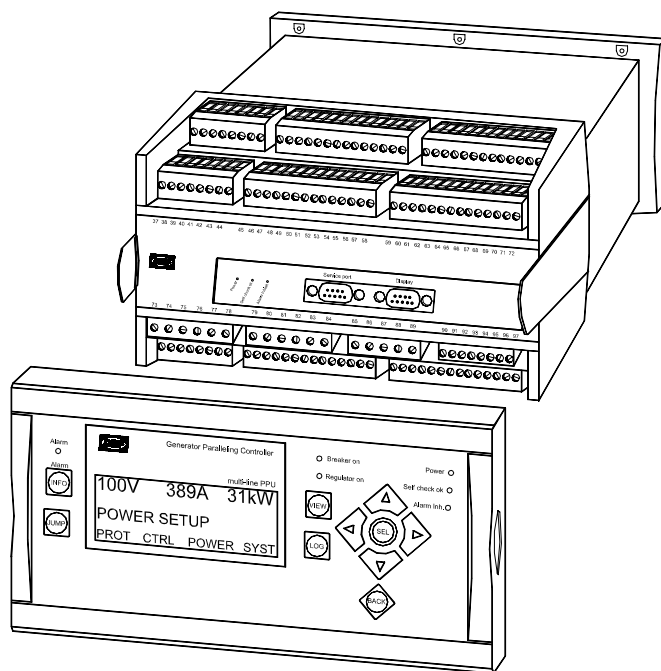*DEIF*

*-power in control*

# *Application note*

## *Hydro power turbine generator Multi-line 2 – version 2*
*4189340366D*

- *Application description*

- *System setup*

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Table of contents

These application notes refer to multi-line 2 GPC version 2.40.0 or later.

# 1. Warnings and legal information

This chapter includes important information about general legal issues relevant in the handling of DEIF products. Furthermore, some overall safety precautions will be introduced and recommended. Finally, the highlighted notes and warnings, which will be used throughout this handbook, are presented.

## Legal information and responsibility

DEIF takes no responsibility for installation or operation of the generator set. If there is any doubt about how to install or operate the generator set controlled by the unit, the company responsible for the installation or the operation of the set must be contacted.

> **The units are not to be opened by unauthorised personnel. If opened anyway, the warranty will be lost.**

## Electrostatic discharge awareness

Sufficient care must be taken to protect the terminals against static discharges during the installation. Once the unit is installed and connected, these precautions are no longer necessary.

## Safety issues

Installing the unit implies work with dangerous currents and voltages. Therefore, the installation should only be carried out by authorised personnel who understand the risks involved in working with live electrical equipment.

> ⚠ **Be aware of the hazardous live currents and voltages. Do not touch any AC measurement inputs as this could lead to injury or death.**

## Definitions

Throughout this document a number of notes and warnings will be presented. To ensure that these are noticed, they will be highlighted in order to separate them from the general text.

**Notes**

> ⓘ **The notes provide general information which will be helpful for the reader to bear in mind.**

**Warnings**

> ⚠ **The warnings indicate a potentially dangerous situation which could result in death, personal injury or damaged equipment, if certain guidelines are not followed.**

# 2. Application description

## System overview

This document describes the basic control system for a system containing a generator driven by a water turbine. The generator can be asynchronous or synchronous.

**Asynchronous generator is also known as induction generator.**

When option O1 is set, it is possible to use the multi-line 2, GPC, to control a water turbine.

Option O1 can be used with relay outputs for speed regulation and voltage regulation (option) or analogue outputs. If analogue outputs are to be used, it is possible to use up to 4 outputs.

Voltage control (option D1) is only possible for synchronous generator, not for asynchronous generator.

For description of analogue control outputs: See paragraph "Analogue output for cascade control of nozzle valves".

## Needed options

The GPC must be equipped with the following options in order to carry out the controls and protections described in this application note.

- Option O water turbine control
- Option M1 or M2 for start/stop control
- Option D1 voltage control (only if the generator is a synchronous generator)
- Option A1 or A2 or A3 mains protection if the generator is a synchronous generator

Other options can be implemented as required.

# 3. System setup

## Asynchronous generator

If an asynchronous generator is installed: Since the asynchronous generator is characterised by not giving a voltage before the breaker closes, the start sequence is controlled using the tacho input (signal from a magnetic pick-up unit).

This input is related to option M1 or M2.

### Tacho (magnetic pick-up unit)

The settings for no. of teeth and running speed must be set:

The setting 4351 is the "running state" signal for the start sequence, the setting 4352 is for the no. of teeth of the flywheel, and the setting 4353 is the nominal RPM (equal to nominal frequency).

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|------|-------------|--------------------|-----------|------------|------------|
| 4350 | Tacho config. | Selection display | - | - | - |
| 4351 | Tacho config. | LIM | 1 RPM | 2000 RPM | 300 RPM |
| 4352 | Tacho config. | Teeth | 0 teeth | 500 teeth | 0 teeth |
| 4353 | Tacho config. | Nom. RPM | 0 RPM | 5000 RPM | 1000 RPM |

### Selection of asynchronous generator and settings

If the generator is asynchronous, the asynchronous generator type must be selected as well as speed wanted before closing the breaker. This speed is normally set slightly higher than what is equal to nominal grid frequency since the asynchronous generator (like the squirrel cage motor) has a slip. For the generator, this means that the generator speed (frequency) must be higher than nominal (50 or 60Hz). This slip is normally 2-4%.

Setting 4941 is the selection of asynchronous generator "synchronisation" and setting 4942 is the selection of the slip frequency where the breaker is to close. This setting is related to nominal generator frequency (50 or 60Hz).

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|------|----------------|-------------------|--------|--------|---------|
| 4941 | Generator type | Asynchron. sync. | OFF | ON | OFF |
| 4942 | Generator type | Slip freq. | -10.0% | 10.0% | 1.0% |

## Synchronous generator

The synchronous generator type is selected as default.

## Control valves

The valve control is for the selection of number of valves (analogue governor output only). Max. 4 valves can be selected in setting 4951 and these will be opened in a cascade system (only one valve will operate at a time). The setting 4952 is the selection of direct proportional or inverse proportional control of the valve control outputs. Inverse proportional is only used for stand-alone synchronous generators where load control is used as speed control (higher load > lower speed).

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|------|---------|---------|--------------|--------------|-----------------|
| 4951 | Valve control | Valves | 1 | 4 | 1 |
| 4952 | Valve control | Inverted | OFF | ON | OFF |

## Start/stop setup

### Starter time

Set the Start prepare 4361 to 0.0 s.

In order to prevent unwanted start fail alarms, the start ON time 4362 must be set as long as possible.

