Hydrocontrol manual

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Content

1 Features

1.1 Intended usage:

- for hydro power generators in off-grid/island operation. For grid connected operation, additional equipment is needed.
- with remote control capability: mobile phone
  ethernet network (beta)
- Electronic Load Controller (ELC) / Induction Generator Controller (IGC)
- Protection Relay
- Auto user load switch /Low priority dump load switch

1.2 Features

1.2.1.1 Features for the user

- Flexible - works for a wide range of installations
- Easy adjustment on site due to micro-controller technology
- P-I auto-tuning (beta stage).
- Reliable - proven technology
- Can be remote controlled via mobile phone network and SMS text messages.
- The HydroControl can also send status information via SMS text messages.
- The configuration can be stored on a SD memory card. In case of replacement, simply load the last configuration. Or transfer settings to another site.
- If the system shuts down, the controller stores the fault/shutdown reason in memory for easy fault tracing.
- Flexible dump load configuration – see below.

1.2.1.2 Features for the engineer

- Simple to use, simple to repair
- Standard components -> cheap to repair
- Flexible: from micro scale (few 100 watts) to medium scale (megawatts)
- Customizable: simply change the software to add features and behaviour
- In circuit serial programming ICSP via USB: firmware update on site possible, only a laptop and USB cable are required
- No flywheel necessary: if there are oscillations, adjust the P-I regulation speed with the help of live graphs on the screen.
- Password-protected settings
- Anti-windup limiter for the P-I controller
- DC component suppression while switching the dump loads on the AC line

- Fault detection for each dump load circuit

1.3 Flexible Dump Load Configuration

You can configure 4 types of dump loads:

1. High Priority Auxiliary Loads

These can be loads of any watts rating. They will be switched on as soon as there is enough power. They are not considered as “dump” loads in this manual.

If the total wattage of all dump loads exceeds the system rating, then these high priority loads can fail or be switched off, without affecting the frequency regulation.

If the load is resistive (Heaters, Boilers etc.), and if the wattage of the load doesn't exceed the rating of the triacs or SSRs, then it can be switched by the built in triacs or SSRs. If your ELC doesn't have SSRs and your load is bigger than the rating of the triacs (normally 12 Ampere or 3 kW), then you need to provide a power relay/contactor suitable for your load.

If the load is inductive (water pumps, heat pumps, compressors, motors etc.), observe the reduced rating of the built in triacs and/or SSRS. The triacs will need an additional snubber circuit (installed on request).

Depending on the rating, the load has to be switched by an external contactor. The contactor would be controlled by the built-in mechanical relays in the hydrocontrol. Observe the amp ratings of the built-in relays for different uses, specified in the correspondig chapter 5.2.1.1

2. Priority dump loads

These have to be resistive, and of roughly the same size, if you configure more than one. They get switched on one after the other. They are either fully on or off. This is useful if you want to prioritize excess power, e.g. first heat the water, then the house.

3. Equal distribution dump loads

These can be of variable size, but have to be resistive. The available power is shared equally among all loads, e.g. an electrical heater in every room. This is done via full wave switching. This also has the advantage that the dump loads and semiconductors are normally not used up to their full rating, which can increase lifetime.

4. “Big” dump load

If your hydrocontrol has SSRs installed, you can connect one or more “big” dumploads, which can have a rating close to the combined wattage of all other dump loads (recommended max. 75%).

5. Mandatory: 1 resistive variable dump load

You need at least one resistive dump load, connected to channel 1, which is equal or bigger than any of the individual loads of type 2 or 3. This variable load serves to balance out the combined dump load wattage and is “dimmed” via phase angle or full wave (zero crossing) switching. This dump load will be partially loaded on average to 50%, over a long period.

1.4 Protection Features

- Over-voltage, Under-voltage
- Over-frequency (over-speed), under-frequency (under-speed)

- Over-current
- Overheating: freely configurable temperature sensors, e. g. to monitor roller bearings or generator temperature.
- Every dump-load is protected with a fuse.

Operating conditions

- The heat sinks must be freely ventilated, maximum ambient temperature 45° Celsius.
- If the heat sinks/triacs get to hot, the HydroControl will shut the system down to prevent damage.

1.5 Metering on the display:

- AC Mains Voltages for all 3 lines
- Frequency
- Current for all 3 lines
- Temperatures
- DC Voltage 12V or 24V, if present
- Hour counter

1.6 Configuration

Control water valves

Control main user relay / main contactor in case of fault

Connect 3 - 48 dump-loads

Use any dump-load size up to 16amps / 4kW (as long as they are resistive loads)

You can even mix different sizes, within certain limitations.

3 Phase: line load balancing

Warning signal for users, if there is no remaining system capacity

Automatically switch low priority user loads, depending on available system capacity

choose between zero crossing and phase angle switching

zero crossing:

does not create RF interference/noise and does not distort the sine waveform, but is a bit slower in regulation -> maximum deviation from set-point, if big user loads are switched, is a bit bigger.

phase angle regulation:

fast regulation, but can introduce RF-Interference and waveform distortion, especially if there are few dump-loads connected.

1.7 Modular Design

Get only the micro-controller unit and connect your own SSRs or triacs

Get the base unit for up to 35 kw and 12 dump-loads, and connect your own additional SSRs / triacs if needed

Get a customized unit, with the specified amount of dump load connections, pre-wired in a switch cabinet.

1.8 Example alternative usages

1.8.1.1 Protection Relay

Use the micro-controller unit in parallel to an existing ELC, to monitor the system. In case of fault, the micro-controller unit can do any/all of the following:

- turn of the water
- disconnect users
- engage a mechanical brake
- connect dump-loads to slow down the system
- connect a second generator
- send an SMS text message

1.8.1.2 Automatic User load switching

If you have low priority user loads in a different location than the main ELC, use only the micro-controller unit to automatically switch these loads on an off, depending on available power. Or use SMS.

1.8.1.3 Backup ELC

Use it in parallel to the main ELC, but set the frequency a bit higher. If the main ELC fails, the backup ELC will kick in.

