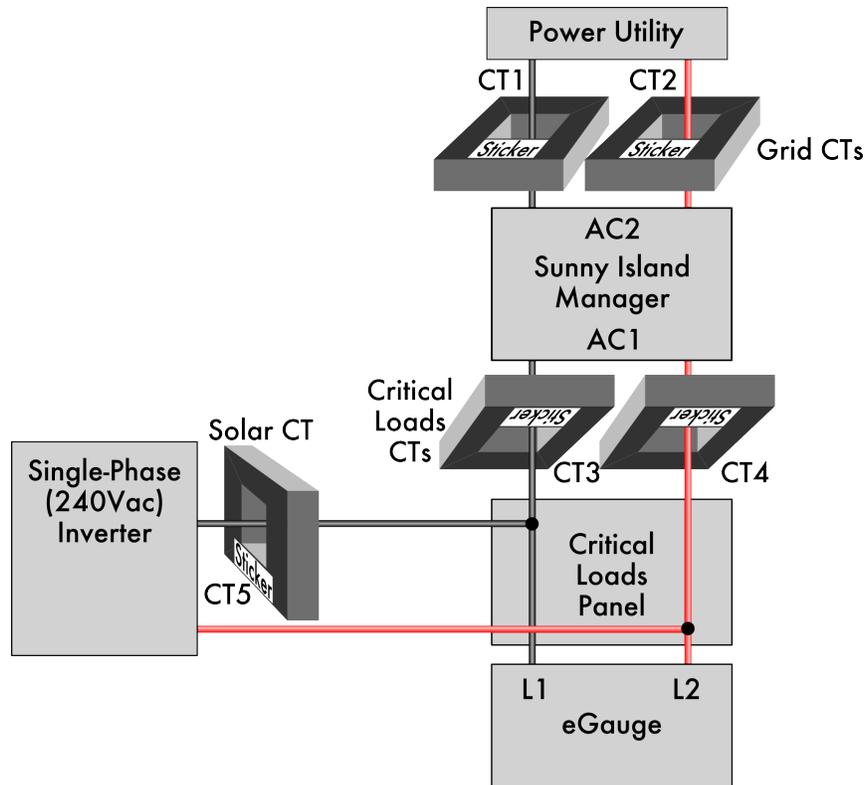
Totals and Virtual Registers

Notes:

- Registers defined for appliances do not appear in the totaling rules. Just defining the registers will make them appear in the appropriate places (e.g., in the legend of the dashboard graph).
- A single CT is sufficient both for 120Vac and pure 240Vac appliances. 240Vac appliances with asymmetric currents on the two legs (i.e., with a non-zero current on Neutral) require separate CTs per leg/phase.

2.10 SMA Sunny Island-based Battery-backed PV System

This example illustrates how to measure a battery-backed PV system using SMA Sunny Island manager.



Registers

Grid	=	[P] [=]	CT1*L1 + CT2*L2
Critical Loads Panel	=	[P] [=]	CT3*L1 + CT4*L2
Solar	=	[P] [=+]	CT5*L1 + -CT5*L2