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|------|---------|---------|--------------|--------------|-----------------|
| 4361 | Starter | Start prepare | 0.0 s | 600.0 s | 5.0 s |
| 4362 | Starter | Start ON time | 1.0 s | 30.0 s | 5.0 s |
| 4363 | Starter | Start OFF time | 1.0 s | 99.0 s | 5.0 s |

### Start attempts and alarm

Set Start attempts 4371 to 1.

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|------|---------|---------|--------------|--------------|-----------------|
| 4371 | Start attempts | Attempts | 1 | 10 | 3 |
| 4372 | Start attempts | Relay output A | R0 (none) | R9 (relay 9) | R0 (none) |
| 4373 | Start attempts | Relay output B | R0 (none) | R9 (relay 9) | R0 (none) |

The settings 4372 and 4373 are the alarm relay outputs for "Start failure alarm".

### Stop sequence and coil type

Set Cooldown time 4401 to 0.0 s.
Set Extended stop 4402 to 1.0 s.
Set Coil type 4403 to RUN.

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|------|---------|---------|--------------|--------------|-----------------|
| 4400 | Stop | Selection display | - | - | - |
| 4401 | Stop | Cooldown time | 0.0 s | 999.0 s | 240.0 s |
| 4402 | Stop | Extended STOP | 1.0 s | 99.0 s | 5.0 s |
| 4403 | Stop | Coil type | STOP | RUN | STOP |

## Jet deflector

What is a jet deflector?

In principle, the jet deflector is a 3-way valve intended to bypass the water flow in case of generator shutdown.

Normally, the jet deflector is "closed" (water flow led to the turbine) and held closed by a holding magnet. In case of shutdown, the jet deflector magnet is deactivated, and the jet deflector immediately changes to "open" (water bypass) position.

The principle looks like this (jet deflector shown in "closed" position):
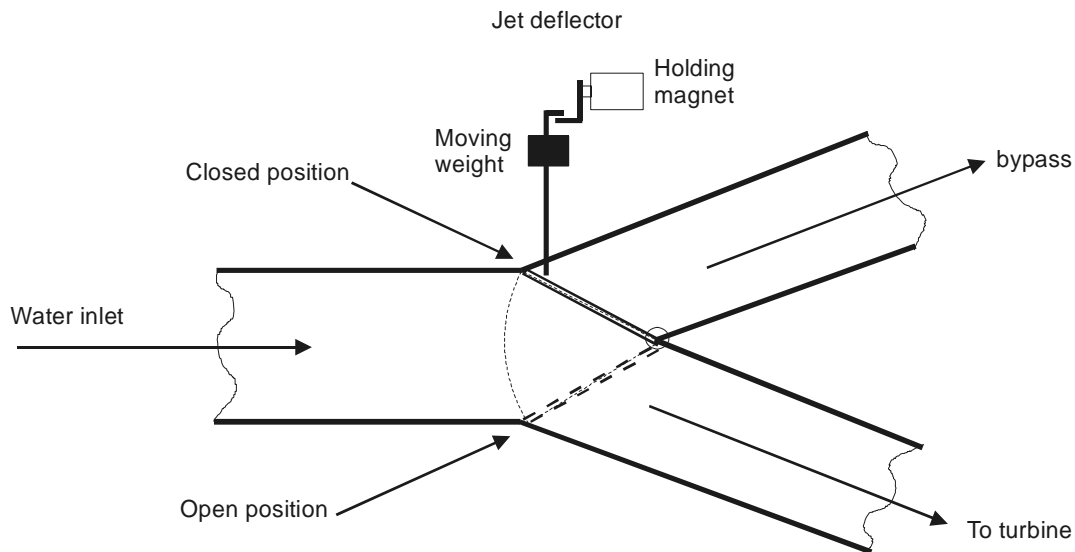


If the jet deflector is moved to the "open" position, it must be set back to "closed" position manually.
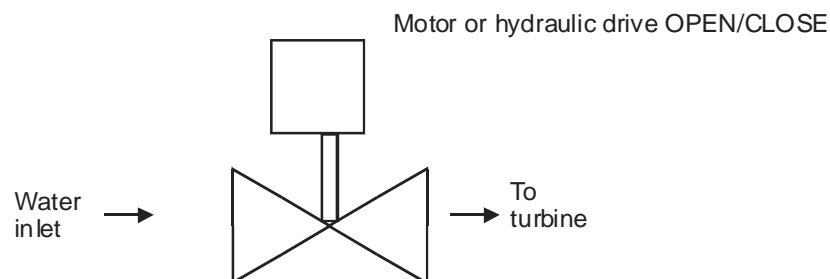
The jet deflector relay output 1 (term. 5 (NO), 6 (Com.), 7 (NC)) is used to hold the jet deflector valve(s) closed (term. 6-7 closed), or to open the jet deflector valve(s) (term. 5-6 closed). If the GPC is without power supply, the output will be in the "closed deflector valve" position. If an opening of the jet deflector is needed in case of GPC fail (processor fail or 24V DC power supply fail), the "STATUS" relay output (term. 3-4, NC) must be used to open the deflector if the relay contacts open.

The GPC will hold the deflector valve closed except in shutdown situations.

## Main valve control relay output

For smaller systems, a main shutoff valve is used.

The main shutoff valve is usually a butterfly valve, held open hydraulically with a counterweight to close, or controlled with open and close command signals.



The main valve relay output 1 (term. 5 (NO), 6 (Com.), 7 (NC)) is used to hold the main valve open (term. 6-7 closed), or to close the main valve (term. 5-6 closed). If the GPC is without power supply, the output will be in the "Open main valve" position. If closing of the main valve is needed in case of GPC fail (processor fail or 24V DC power supply fail), the "STATUS" relay

output (term. 3-4, NC) must be used to close the main valve if the relay contacts open.

The GPC Relay 1 will hold the main valve open except in shutdown situations.

### Binary input for jet deflector/main valve feedback

The GPC must know that the pipeline to the water storage is open before starting to open the control valve(s). This is easiest done by using the input on terminal 115 (start enable). If this input is OFF, the regulation will not start.

For a jet deflector, the "jet deflector closed" (bypass closed) feedback must be used. For a main valve the "main valve open" feedback must be used.

# 4. Functional description

## Outputs

**Relay output settings**

Because regulation of bigger water turbines is relatively slow, some maximum regulation settings are increased:

Maximum general failure timer (menu 2061) is increased to 3000.0 s.
Maximum relay output ON time is increased to 6500 ms.
Maximum relay output period time (menu 2252) is increased to 32500 ms.