1.9 Technical specifications

Voltage nominal: 120V or 220 - 240V

Frequency: 50/60 Hz (adjustable from 45 - 64 Hz)

very precise frequency regulation: +- 0.01Hz (+/- 0.02%)

Power: from micro scale (few 100 watts) to medium scale (megawatts)

Phase: 1 or 3 phase

Generator: Induction generator (asynchronous) or synchronous generator

2 Operating modes

The hydrocontrol has 3 operating modes:

2.1.1.1 1. Electronic Load Controller ELC

Controls the frequency by switching electric dump loads.

Voltage is typically controlled by a separate system, the automatic voltage regulator AVR.

2.1.1.2 2. Induction Generator Controller IGC

Controls the voltage by switching electric dump loads. Frequency is controlled by the design of the induction motor (asynchronous motor)

The rest of the manual refers to frequency regulation, but in case of IGC operating mode, always voltage regulation is implied.

2.1.1.3 3. Automatic user load

If you have low priority user loads in a different location than the main ELC, use only the micro controller unit to automatically switch these loads on and off, depending on available power.

2.1.1.4 4. Output test

Not an operating mode, but a test mode to test all outputs. See description below

2.2 Function description

In ELC and IGC mode, the controller tries to keep the measured frequency (IGC: voltage) as close as possible to the target frequency (set point), by adjusting the dump loads via a P-I regulation loop. This regulation is always active, regardless of system state and protection features. It can be only switched off by changing the operating mode to “automatic user load” or “output test”.

Dump loads are switched in 3 different ways:

One dump-load only (3 dump-loads in 3 phase systems) is variably adjustable. That means, it can be powered in steps from 0% to 100%. This is for the fine tuning of the frequency.

Up to 8 (24 in 3 phase systems) other dump-loads are either completely on or completely off (priority loads), or equally loaded via full wave switching, individually switched by triacs.

On top of that, all additional dump-loads are switched in bulk by SSRs.

3 Main Screen

3.1.1.1 [START] button

If water valve(s) are connected to the controller, this button opens them. Then the system waits for all parameters (frequency, voltage, current, temperature) to get inside of operating range (starting phase). As soon as all parameters are in range, the user load relay switches on. We are now in normal operating mode.

If the connected user load is close to system capacity, the system might slow down very much. In this case, you can specify that a certain percentage of dump loads shall be on, before the user load is connected. See below.

You can specify that the controller automatically goes into starting phase after power up. In this case, it is not necessary to use the [START] button. See below.

If you don't have an electrically powered water valve or an automatically operated mains contactor, this button is irrelevant.

3.1.1.2 [STOP] button

If water valves are connected, this button closes them. Then the user load is disconnected.

If you don't have an electrically powered water valve or an automatically operated mains contactor, or any other automatic shutdown procedure connected to one of the relays, then this button is irrelevant.

The frequency regulation continues to function.

3.1.1.3 [Settings]

Change settings. See Settings description

3.1.1.4 [Status overview]

Look at various information.

3.1.1.5 User load

calculates the current user load by subtracting the total measured electrical current minus active (switched on) dump loads.

3.1.1.6 Dump loads

the percentage of dump loads, which is currently switched on.

3.1.1.7 Last shutdown reason

The offending parameter which caused the last shutdown is displayed. If there are multiple shutdowns, the previous error message is overwritten. Resetting the message is only to clear the display.

3.1.1.8 [Warnings] button

Warnings are not errors.

A warning means, that some component is not working as expected or some value is close to its maximum limit, but the hydrocontrol is still working.

An error means some value has exceeded its maximum limit or some vital component has failed. In this case the hydrocontrol tries to shut down the system, depending on how your system is set up.

This is the list of current warnings. If there are no warnings, the button is not visible. If you have warnings regularly, try to find the problem and fix it

4 Settings

4.1 Operating modes:

See above

4.1.1 Output test

Be aware: only use this while the system is shut down. All dump loads will be disconnected immediately.

You can try each triac, SSR and relay separately, to verify correct wiring and for fault finding.

You can test the variable dump load by "dimming" it.

Consider connecting a light bulb in parallel to each dump load which you want to test.

The relay button color indicates the physical state: blue is powered, gray is off. If this means connected (closed) or not connected (open), depends on your wiring.

4.2 ELC/IGC Settings

4.2.1 General Settings

4.2.1.1 Total dumpload capacity

This value helps the hydrocontrol to determine when there is enough spare power to switch on a high priority aux load.

With variable water flow (either variable valve or several fixed flow valves), the current dump load percentage does not reflect the currently available system capacity.

In "status overview -> system capacity", with variable water flow, the available system capacity is calculated by subtracting total system capacity minus total electrical current.

4.2.1.2 ELC: frequency set point.

Typically, this would be 50Hz or 60Hz, depending on your location. If you have 2 ELCs installed, set the backup ELC to a slightly higher frequency, e. g. 51Hz. In this case, the backup dump-loads will never go on during normal operation, because the backup ELC thinks the actual frequency is too low.

4.2.1.3 IGC: voltage set point.

This value is also used to compute live graph scales. So even though it is not relevant for ELC function, please set it to the correct value for your power system.

4.2.1.4 AC Phases (1 or 3)

This decides, if voltage lines 2 and 3 should be monitored or not.

If you have a 3 phase system and set this to one phase, the system will not shut down if there

is voltage loss on line 2 and 3.

If you have a 1 phase system and set this to 3 phase, the system will never switch to normal operation, because power on lines 2 and 3 is missing.

4.2.1.5 Automatic start-up

On powering up the controller...

You can decide if water valve and user relay shall be opened /connected automatically (if wired), or if you want to start manually with the start button. Frequency regulation is always active, independently of this setting.

If you don't have an electrically powered water valve or an automatically operated mains contactor, this setting is irrelevant.

4.2.1.6 Connect users

Connect users, as soon as a certain percentage of dump loads are on.

This is to prevent the controller from connecting user loads, while the water pressure in the pipe is still building up. In case of a user load close to maximum system capacity, this could lead to a long period of under-voltage / under-frequency, in which case the system would shut down again.

So wait till e. g. 80% of dump-loads are on, before users are connected. The dump loads will then immediately switch off again.

4.2.1.7 Droop

This varies the setpoint, as the dumpload output changes. E.g. with a setting of 10%, the frequency will vary between 45 and 55 Hz. With 0% dumploads on (no capacity left), the frequency will drop to 45 Hz, and with 100% dumpload on, the frequency will rise to 55Hz.