Totals and Virtual Registers

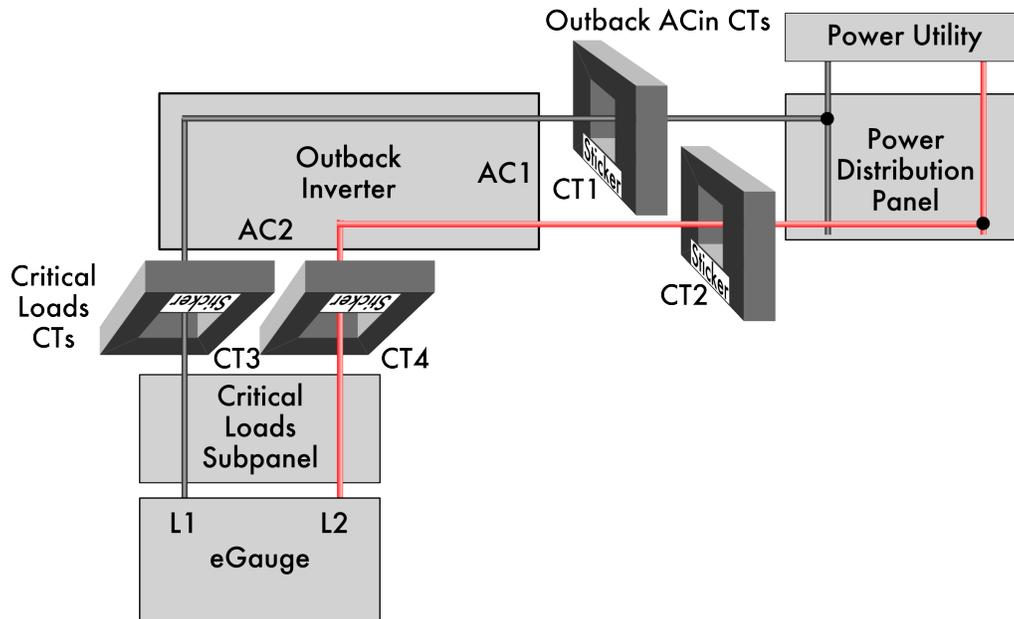
Usage	=	Grid + Solar+
Generation	=	Solar
Critical Loads Usage	=	-Critical Loads Panel - Solar+

Notes:

- The stickers on the CTs should point towards what is being measured: towards the utility for the Grid CTs, the subpanel for the Critical Loads CTs, and towards the PV inverter for the Solar CT.
- It is recommended, but not required, to power eGauge through the critical loads subpanel. Doing so ensures eGauge can properly record data even during a utility power outage.
- The Sunny Island manager has a built-in surge suppressor which filters out the HomePlug signal. Thus, the HomePlug adapter must be installed on the same side of the Sunny Island manager as the eGauge. We recommend powering both through the Critical Loads subpanel.

2.11 Outback System Using Separate Sets of CTs

This example illustrates how to measure a battery-backed solar system using an Outback inverter.



Registers

```

Outback ACin    = [P] [= ] CT1*L1 + CT2*L2
Critical Loads  = [P] [= ] CT3*L1 + CT4*L2

```

Totals and Virtual Registers

```

Usage          = ... + Outback ACin - Critical Loads + ...
Generation     = ... + Outback ACin - Critical Loads + ...

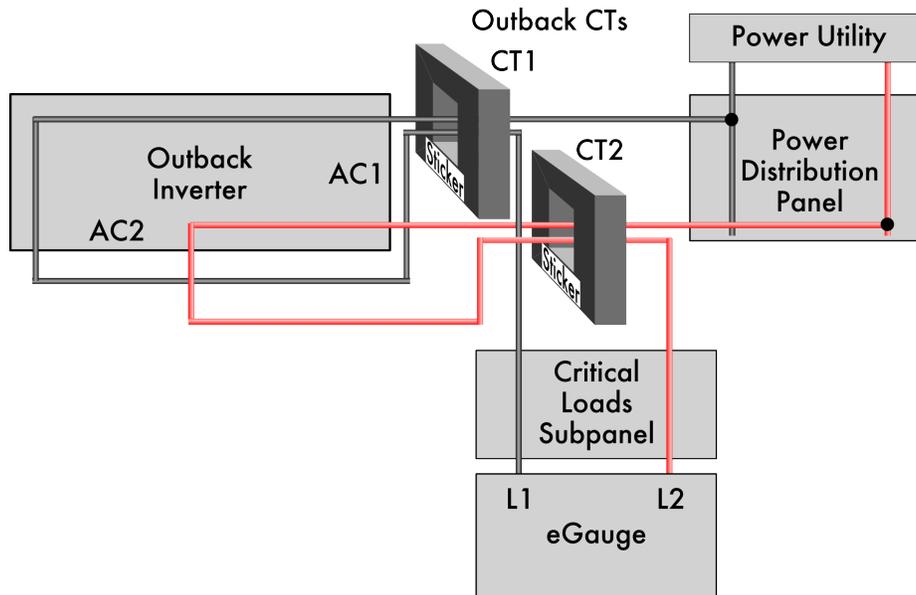
```