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|-----|---------|--|--------------|--------------|-----------------|
| 2251 | Relay control | Governor ON time | 10 ms | 6500 ms | 1000 ms |
| 2252 | Relay control | Governor per. time | 250 ms | 32500 ms | 2500 ms |
| 2253 | Relay control | Turb. Start | 0s | 100s | 10s |

In order to make the turbine start, the setting "Turbine start" is used. This setting is a timer which will activate the GOV UP relay output for the number of seconds chosen, and thereby make the turbine run. The timer setting must be such that the turbine does not overspeed but at the same time reaches the running RPM (setting 4351). When this happens, the normal regulation will take over the control of the GOV UP and GOV down relays.

**Relay output for open/close of single control valve**

If the turbine is controlled with a single nozzle/wicket gate or similar speed control valve, the relay control outputs can be connected directly:
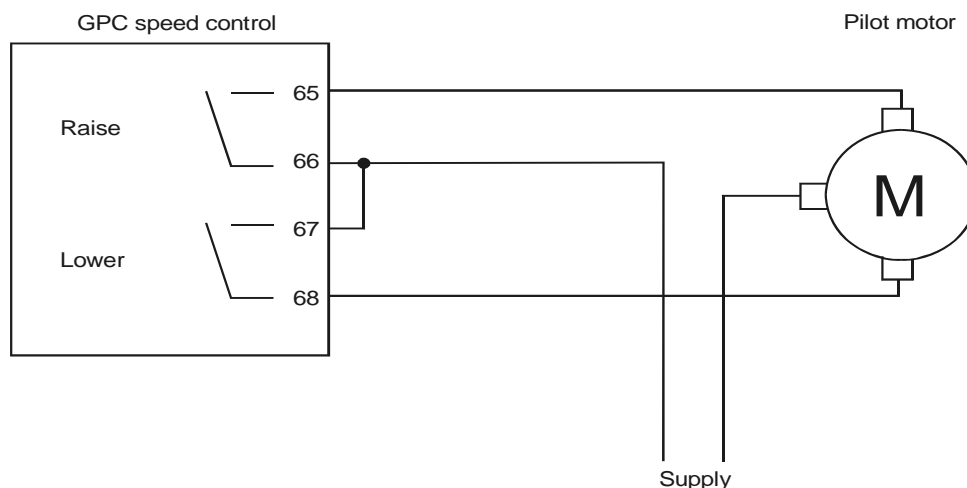
# Cascade control

### Relay output for cascade control of nozzle valves

The GPC has only one set of relay outputs for speed control. This means that an (external) PLC must be used to create the cascade control of multiple nozzles.

In the following example, a system with 4 nozzle valves is described.
The opening/closing of the nozzle valves looks like this:
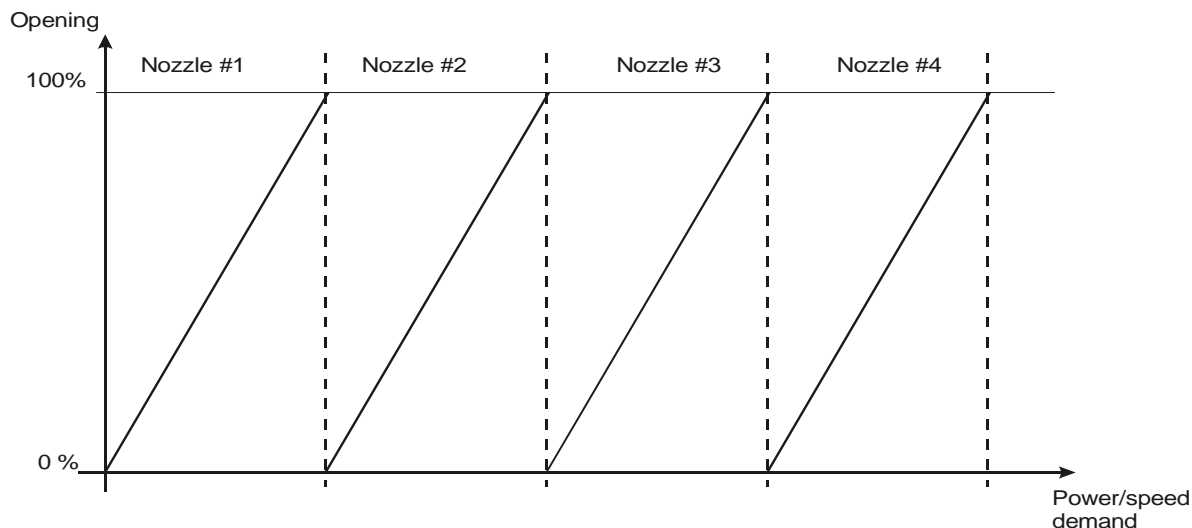


To obtain this, 2 relay outputs and 2 binary inputs per nozzle are needed:
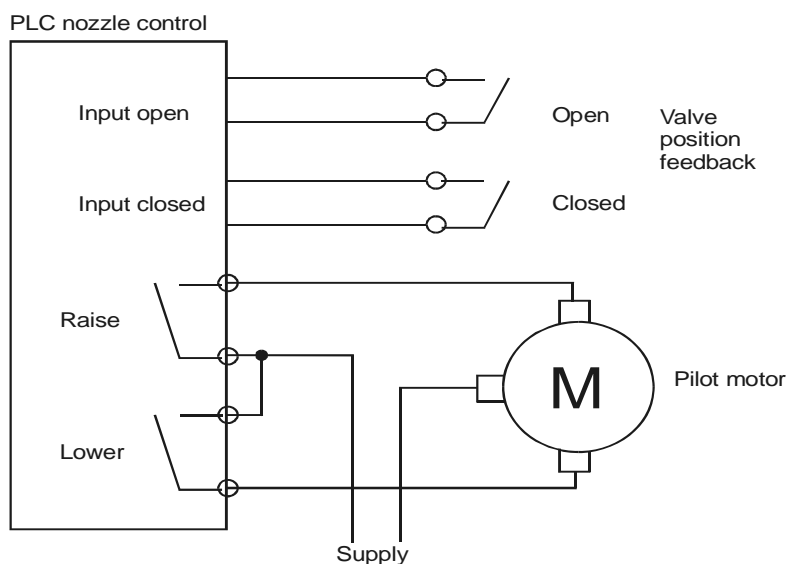