This is useful for following purposes:

1. If the hydrocontrol ELC is installed remotely, you an connect a cheap frequency meter in your home (many readily available energy consumption meters for home use display the frequency). A low frequency will indicate little remaining capacity.

2. If you have 2 ELCs or generators connected, you can balance the load between them.

4.2.2 Water valves

This setting is relevant for systems which either have a variable water flow inlet valve, or which have several fixed flow valves.

4.2.2.1 Valve operation threshold

If less than a given percentage of dump loads remain for regulation, before all dump loads would be on/off, then operate valves. E. g. if less than 20% of dump-loads are on, open the valve(s). If less than 20% of dump load are off, close the valve(s)

4.2.2.2 Fixed flow/variable flow

Variable flow: use this if your valve can be partially open.

Fixed flow: use this if you have several valves (up to 3), but they are always completely opened/closed during normal operation.

4.2.2.3 Fixed flow mode:

It may be useful to wait a while after one valve has been opened, before the next valve is opened.

During the waiting time, the system regulation can settle again. A short waiting time might be necessary if you have one really big user load, but it increases the risk of oscillation due to over-regulation.

Be aware that the total kW of you dump-loads has to exceed the kW produced by one valve, plus a safety margin on both sides.

E. g. if one valve and the turbine driven by that valve produces 40kW, and you want 10kW of spare dump-load capacity for regulation, then your total dump load capacity has to be at least 10kW + 40kW + 10kW = 60 kW.

4.2.2.4 Water valve duty cycle

If you have a motorized variable flow input valve, which drives very quickly, then the system might start to oscillate, because there is a too big delay between the operation of the valve, and the resulting change in power output. With this setting, you can slow down the valve motor and achieve a slower regulation.

4.2.3 P-I Setup

4.2.3.1 Adaptive control

Currently not implemented. This feature is supposed to detect oscillations in regulation, and then tune the P and I value down a bit. If on the other side the regulation takes very long to reach the set point, the adaptive control would turn up I. If the regulation has a big deviation from the set point, the adaptive control would turn up P. The software to reliably detect oscillations is not ready, so you have to do it by hand for now.

4.2.3.2 Manual Tuning of the P and I values

1. Turn I completely down.
2. Turn P up until the system oscillates (The frequency (IGC:Voltage) starts to go above and below the set point in a regular rhythm)
3. Turn P down a bit again, so the oscillation is reliably gone.
   You can try to trigger oscillation by connecting and disconnecting additional loads of different sizes.

   If dump load 8 is not used, the [Step] button tries to switch on dump load nr. 8 for 2 seconds, to produce a regulation "step". This is a convenient way to switch an additional load.

   If you have some kind of water regulation, try to test for oscillation with different amounts of water flow.
4. Do the same procedure with I.

If the system reaches the target frequency (set point) very slowly: turn I up.

If the system has a big maximum deviation: turn P up

P and I values influence each other to a degree. So if the system reaches the set point very slowly, but turning up I still produces oscillation immediately, turn down P a bit more.

P-I tuning is always a compromise between fast regulation (aggressive tuning) and avoiding oscillation. It you really need fast regulation, a bit of decaying oscillation might be acceptable. Decaying oscillation: after a load change, the system goes into oscillation, but the oscillation quickly calms down again.

But be aware: if you tune too aggressively, the oscillation might also build up over time, and damage your system.

See also the paragraph about frequency input averaging.

This manual is not the place to explain a P-I regulation loop, but Wikipedia explains it well (look for "PID controller") The hydrocontrol does not use the D (derivative) component.

Hint: changing dump loads after initial startup
If you remove or add dump loads to the ELC after you have adjusted the P and I values, it is advisable to readjust P and I.
If you have added dump loads, the regulation will be more aggressive now, since the controller has more "leverage". If you have removed dump loads, the regulation will be slower.

4.2.4 Dump load outputs.

The first dump-load is the variable dump load. You can choose between 2 ways to control this dump load.

4.2.4.1 1. Zero-Crossing switching.

The dump load is turned on and off, while the AC voltage is Zero (it crosses the zero-line)

Advantages: the switching produces no RF (radio frequency) noise and the sine wave of the AC power is not distorted.

Disadvantage: the regulation response might be a bit slower, and the control is not so fine-grained.

4.2.4.2 2. Phase angle switching

The dump load is turned on every period of the AC sine wave. Depending on where in the wave this happens (in which "angle" of the sine curve), the dump load gets more or less power.

Advantage: quick and precise regulation

Disadvantage: might produce RF-noise, can distort the sine waveform. If only a few dump loads are connected, the distortion is bigger.

One or the other switching type might also interfere with your AVR automatic voltage regulator, depending on if you AVR uses peak voltage or RMS voltage as input signal, and how much averaging the AVR uses. If you have problems in this area, try the other switching method.

If you really have big issues, try to use more, but smaller dump loads, to minimize the influence of the variable dump load.

Summary:

If your radio reception suffers interference, or your appliances start to hum, use zero-crossing.

If you don't have these effects, take advantage of the more precise regulation.

4.2.4.3 Total dump loads per phase including SSR dump loads.

E. g.

1 variable dump load

8 triac dump loads

6 SSR dump loads, 3 per SSR

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15 → enter this in the field.

If you have a 3 phase system, you will have e.g. 15 x 3 = 45 dump loads, but you still enter 15!

4.2.4.4 Dump loads per SSR

If you don't have any SSRs in use, this field is irrelevant.

ATTENTION: the software does no error checking here. Make sure you get it right.

If you get it wrong, the system will either not use all your dump loads, or it will not regulate water intake in time, or there might be jumps in regulation, when SSRs get switched.

(Future feature: there are plans to detect a faulty dump load / triac circuit. If the system detects faulty circuits, but you are sure they are not faulty, check if the figures here are correct.)

4.2.4.5 Dump load rating in Watts:

This value is used for the load balancing over the lines of a 3 phase system. It calculates how many ampere are taken away/added to a line, it a dump load is added/ removed.

If you don't use load balancing, this is irrelevant.