Notes:

- The stickers on the CTs should point towards what is being measured: towards the Outback inverter for the Outback ACin CTs and towards the subpanel for the Critical Loads CTs.
- It is recommended, but not required, to power eGauge through the critical loads subpanel. Doing so ensures eGauge can properly record data even during a utility power outage.
- The Outback system's net output (solar system output net of any power used to charge batteries or power supplied by batteries) is equal to Outback ACin - Critical Loads. The first addend (Outback ACin) can be negative or positive, depending on whether power is flowing into the Outback Inverter or out of it, respectively. The second addend (Critical Loads) is always negative, indicating a load. For example, if 1000W is flowing out of AC1, then Outback ACin = 1000W and if 500W is flowing out of AC2 into the critical loads subpanel, then Critical Loads = -500W, so subtracting the latter from the former yields a total output of 1500W from the Outback Inverter.

2.12 Outback System Using Single Set of CTs

Same as previous example except that a single set of CTs is used to measure the Outback System's net output.



Registers

```
Outback = [P] [=+] CT1*L1 + CT2*L2
```

Totals and Virtual Registers

```
Usage      = ... + Outback+ + ...
Generation = ... + Outback + ...
```

Notes:

- The stickers on the CTs should point towards what is being measured, i.e., towards the Outback inverter.
- The summing of the power coming out of AC1 and AC2 is achieved by running a pair of wires through each of the two CTs. It is critical to ensure that wires on the *same leg* are run through the CTs.
- This configuration uses fewer CTs than the previous example, but is usually more difficult to install because of the more complicated wire-runs.

3 Troubleshooting

If an installation does not work as expected, we recommend using the channel checker tool to troubleshoot the problem. This tool is available through the “Tools” link in the top right menu of the eGauge web pages. Click on that link, then click on “Channel Checker” in the left menu. Figure 2 provides an example of what this tool looks like.

As of Thu Nov 05 2009 15:21:49 GMT-0700 (MST):

Frequency:	59.99 Hz	Grid (L1^CT1)	567.2 W (PF 0.77)
L1 (ch0):	n/a	Grid (L2^CT2)	607.5 W (PF 0.81)
L1 (ch8):	120.5 V	Oven (L1^CT3)	-15.7 W (PF 0.67)
L2 (ch1):	121.3 V	Oven (L2^CT3)	-16.2 W (PF 0.69)
L3 (ch9):	n/a	Solar (L1^CT4)	50.8 W (PF 0.14)
CT1:	6.09 A	Solar (L2^CT5)	48.3 W (PF 0.14)
CT2:	6.18 A	Aquarium Lgts (L2^CT6)	-153.3 W (PF 0.99)
CT3:	0.19 A	Drawer Fridge (L2^CT7)	0.0 W (PF 0.00)
CT4:	2.95 A		
CT5:	2.93 A		
CT6:	1.27 A		
CT7:	0.05 A		
CT8:	n/a		
CT9:	n/a		
CT10:	n/a		
CT11:	n/a		
CT12:	n/a		

Figure 2: Example of eGauge Channel Checker Tool

The channel checker reports the real-time RMS voltages measured for each active voltage probe and the RMS currents for each active CT (eGauge automatically determines which voltage and current probes are active based on the register definitions; if a voltage or a CT is not used by any register, it is deactivated). In addition to the currents and voltages, the page also reports power figure for each component of all registers. The power figure is accompanied by a power-factor, which is a value between 0 and 1. A value of 1 indicates a purely resistive load whereas a value of 0 indicates either a purely inductive or purely capacitive load.

3.1 Fixing CTs Pointing in the Wrong Direction

If a CT accidentally was installed pointing in the wrong direction, its polarity will be reversed (i.e., the power will read negative when it should be positive and vice versa). Since fixing the installation may be time-consuming, it is usually easier to adjust the configuration. This can be done easily by adjusting all register definitions which use the incorrectly installed CT to use the CT value of opposite polarity. For example, if CT3 was installed incorrectly, change all appearances of CT3 to -CT3 and vice versa.