By doing this, the PLC can send the open/close commands from the GPC to the nozzle presently being manoeuvred.
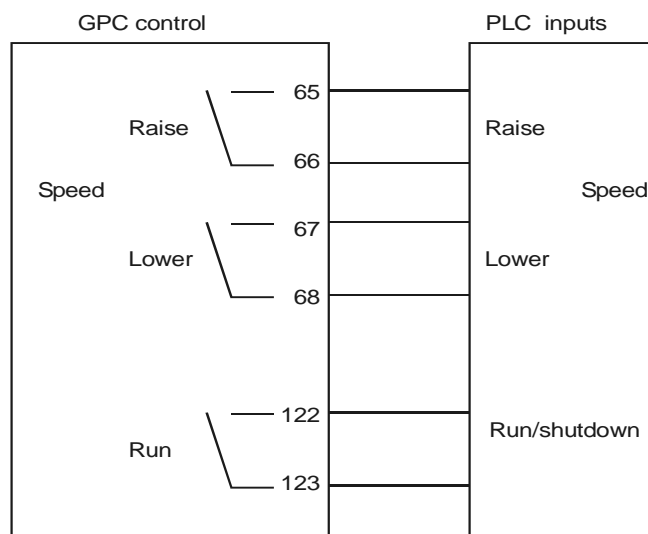
The **RUN output is ON during normal running. In case of a stop (normal stop or shutdown), the output opens. This can be used to make the PLC close all nozzles simultaneously in case of a shutdown.**

## Analogue outputs

**Analogue output for cascade control of nozzle valves**

The analogue output(s) can handle up to 4 analogue outputs for cascade control of valves.

The outputs are:

2 outputs:     Terminals 66(+), 67(0), frequency/power control cascade #1
               Terminals 70(+), 71(0), frequency/power control cascade #2

4 outputs:     Terminals 66(+), 67(0), frequency/power control cascade #1
               Terminals 70(+), 71(0), frequency/power control cascade #2
               Terminals 91(0), 92(+), frequency/power control cascade #3
               Terminals 95(0), 96(+), frequency/power control cascade #4

The cascade works like this:

At turbine start, all outputs are 0mA. As the speed/load increases, the cascade #1 will give increasing signals until reaching 20mA. At this point, cascade #2 will take over and increase its output until 20mA, and so on.

The output sequence looks like this:
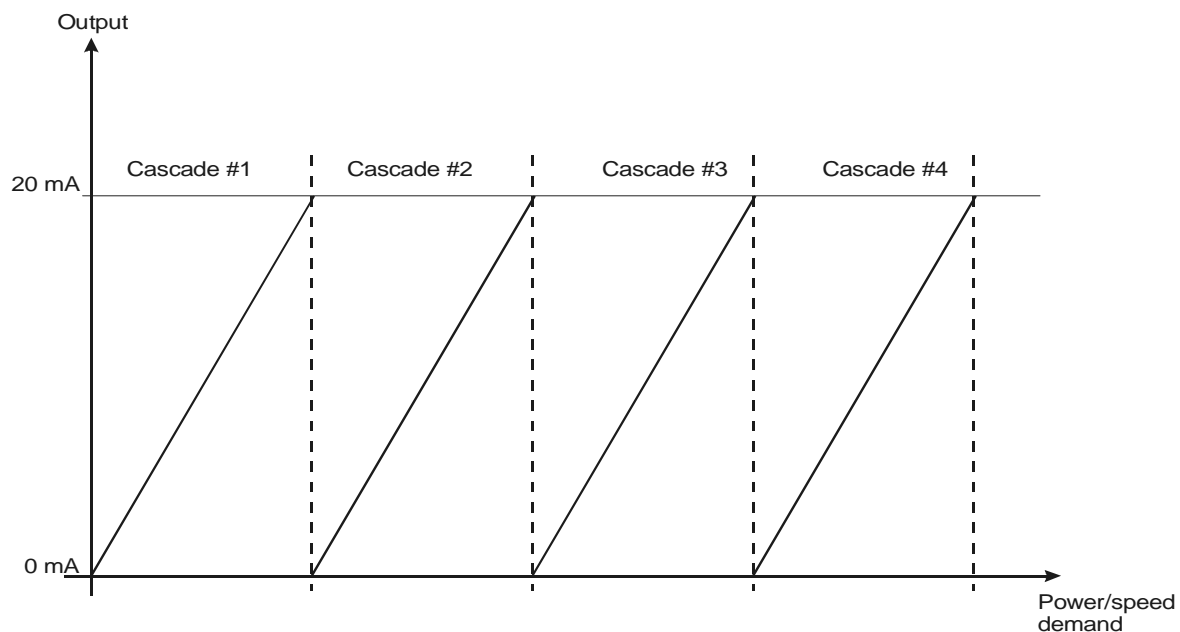
## Analogue output for cascade control of variable loads

The analogue control of variable loads is used for stand-alone "microturbines" where there are no nozzle control valves. In this case, the maintaining of nominal frequency is carried out by applying thyristor (single phase) or frequency converter (3-phase) load control of resistive load.

The control works in an "inversed" manner, i.e. higher load => lower frequency.

The inversed function is selected:

| No. | Setting | | Min. setting | Max. setting | Select setting |
|------|----------------|---------|------|-----|------|
| 4951 | Valve control | Valves | 1 | 4 | 2-4 |
| 4952 | Valve control | Inverted | OFF | ON | ON |

The analogue output(s) can handle up to 4 analogue outputs for cascade control of variable loads.

The outputs are:

2 outputs:     Terminals 66(+), 67(0), frequency/power control cascade #1
                    Terminals 70(+), 71(0), frequency/power control cascade #2

4 outputs:     Terminals 66(+), 67(0), frequency/power control cascade #1
                    Terminals 70(+), 71(0), frequency/power control cascade #2
                    Terminals 91(0), 92(+), frequency/power control cascade #3
                    Terminals 95(0), 96(+), frequency/power control cascade #4

The cascade works like this:

At turbine start, all outputs are 0mA. As the speed increases, the cascade #1 will give increasing signals until reaching 20mA. At this point, cascade #2 will take over and increase its output until 20mA, and so on.