Hint: changing dump loads after initial startup

If you remove or add dump loads to the ELC after you have adjusted the P and I values, it is advisable to readjust P and I.
If you have added dump loads, the regulation will be more aggressive now, since the controller has more "leverage". If you have removed dump loads, the regulation will be slower.

4.2.5 Frequency Input noise filtering

If the frequency reading is noisy due to a noisy power line with spikes and transients, the input reading can be smoothed to achieve a more stable regulation.

ATTENTION:

Make sure the noise doesn't come from oscillating ELC regulation, due to too high P and I.

IF you need a high P, you can reduce regulation oscillation a bit by turning up this filter.

Too much smoothing will make the regulation very slow.

1 = no filtering.

The graphs shows filtered and unfiltered frequency reading in parallel.

4.2.6 3 Phase load balancing.

ATTENTION untested feature. Your mileage may vary.

If one line has a much higher current than the other lines, the voltage might drop on this line

or the generator might be overloaded. First try to distribute the user loads evenly over all three lines. If this is not possible, this option tries to distribute the dump-loads so that all 3 lines are loaded equally again.

It only does this in steps of whole dump loads. The 3 variable dump loads are not used for this.

4.2.7 Overload warning signal

When activated, this will regularly switch on some dump-load if there is no remaining available system capacity (all dump loads off). The resulting frequency drop will change the sound of the hum in user appliances. If they hear this, they should switch off loads.

- % of dump-load to switch on
- duration of signal secs
- interval between signal secs

Try to find a setting which is visible/audible, but does not let the frequency drop too low.

You will have to educate the users to react to this signal.

4.2.8 (User) Protection Relay

This feature is used to shut down the system, if input parameters go out of range, and/or to disconnect users. It controls relay no. 4, the “protection relay”, and relay no. 1, water valve relay.

The protection relay is powered/energized in normal operation. If one of the monitored parameters trips the shutdown or if the hydrocontrol fails, the relay will go to unpowered state. Also the water valve relay will be de-energized.

The dump loads are never disconnected, since they are needed to keep the system from going into over-speed. Consequently, they are only indirectly protected by this feature: Since the system is shutting down, any over-voltage will eventually decrease.

This feature also automatically energizes the protection relay **on start-up only**, once all parameters are “green”.

The valve relay is energized with the start button, or, if automatic start is configured, automatically.

Once the protection feature has tripped, it will not go live anymore, even if the offending parameter is okay again. This is to prevent multiple automatic start-ups / shutdowns. Somebody will have to press the [START] button to start the system again.

Adjust these parameters, so you don't get any unnecessary shut downs. This depends a lot on how your system reacts to load changes, so I can't provide any "standard" settings.

(Planned for a future release:

The specified maximum time is valid, if the parameter is just out of range.
If the parameter is out of range by 200%, the max. time goes to 50%.

E. g. if you have set a maximum frequency deviation of 10 Hz and 2000 ms, the system will shut down if the frequency is just below 40 Hz for more than 2 seconds.

If the frequency is 30 Hz (20 Hz deviation), the system will only wait 1 second, before it shuts down.)

4.2.9 Automatic user load control

This feature is intended to switch a low priority user load, which is not installed close to the ELC. It does this **without feedback from the ELC, how much power capacity is left.**

Basically if voltage and frequency are in range, it simply goes on. If it then turns out that turning on this load pulls down voltage or frequency to an unacceptably low level, it turns itself off again. These levels can be set here. Preferably the levels should be higher and the time should be shorter than the ones set in the protection relay, or else the protection relay will trip before the user load will switch itself off again.

After the specified waiting time it will try again.

(Feature planned for the future:

If the overload warning signal is on, it should be possible to recognize this regular pattern. If the automatic user load control detects the overload warning, it will switch itself off before values go out of range, and it will not try to switch itself on while overload warning is present. This could be especially useful if there are several low priority user loads, or if this low priority user load is very large.)

4.2.10 Low priority load

Planed for future release:

Switch 2 low priority loads connected directly to the hydrocontrol.

These loads are independent of the other dump loads. So if this low priority circuit fails, regulation is still functional.

You can adjust the kW thresholds, before the loads go on/off.

E. g. first load has, say, 4 kW. You would set the threshold so that it goes on if there is at

least 5 kW of free capacity, which is currently diverted to dump loads. it goes off again if: there is less than 1 kW of free capacity AND load 2 is off.

E. g. second load has say 6 kW - goes on if: first load is on AND 7kw free capacity. Goes off if less than 1kW capacity.

4.2.11 Mobile GSM communication

Prerequisites, quoting the manufacturer of the GSM module, adafruit:

A 2G Mini SIM card is required to use the module. Nearly any cell phone shop can sell you a SIM card. It must be a 2G GSM card.

MicroSIMs won't fit - so make sure its a "Mini" SIM. Sometimes these are just called plain "SIM" cards since the huge-size SIMs are rarely used nowadays.

Mini SIMs are 1" x 0.6" / 25mm x 15mm. These are by far the most common size.

4.2.11.1 This SIM card needs to be activated in your mobile phone.

If your SIM card is new, you first need to register and/or activate it. Insert it into your phone and follow the instructions supplied by your mobile provider. If you can send and receive SMS texts on your phone to/from other people, then everything is OK.

4.2.11.2 No PIN lock/SIM lock

Also permanently deactivate any PIN lock / SIM lock setting while the card is in your phone. This “PIN lock deactivated” setting will be stored on the SIM card. A SIM card with PIN enabled on start-up will not work in the hydrocontrol, because there is no possibility to enter the PIN.

I would recommend to get a SIM card with a contract, so it can't run out of credit.

Prepaid SIM cards sometimes get deactivated if there are no calls/ top-ups for a certain amount of months, even though there still would be enough credit.

Read the fine print from your mobile phone provider.

Once this is done, switch off the hydrocontrol and insert the SIM. I haven't tested if the SIM is hot-swappable. Warranty void if you try it and break it.

Use the signal strength reading to position the antenna where you have maximum signal strength. The display updates every second, but the GSM module only updates the value every few seconds. So be patient.

ATTENTION:

Anybody who knows the telephone number of the system can remotely shut it down. Treat this number as a secret password.

4.2.12 Input calibration

This has been done during assembly already. Normally you don't need to re-calibrate. It could be that after several years of operation, the accuracy has drifted, and then a re-calibration is

necessary.