3.2 Fixing Leg/Phase Mixups

For installations involving multiple subpanels, it is sometimes not easy to track down which conductor belongs to what leg or phase. If a CT is thought to have been installed on a conductor wired to L1 but actually was on a conductor wired to L2, the reported power will be wrong. In a split-phase system, the power will have wrong polarity (negative when it should be positive and vice versa). In a three-phase system, the power-factor will be significantly lower than expected. Rather than moving the CTs or the CT wiring, it may be easier to adjust the configuration to match reality. This can be done by adjusting the register definitions such that the incorrectly installed CT(s) are multiplied by the voltages that they're actually connected to. If the polarity of the reported power is correct and the power-factor is close to 1, that usually can be taken as a sign that the correct phases are being used. It is usually a good idea to temporarily turn off any renewable energy systems to confirm that the polarities and power-factors make sense even when there is no renewable power.

A Formula Operators and Functions

The following operators are available in register formulas (in decreasing order of precedence):

Operator:	Precedence:	Description:
$\$r$	6	The value of register r .
(e)	5	The value of parenthesized sub-expression e .
$-e$	4	The negative of e .
$e_1 * e_2$	3	The product $e_1 \cdot e_2$.
e_1 / e_2	3	The quotient e_1 / e_2 .
$e_1 + e_2$	2	The sum $e_1 + e_2$.
$e_1 - e_2$	2	The difference $e_1 - e_2$.
$e_1 < e_2$	1	1 if $e_1 < e_2$, 0 otherwise.
$e_1 > e_2$	1	1 if $e_1 > e_2$, 0 otherwise.
$e_1 \leq e_2$	1	1 if $e_1 \leq e_2$, 0 otherwise.
$e_1 \geq e_2$	1	1 if $e_1 \geq e_2$, 0 otherwise.
$e_1 = e_2$	1	1 if $e_1 = e_2$, 0 otherwise.
$e_1 ? e_2 : e_3$	0	e_2 if e_1 is not 0, e_3 otherwise.

Caveat: Care needs to be taken when comparing floating-point values for equality. Except when comparing the result of a conditional operator, it is usually better to replace $e_1 = e_2$ with a test of the form $\text{abs}(e_1 - e_2) < \epsilon$, where ϵ is the largest expected error.

The following table describes the list of functions that are available in formula registers:

Function:	Description:
$\text{abs}(x)$	Absolute value of x .
$\text{max}(x,y)$	The greater value of x and y .
$\text{min}(x,y)$	The smaller value of x and y .
$\text{mod}(x,y)$	The remainder of dividing x by y .
$\text{sqr}(x)$	x^2 .
$\text{sqrt}(x)$	\sqrt{x} .
$\text{exp}(x)$	10^x .
$\text{log}(x)$	Common (base-10) logarithm of x .
$\text{floor}(x)$	Largest integral value not greater than x .
$\text{VAr}(r,a)$	Given real power r and apparent power a , return reactive power.
$\text{month}()$	Number of months since January (0...11).
$\text{wday}()$	Number of days since Monday (0...6).
$\text{time}()$	Number of hours since midnight (0...23). Fractional part gives the part of the hour that has elapsed already, i.e., 0.5 for 30 minutes.
$\text{P_PV}(i,t,p,c)$	Given irradiance i , panel temperature t , STC-rated power p , and power-temperature-coefficient c , return expected PV output.
$\text{pref}("p")$	Return value of preference-setting named p (e.g., "global.production.rated").

Revision History

3-Apr-2012	Fixed typos: 408V/408Y should have been 480V/480Y. Changed phase colors for Three-Phase 277V/480Y to brown/yellow/orange as it was meant to be...
1-Mar-2012	Added Section 1.2.1 on self-powered rope CTs. Documented RS485 protocol in Section 1.3. Marked Power-One Aurora inverter protocol as obsolete (RS485 should be use instead for reading such inverters). Documented formula registers in Sections 1.4.2, 1.4.4, and Appendix A.
30-Jan-2012	Added SMA Sunny Island configuration example. Created separate page for three-phase 277/480Y.