The output sequence looks like this:
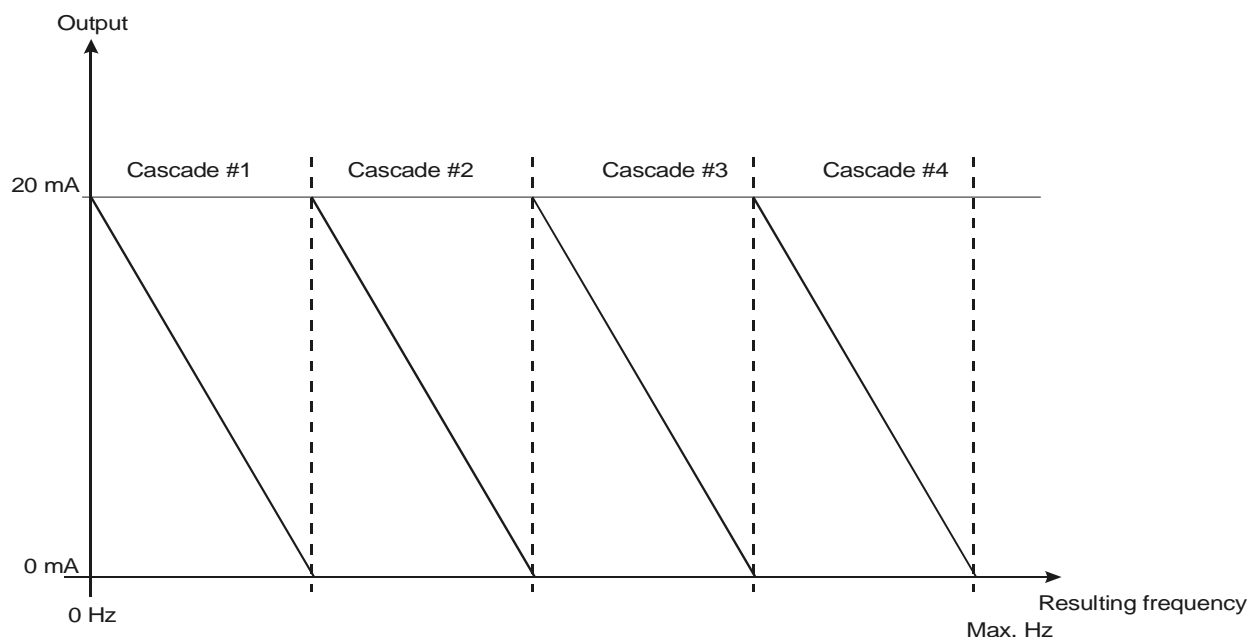


## Delayed generator voltage ON

If the RPM must reach a certain level before enabling the generator voltage to activate, a relay output can be chosen to set an AVR ON output signal.

This example uses relay no. 7:

In order not to trigger an alarm, the relay must be set to be a limit switch:

| No. | Setting | | First/min. setting | Second/max. setting | Third setting | Factory setting |
|---|---|---|---|---|---|---|
| 4671 | Relay 7 | Function | Alarm | Alarm/sync. block. | Limit | Alarm |
| 4672 | Relay 7 | Off delay | 0.0 s | 999.9 s | - | 5.0 s |

Set the relay to Limit (setting 3 in the PC utility software).

Subsequently, one of the RPM alarms can be used to activate the relay as a limit switch:

| No. | Setting | | Setting |
|---|---|---|---|
| 3651 | Overspeed 2 | Set point | 600 RPM |
| 3652 | Overspeed 2 | Timer | 1.0 s |
| 3653 | Overspeed 2 | Relay output A | R7 (relay 7) |
| 3654 | Overspeed 2 | Relay output B | R7 (relay 7) |
| 3655 | Overspeed 2 | Enable | ON |

The example enables AVR at 600 RPM.

> **Since the generator speed control is using generator frequency when synchronous generator is chosen, the UP output will be constantly ON until, in this example, reaching 600 RPM. If the result is that the turbine speed runs up too fast, external precautions must be made to slow it down (PLC or pulse-pause timer).**

# Water level regulation

The GPC can run in "Fixed water level mode" by setting the GPC mode inputs to "Fixed power mode" (term. 48 = ON, term. 49 = OFF) and enabling "Fixed water level mode" in menu 4131.

The 4…20mA water level input can be configured in menu 4040 to calibrate the water level sensor.

> **(i)** **The water level regulation uses analogue input #5 (terminals 126-127) as reference.**

The water level corresponding to a 20mA input signal is set in menu 4044.
The water level corresponding to a 4mA input signal is set in menu 4045.

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|------|-----------|-----------------------|-------------|-------------|-----------------|
| 4041 | Power set | Fixed power set point | 0% | 100% | 100% |
| 4042 | var set | Fixed var set point | 0% | 100% | 30% |
| 4043 | PF set | Fixed PF set point | 0.60 | 1.00 | 0.90 |
| 4044 | Water set | Water level nominal | 0% | 250% | 100% |
| 4045 | Water set | Water level min. | -100% | 250% | 0% |

The GPC can run in "Fixed water level mode" by setting the GPC mode inputs for "Fixed power mode" (term. 48 = ON, term. 49 = OFF) and enabling "Fixed water level mode" in menu 4133.

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|------|---------------|--------|-------------|-------------|-----------------|
| 4133 | Water control | Enable | OFF | ON | OFF |

When the fixed water level mode is ON, the generator power production is related to the settings "Fixed water level set point" (4042) and "Fixed water level min. point" (4044).

The GPC will regulate the generator power according to the water level:

- If the water level is equal to or above "Water set nom." (4044), the generator power will be according to the "Fixed power setting" (Pset, 4041)
- If the water level is equal to or below 0%, the generator power will be the resulting value of the linear curve when crossing the water level = 0 power value (see the figure below)

The "Fixed water level min." can be set to negative values. This way, the generator power can be controlled not to go below a certain value (in the graph approx. 25%) since the actual water level cannot be negative. This is made in order to keep the generator in the economical working range, even at low water levels.
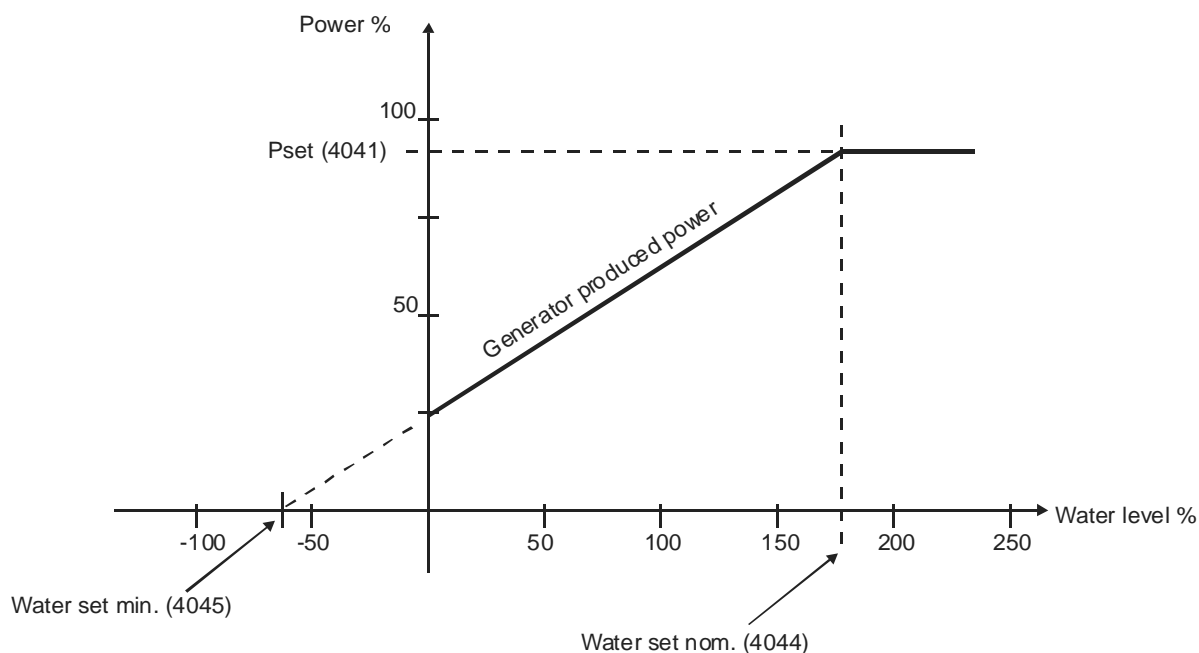
**Caution!**
Before the GPC enters the water control mode, it will be in ramp up mode. In this mode, the GPC will ramp the power up with the settings in menu 2141 and 2142.