ATTENTION:

Calibrate the inputs only once the system has been running for 60 minutes and has reached operating temperature.

Disclaimer: The voltage and ampere readings are not as precise as from a calibrated digital multimeter. They can drift up to 2% due to temperature effects.

Also this is not a real RMS measurement. The AD converter takes 3 samples per half wave, so it only approximates the RMS value. It's more of an average measurement. If the generator produces varying wave forms, accuracy might suffer.

It also only samples one half wave per period, so it won't detect an unsymmetrical AC voltage.

Also due to the averaging nature and the low sample rate of the measurement, it won't detect spikes and transients.

Use a reference volt meter to adjust the correction factor, so the readings are correct in the desired operating range (e. g. 230V)

If you then measure a significant offset error in the voltage range of the protection relay threshold, then adjust the threshold values in the protection relay section accordingly.

If your hydrocontrol is set up as IGC, and the AC voltage reading drifts, because the waveform of the generator changes a lot during operation (different loads), then your set point will also drift. If this is a serious problem, then a separate true RMS AC volt meter module with I2C output is necessary.

(Feature planned for the future:

Use the temperature sensor on the micro-controller board, to correct temperature-induced measurement errors.)

4.2.12.1 5V internal voltage

You need several measurement points to calibrate this reading.

The gain affects the steepness of the correction curve (e. g. if 4.5V is measured correctly, but 5V is measured too low, increase the gain)

The offset affects the overall error (erg if all measurements are 0.1V too high, increase the offset. (The offset is actually negative)

The actual voltage can only be adjusted directly at the power supply. Adjust it to 5.0 Volt. The controller will continue to work between 4.5 and 5.1 Volt. This range is the acceptable drift tolerance. Normally power supplies tend to drop their output voltage over time, therefore the idea is to set it to the top end of the range.

4.2.13 Temperature sensor calibration

The beta value is specified in the data sheet of the manufacturer.

The sensors currently used are 10kOhm and have a beta value of 3977.

It is not possible at the moment to account for sensor tolerances. Instead, adjust the protection thresholds.

The currently recommended threshold for heat sinks is 50 deg Celsius.

Explanation: maximum permitted triac/SSR casing temperature is 70 deg.

Assuming a temperature decrease of 10 deg between casing and heat sink, the heat sink will be 60 deg. The temperature sensors are on the surface of the heat sink and are also influenced by the air temperature. Assuming an air temperature of 40 deg, the temperature sensor will in the worst case average to 50 deg.

4.2.14 AC input noise reduction

You can smooth the Mains AC voltage and the electrical current measurement here, if the readings are noisy.

The graph shows the raw input and the filtered input.

1 = no filtering

4.2.15 Output test

Is the same as the operating mode “output test”.

4.2.16 Password

This password protects settings only.

All readings and the start and stop buttons are still accessible.

There is no way for the end user to recover the password, so be careful.

However, there is a hard coded master password. Ask for it if you need it.

4.2.17 Import settings

Import settings from SD card.

The file "settings_current.txt" is always automatically updated every time you change a setting, if the SD function is enabled in the settings.

The file "settings_backup.txt" is created if you klick on the corresponing button in the SD menu.

The filenames "settings_current.txt" and "settings_backup.txt" are hardcoded. If you change them, the import functions won't work.

The write function however will always work. It will create a new file, if it doesn't find the appropriate file.

You can use this behaviour to create multiple backups by simply changing the file name of the existing backup to something like "my backup 2016".

If you want to import this backup, you need to change the file name to "settings_backup.txt" again.

You can save these files anywhere on your PC, and also edit them.

4.3 Status overview

- Input reading electrical measurements
- Temperatures
- Output status
- *(Regulation response – not implemented)*
- Live graph – still buggy
- micro-controller status

85% processor usage is normal

53% used ram is normal.

Here you can warm reset/restart/reboot the controller.
For a cold restart, disconnect the power.

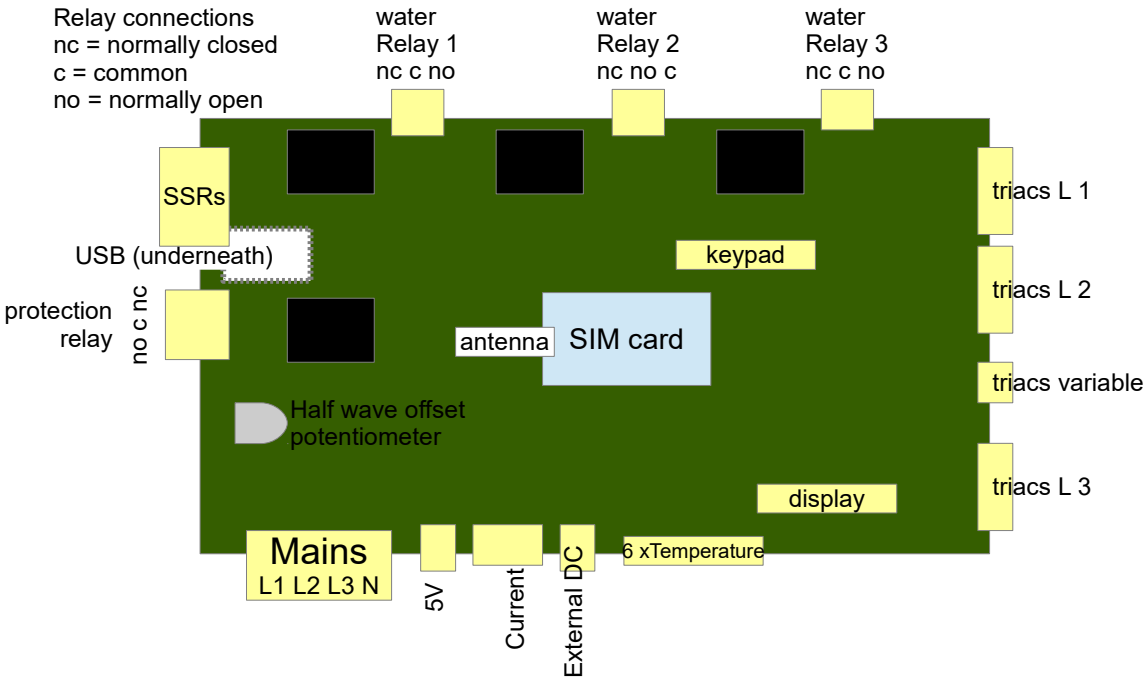
So far I'm not aware of any case where a restart would actually be necessary.