When the analogue input is less than the water control set point (menu 4044), the GPC enters the final regulation mode (water control).

## Water level governor (settings under CTRL)

These are the settings used for the regulator when running water level control. The water level control is carried out using the power control PI parameters.

**Power control settings**

Power % settings relate to nominal generator power (setting 4012).

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|---|---|---|---|---|---|
| 2131 | Power control | Dead band | 0.2% | 10.0% | 0.2% |
| 2132 | Power control | P $K_P$ | 0 | 1000 | 250 |
| 2133 | Power control | P $K_I$ | 0 | 1000 | 160 |

## Relay outputs (settings under SYST)

2 relay outputs must be selected for the start and stop commands. Since the "deflector open" alarm output occupies relay 1 (terminals 5, 6, 7) and the relays 2 and 3 are very often used for alarm indications, the following example uses relays 5 (terminals 57-58) and 6 (terminals 59-60) as "start" and "stop" command outputs.

The relay settings are:

**Relay 5 "Start"**

| No. | Setting | | Min. setting | Middle setting | Max. setting | Set to |
|------|---------|---|-------------|----------------|--------------|--------|
| | PC utility software no. set. | | 0 | 1 | 2 | 2 |
| 4651 | Relay 5 | Function | Alarm | Alarm/sync. block. | Limit | Limit |
| 4652 | Relay 5 | Time | 0.2 s | - | 999.0 s | 600.0 s |

The above setting means that after the water level has dropped below "start" level, it takes 100 sec. before the relay 5 output resets.

**Relay 6 "Stop"**

| No. | Setting | | Min. setting | Middle setting | Max. setting | Set to |
|------|---------|---|-------------|----------------|--------------|--------|
| | PC utility software no. set. | | 0 | 1 | 2 | 2 |
| 4661 | Relay 6 | Function | Alarm | Alarm/sync. block. | Limit | Limit |
| 4662 | Relay 6 | Time | 0.2 s | - | 999.0 s | 1.0 s |

The above setting means that after the generator power has exceeded the minimum power "stop" level after restart, it takes 1 sec. before the relay 6 output resets.

**Start water level setting (setting under PROT)**

The start water level is related to the 4-20mA input no. 5.1. The water level where start is allowed must be selected <u>after</u> the scaling of the input has taken place (setting 3520, the scaling can only be done using the PC Utility software) since the setting scale relates to that setting. In this example, the scaling is set to be 0-100%, equal to 4-20mA.

The example setting is 50% with a timer setting of 10 sec., i.e. the generator will automatically start after the water level has reached 50% and stayed there for at least 10 sec.

| No. | Setting | | Min. setting | Max. setting | Select setting |
|------|---------|---|-------------|--------------|----------------|
| 3521 | 4-20mA in no. 5.1 | Set point | 0.0% | 100.0% | 50.0% |
| 3522 | 4-20mA in no. 5.1 | Time | 0.2 s | 100.0 s | 10.0 s |
| 3523 | 4-20mA in no. 5.1 | Relay output A | R0 (none) | R6 (relay 6) | R5 (relay 5) |
| 3524 | 4-20mA in no. 5.1 | Relay output B | R0 (none) | R6 (relay 6) | R5 (relay 5) |
| 3525 | 4-20mA in no. 5.1 | Enable | OFF | ON | ON |

> **If the water level limit switch is used to start the generator, the level alarm described in paragraph "Water level protection (settings under INPUT)" cannot be used.**
>
> **In the PC utility software, the tick window "High alarm" for setting 3520 must be ON.**

## Stop water level setting (setting under SYST)

The stopping of the generator is really related to the min. produced power allowed for the generator. This selection is related to the fact that an asynchronous generator does not produce economically below a certain power level.

In the following example, the min. allowed power for the generator is selected to be 25% (related to nominal power setting), and the time delay before stop is selected to be 100 sec.

| No. | Setting | | Min. setting | Max. setting | Select setting |
|-----|---------|---|--------------|--------------|----------------|
| 4271 | Stop next gen. | Stop point | 0.0% | 100.0% | 25.0% |
| 4272 | Stop next gen. | Time | 0 s | 200 s | 100 s |
| 4273 | Stop next gen. | Relay output A | R0 (none) | R9 (relay 9) | R6 (relay 6) |
| 4274 | Stop next gen. | Relay output B | R0 (none) | R9 (relay 9) | R6 (relay 6) |
| 4275 | Stop next gen. | Enable | OFF | ON | ON |

## Water level sensor hardware input

To get a 4…20mA input for water level input, the option M15 (4 x 4…20mA input) must be selected separately. The inputs are placed in slot #8 (terminals 126-133).

The 4…20mA analogue input 5 (term. 126, 127) can only be used for water level sensor and will always be scaled in % when option O1 is selected.

### Water level protection (settings under INPUT)

By using menu 3520/3530 it is possible to use the water level input as water level protection.

If the input must be used for low water level protection, then the input must be configured as a low alarm. This can be done with the utility software. Find the menu, double click and deactivate "High Alarm".