4.3.1.1 Positive and negative half wave offset

This offset changes with the 5V supply voltage. So first adjust the 5V on the 5V supply.

Then you can adjust this offset on the only potentiometer on the controller board. This offset is not very critical. It influences the precise point of the zero crossing detection. So if it's off a bit, the load will not be switched exactly during the zero-crossing, but a bit later. This parameter does not influence the precision of frequency measurement.

5 Wiring



5.1 Dump load wiring

5.1.1.1 Dump load rating for loads connected to TRIACS:

Maximum 20 A (4,5 kW @ 230V) with integrated temperature monitored cooling fans (active cooling)

With passive cooling, and well ventilated surroundings:
Max. 12A (approx 3kW) is recommended.

With passive cooling and hot surroundings:
Max. 8 A (approx. 2kW) is recommended.

Minimum is 20W, because lower than that the triacs don't fire reliably anymore.

5.1.1.2 Dump loads connected to SSRs

Absolute maximum load is the rating of the used SSR, generally 50A, with cooling fans.

With passive cooling, the recommended load is half of the maximum load, generally 25A.

You can connect differing loads to each SSR.

In the software you have to specify the load of an SSR control output in multiples of a triac output. E. g. the triac switches 2kW, and the SSR output switches 6kW (per phase) -> SSR load = 3 x triac load. So once the controller switches on an SSR output, it will simultaneously switch off 3 triacs.

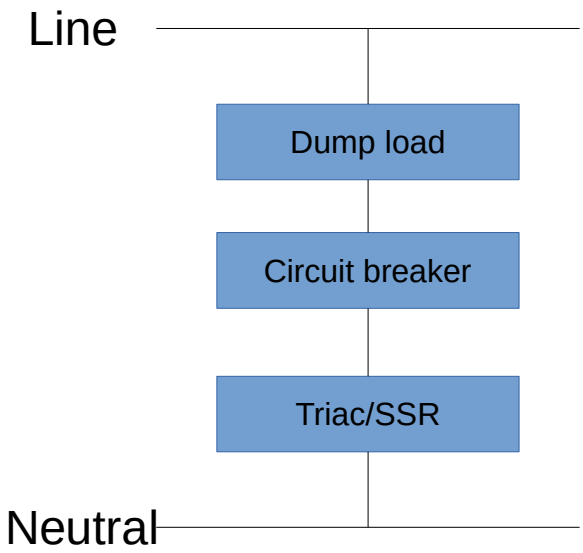
If you now make the load on a SSR output smaller or bigger than specified, the regulation loop will simply add/remove triacs again as needed. So that's okay, it's as if some user load goes on or off. Just be careful to make the actual SSR load less than double the specified load, or else the regulation loop will start hunting around for the set point and constantly switch this SSR

output on and off.

5.1.1.3 Dump load connections

In the case of triacs and a 3 phase system, make sure that the dump load is connected to the correct phase.

Brown = Line 1
Black = Line 2
Grey = Line 3



For single phase operation of a 3 phase model, connect only Line 1 dump loads.

5.2 Relays

The hydrocontrol PCB relays are single pole dual throw SPDT.

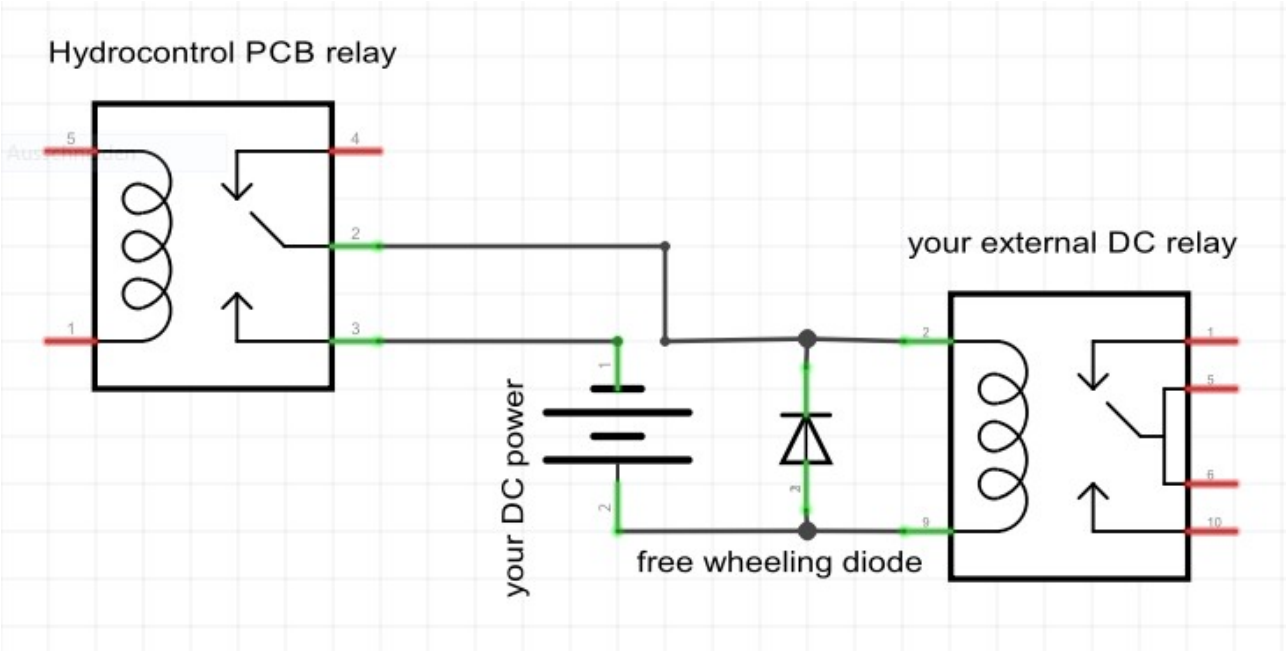
ATTENTION:
The order of the connections is different for each relay. Check the wiring diagram above.

Use the output test operating mode to check the proper function.

5.2.1.1 Current Ratings for the PCB relays

AC-1 (purely resistive load)	10A or 2300VA at 230V
AC-15 (Relays)	2A or 500VA at 230V
AC-3 (Motors)	1,6A or 370VA at 230V
DC-1 24V (Resistive)	10A or 240W

DC-13 (Relays): ALWAYS include a free-wheeling diode, or else the lifetime of the hydrocontrol relay will be greatly reduced.



Also check out https://en.wikipedia.org/wiki/Utilization_categories

5.3 Current transformers

Because the micro-controller only samples every other half-wave, the order of lines and the direction of the current is relevant. Connect current transformer line 1 to input 1 etc.

If there is no reading, put the transformer over the cable the other way around.

6 Initial start-up

6.1 Settings

First connect the controller to a separate AC mains power supply (not to your generator) and adjust the most important settings:

- operating mode
- set points (Menu ELC/General)
- dump load configuration (Menu ELC/dump load outputs)
- relays (Menu ELC/relays)

You can also use USB power - > **but the voltage must not exceed 5V!**

Other settings like input calibration, P-I tuning, smoothing have to be done during operation.

6.2 Mounting

Models with convection cooling:
Mount cabinet UPRIGHT, so that the hot air can ventilate upwards between the cooling fins. Do

not mount it directly under the ceiling, or else the hot air can not escape and will collect under the ceiling.

Models with fan cooling:
Keep air entry and air exit well clear (at least 20 cm)

6.3 Wiring

Connect AC lines and dump loads. If applicable, connect current sensors, relays, communication, SIM card etc.
Relays: Pay attention to the current rating of the relays and don't forget the freewheeling diode (see chapter 5.2 relays)

For startup purposes, connect at least one dump load directly to the AC line. This serves as "emergency" electrical load, if the hydrocontrol for some reason won't switch on the dump loads.

Keep cable entries water-proof, in order to minimize humidity inside the cabinet.

6.4 Powering up the system:

Open water very carefully, partially and slowy, until frequency and/or voltage are at nominal value.

Initially, the hydrocontrol will regulate very slowly, to avoid oscillation. Tune the P and I values to achieve a good regulation (see chapter 4.2.3 P-I setup)

Once everything is working fine and stable, you can disconnect the emergency dump load from the AC line again, and connect it to the ELC.

6.5 Save settings

If you're done with all the settings, and you do not use an SD card for storing the settings, then use the following table to enter all the values. You will need them if the controller board needs to be replaced.

6.5.1.1 Settings Table

Operating mode		
ELC settings /General	Total system capacity	
	Target frequency	
	Target voltage	
	AC Phases	
	Start-up manual/automatic	
	% dump-loads on	
Water valves	Yes/no	
	% remaining	
	Variable/fixed	
	Fixed flow seconds	
	Seconds on	
	Seconds off	
P/I	adaptive	
	P-Value	
	I-Value	
Dump load outputs	Zero-crossing/phase angle	
	Total dump loads per phase	
	Dump loads per SSR	
	Dump-load rating watts	
Frequency noise reduction	Smoothing value	
3 phase load balancing	Yes/no	
Overload warning	Yes/no	
	% on	
	Seconds on	
	Seconds off	
Protection relay	Minimum AC volt	
	Maximum AC volt	
	Minimum frequency	
	Maximum frequency	
	Maximum error milliseconds over-voltage	
	Max. error ms all other	
	Max. amps per phase	
	Minimum external DC volts	
	Max. temperature heat sinks	
	Max. temperature bearings	
Automatic user load control	Minimum AC volt	

	Back on AC volt	
	Minimum Frequency	
	Back on frequency	
	Out of range Time before shut off	
	Delay time back on	
Mobile communication	Admin/operator phone number	
Input calibration	AC Volts Line 1	
	AC Volts Line 2	
	AC Volts Line 3	
	Amps Line 1	
	Amps Line 2	
	Amps Line 3	
	External DC	
	5V gain	
	5V offset	
Input calibration/ Temperature	Sensor 1 kOhm	
	Sensor 1 beta value	
	Sensor 2 kOhm	
	Sensor 2 Beta value	
	Sensor 3 and 4 kOhm	
	Sensor 3 and 4 beta value	
	Sensor 5 and 6 kOhm	
	Sensor 5 and 6 beta value	
Input calibration/ AC noise reduction	Volts smoothing	
	Ampere smoothing	
Password	Yes/no	
	(consider if you want to write down the password here)	

7 Troubleshooting and repair

Use the output test operating mode to check if there is a wiring/mechanical problem.

7.1 Microcontroller PCB

Check if the board receives 5V DC power.

If the green LED on the board is blinking around once per second (sometimes a bit slower, if the processor is busy), then the microcontroller is okay. If 5V is okay, but LED not blinking, then the microcontroller board is defective.

Temporary solution: Replace with an arduino/genuino mega and configure/import settings.

Permanent solution: the factory bootloader of the mega has a problem with the watchdog feature (automatic restart after MCU crash) Get a mega with fixed firmware directly from me for reliable operation (or flash the bootloader yourself :-)

If the microcontroller is running, but the display is black, and you pressed any button on the keypad to wake the display, and the keypad is connected, then the LED background light of the display is broken. Replace with any display which operates at 5V and uses the ILI9340 or ILI 9341 controller.

If the MCU is working, but other features of the board were working, but are broken now (apart from dump load outputs, see below):
This is hard to diagnose. Get a new PCB from me and send the defective one to me for repair.

7.1.1.1 Advanced dump load output trouble shooting

You need a basic understanding, how transistors, opto-couplers and triacs work.

The menu “status overview /output status” indicates the state of each triac, SSR output, and relay, such as the software logic is putting it out at the moment.

Then there is a test LED and a jumper lead on the PCB to check each triac driver transistor.

Attention: the transistors are not getting permanent power, but only pulses. With a DMM digital multimeter, you will only get a few millivolts, if you get anything at all.

The LED will glow dimly, if there are pulses.

To test the triac itself, you would have to connect a load with a visible indication, e. g. a 40W light bulb (it has to be at least a 20W load)

One output pin and one transistor drives all 3 lines (3 opto-couplers and triacs / 3 SSRs) of one dump load set.

So if all three lines of one dump load set fail, then the MCU pin or the transistor is defective.

If only one or two lines of one dump load set fail, then the problem is with the optocoupler or the triac.

So with these indicators, you can work out if the problem is

- in the software (wrong logic),
- or in the physical IC chip output pin (logic is okay, but transistor is not getting power),
- or in the transistor (controller pin is producing output, but transistor is permanently on/off)
- or in the opto-coupler (transistor is switching, but triac is not firing)
- or in the triac (opto-coupler is conducting, but light bulb is not glowing/glowing permanently)
- or in the dump load (light bulb is glowing, but nor current/ dump load is not getting hot)

The SSRs have their own LED's.

7.1.1.2 Replacement of triacs/SSRs:

Make sure to use heat sink grease / compound / paste.

for the full wave switching, the type is BTA41-800

for the phase angle switching, the type is TIC263M.
ATTENTION: the TIC263M casing carries line voltage. Do not remove the insulating plates and rings.

The TIC263M is discontinued. type D will also do, but has lower high voltage resistance. type N is even better. If you do not need phase angle switching, then configure the hydrocontrol to zero crossing switching and replace with BTAs.

7.1.1.3 Software update

Instructions will be delivered together with the update.

7.1.1.4 Controller board replacement

The order of the relay connectors (n.c., c., n.o.) may change with hardware revisions. Verify before connecting.

Make sure you have all your settings either on paper or on the SD memory card before installing the new controller.

If installed, remove your SIM card.

The settings file on your SD may not be compatible with newer software versions.
In this case, open the SD file on your PC and read out the values.

7.2 Protection/redundancy features

7.2.1.1 Safe design

All triacs and SSRs are galvanically insulated from the controller up to a maximum voltage of 4kV. So in case of triac failure, the controller will continue to function.

The triac/SSR dump-load circuit fault detection will display an error message in case of triac/SSR failure.

In case of controller failure, all relays will return to their “normal” de-energized, unpowered state. This means that users will be disconnected, and water valve relays will close.

In case of microprocessor failure, all triacs will be fully powered by an emergency circuit. This means while the water supply is being closed, full load will be applied to the generator, in order to avoid an over-speed situation.

There are 2 redundant 5V power supplies. In case of one supply failure, there will be an error message.

Varistors and an EMC filter for the DC part.
This will protect the controller, but not the triacs and SSRs. The varistors can "eat" 175 Joule at 8000 amp and 2.5 kV.

If they are "used up", they lose their protection function and start stinking like burning fumes. Then you know it's time to replace them.

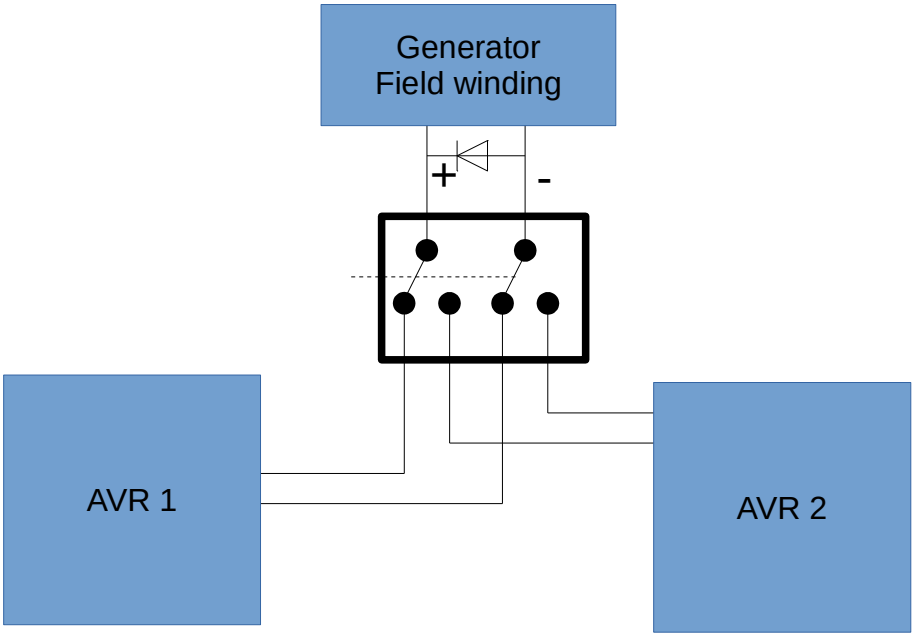
Protective casing for the controller board

This EMC metal casing is air-tight.

- it protects against electromagnetic interference
- corrosion from humid and salty air is reduced due to the air-tight casing
- the metal aids heat dissipation.

7.2.1.2 AVR

If the mains voltage rapidly declines to 0V, an automatic voltage regulator AVR failure is likely. This means that dump loads can not act as load/electrical brake on the generator. In order to avoid this situation, the hydrocontrol can detect a rapidly declining mains voltage and activate an auxiliary relay. This 2 pole dual throw 2PDT relay could switch the field winding of the generator to a second AVR. This would enable the generator mains output again. So the dump loads will again receive power and prevent over-speed.



There will be an error message indicating that the system has switched to the second AVR.If the AVRs have a common voltage potential for the field winding, then the relay can possibly be omitted. Please verify before trying.

8 Warranty conditions

8.1.1.1 Controller board

2 years warranty.

You report a defective board/power supply. I will ship out a new one immediately, but I want the old one back for error diagnosis / design improvement and repair. If I don't get the old one back within 4 weeks, I will charge the regular price for the replacement one.

8.1.1.2 5V power supply

1 year warranty from the external vendor.

So I will pass that on and give 1 year to the operator, provided I receive the defective power supply. I will then claim warranty from the external vendor.

8.1.1.3 Software updates

Bug fixes are free for lifetime. However you have to install the patch yourself.

New features are free for the next 2 years, but there is no obligation from my side to fulfill customer requests.

It remains at my discretion to charge for new features, if the work involved is substantial.

8.1.1.4 Defective triacs and SSRs

No warranty.

These parts die because of over-current, over-voltage, overheat, and that's beyond my control. And these parts are readily available (either from me or other sources), so can be replaced by the operator.

Ask for a quote if you need spare parts or a repair service.