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|-----|---------|---|--------------|--------------|-----------------|
| 3521 | 4-20mA in no. 5.1 | Set point | 0.0% | 100.0% | 10.0% |
| 3522 | 4-20mA in no. 5.1 | Time | 0.2 s | 100.0 s | 10.0 s |
| 3523 | 4-20mA in no. 5.1 | Relay output A | R0 (none) | R6 (relay 6) | R2 (relay 2) |
| 3524 | 4-20mA in no. 5.1 | Relay output B | R0 (none) | R6 (relay 6) | R0 (none) |
| 3525 | 4-20mA in no. 5.1 | Enable | OFF | ON | OFF |

| No. | Setting | | Min. setting | Max. setting | Factory setting |
|-----|---------|---|--------------|--------------|-----------------|
| 3531 | 4-20mA in no. 5.2 | Set point | 0.0% | 100.0% | 10.0% |
| 3532 | 4-20mA in no. 5.2 | Time | 0.2 s | 100.0 s | 10.0 s |
| 3533 | 4-20mA in no. 5.2 | Relay output A | R0 (none) | R6 (relay 6) | R2 (relay 2) |
| 3534 | 4-20mA in no. 5.2 | Relay output B | R0 (none) | R6 (relay 6) | R0 (none) |
| 3535 | 4-20mA in no. 5.2 | Enable | OFF | ON | OFF |

## Protection relay output

Any protection function can be designated to 2 x 2 relays (relay output 2-3 and 5-8).

If the jet deflector is to open upon an alarm (shutdown) or a main valve is to close, the protection function must be designated to relay 1 where the jet deflector/main valve is connected. In factory setting, the relay 1 has contacts 6-7 closed for closed deflector valve/open main valve.

## Close control valve upon shutdown

If a shutdown is to stop the turbine, the trip must be designated to relay 9. By doing this (relay 9 is considered the "run" output), the shutdown will cause the control valve(s) to close.

## Alarm inhibit

When option O1 is selected and the generator protections are set to be inhibiting when not running (U <30%) via the PC utility software, the generator protections will not be enabled during start before the generator breaker is closed.

The generator protections will not be disabled again until the generator voltage is below 30% of nominal voltage.

# 5.  Sequences

## Start/stop sequences, external controls

To run the generator with external controls, the "mode" selection (push-button on the display) must be set in "remote".

### Start sequence

1)      Set input 115 (Start enable) ON (deflector closed or main valve open)
2)      Set input 25 (Start sync./reg.) ON
3)      Relay 9 (term. 122-123) closes,
4)      Opening control valve 1, synchronising using magnetic pick-up speed signal (asynchronous) or generator/mains frequency (synchronous)
5)      Breaker closes
6)      Power control for parallel with mains

### Stop sequence

1)      Set input 43 (Deload) ON
2)      Ramp down of generator to load 0kW
3)      Opening of breaker
4)      Remove input 25 (Start sync./reg.)
5)      Relay 9 (term. 122-123) opens
6)      Closing of all control valve(s)

## Start/stop sequences, manual control

To run the generator with manual controls, the "mode" selection (push-button on the display) must be set in "local", i.e. the "remote" LED must be OFF.

### Start sequence

1)      Set input 115 (Start enable) ON (deflector valve closed or main valve open)
2)      Set input 25 (Start sync./reg.) ON if a semi-automatic control of speed is required, and OFF if the binary inputs for speed control are required
3)      Push the "START" button
4)      Relay 9 (term. 122-123) closes
5)      Opening control valve 1, synchronising (magnetic pick-up speed signal or frequency synchronisation)
6)      Push the "Breaker" button to close breaker
7)      Power control for parallel with mains

### Stop sequence

1)      Push the "Breaker" button
2)      Ramp down of generator to load 0kW
3)      Opening of breaker
4)      Push the "STOP" button
5)      Closing of control valve(s)
6)      Generator stops

## Shutdown sequence

1)      Generator breaker trip
2)      Jet deflector open (bypass water flow) or main valve close command from relay 1 (term. 5-6-7)
3)      Shut control valves

To reset shutdown, acknowledge alarm.

The main valve will then automatically open (relay 1 resets) if the valve has ON/OFF control. Usually, the closing of the jet deflector must be done manually.

The setting for the shutdown is made like this example (overcurrent 1):

| No. | Setting | | Setting |
|------|---------------|----------------|---------------|
| 1021 | Overcurrent 1 | Set point | 115.0% |
| 1022 | Overcurrent 1 | Time | 10.00 s |
| 1023 | Overcurrent 1 | Relay output A | R9 (relay 9) |
| 1024 | Overcurrent 1 | Relay output B | R1 (relay 1) |
| 1025 | Overcurrent 1 | Enable | ON |

This will activate the shutdown by setting relay 9 (stop command and open breaker) and relay 1 (open deflector or close main valve).

Note that normal stop will not open the deflector/close the main valve. It only closes the control valve(s).

## Soft stop sequence (AUTO mode only)

1)      Deload generator and open breaker
2)      Shut control valves

In case of an alarm where a soft stop is needed (e.g. winding temperature high), some special sequencing is needed since this is not a programmable option.

1)      Select a relay output (e.g. relay 2) for soft stop
2)      When relay 2 is activated, this signal is sent to term. 43 (Deload)
3)      When the breaker is opened, deactivate term. 25 (Start sync./reg.)
4)      Turbine is stopped by closing of the control valve(s)

## Water level dependent start/stop

The water level dependent start/stop is based on 3 factors:

1)      The generator power is controlled by the water level (setting 4133 "Fixed water level mode" is ON, option O water turbine function)
2)      The setting "Stop next gen." (settings 4271 to 4275, standard functions) is used to stop the generator based on low power being equal to low water level
3)      The setting "4...20mA input 5" (settings 3521 to 3525, option M15 functions) are used to create a "water level high enough to start" limit switch
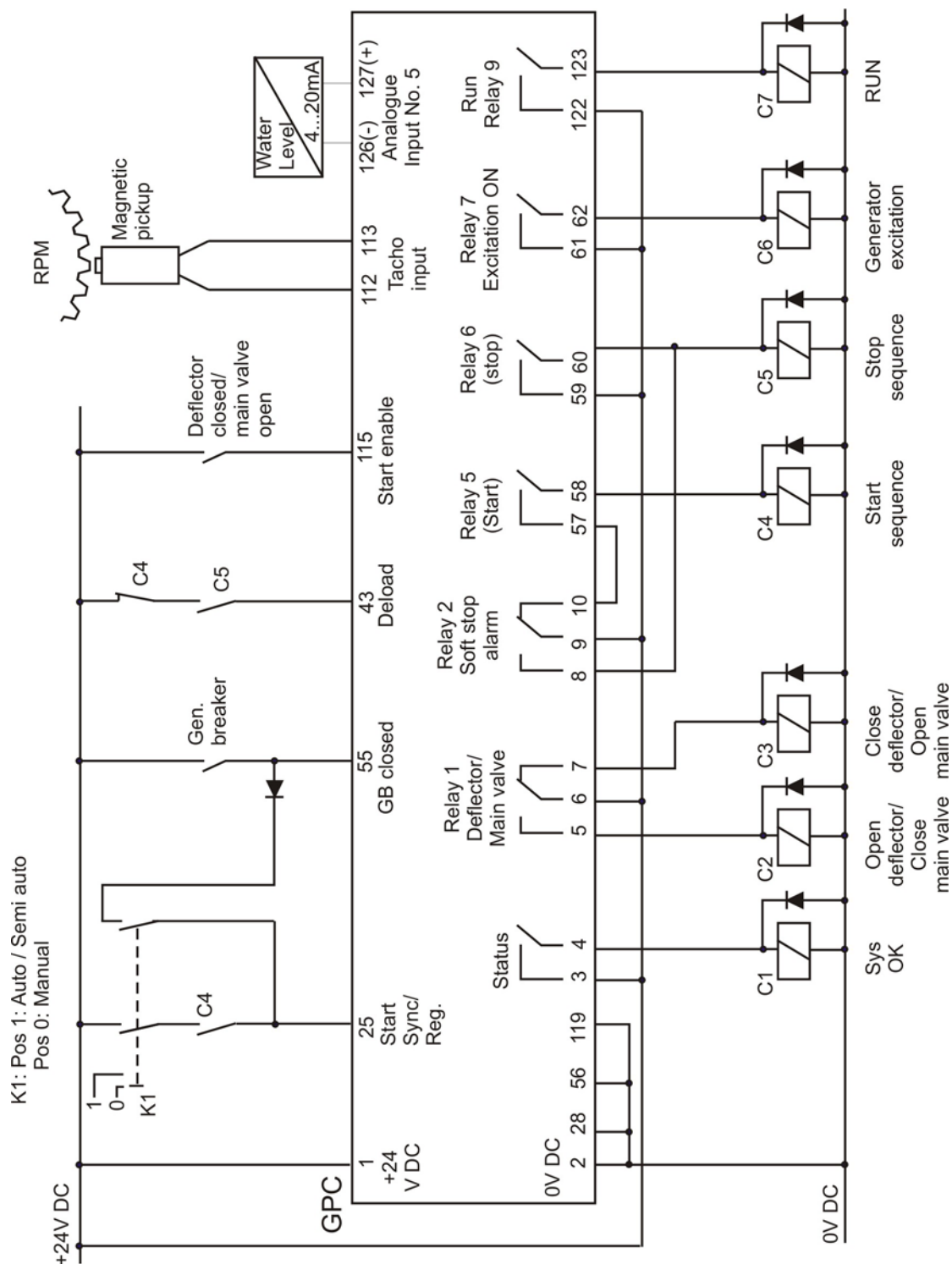
The settings in the below diagram will be used in the following example. All settings can be adapted to the individual plant.
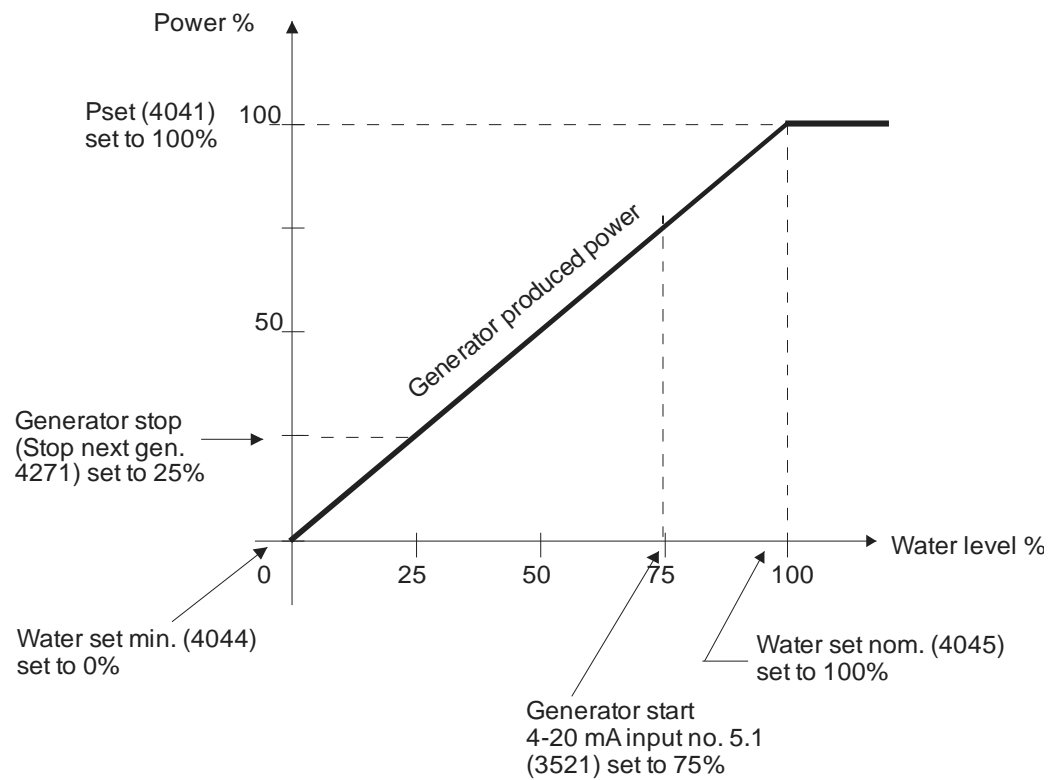
# 6. Wiring

## Wiring for water level dependent start/stop and shutdown/soft stop alarm

The system requires some external logic to carry out the start/stop. In the following, only wiring and relays related to the functions are shown:

## Functional explanation

| | |
|---|---|
| Switch K1 | Selector of running mode.<br> - AUTO: Automatic water level dependent start/stop and power control<br> - Manual: Push-buttons on display can be used for start/stop. Regulation is disabled |
| Relay C1 | System OK when activated. This may be used to shut down the plant if the GPC fails. |
| Relay C2 | Open deflector/Close main valve upon shutdown when activated |
| Relay C3 | Close deflector/Open main valve when activated (no shutdowns present) |
| Relay C4 | AUTO start. This relay will activate when the water level is above the chosen start level |
| Relay C5 | AUTO stop. This relay will activate when the generator produced power drops below the chosen stop value (running is not economically attractive). |
| Relay C6 | Activates when the RPM is high enough for generator excitation. De-activates when the RPM drops below the same value. |
| Relay C7 | RUN output. This relay can be used for the control valve(s):<br> - Activated: The control valve(s) can be operated<br> - De-activated: The control valve(s) must close. |

# Option O connections

## Terminal strip overview

This is only an overview of the inputs and outputs which are special for the option O1 - water turbine.
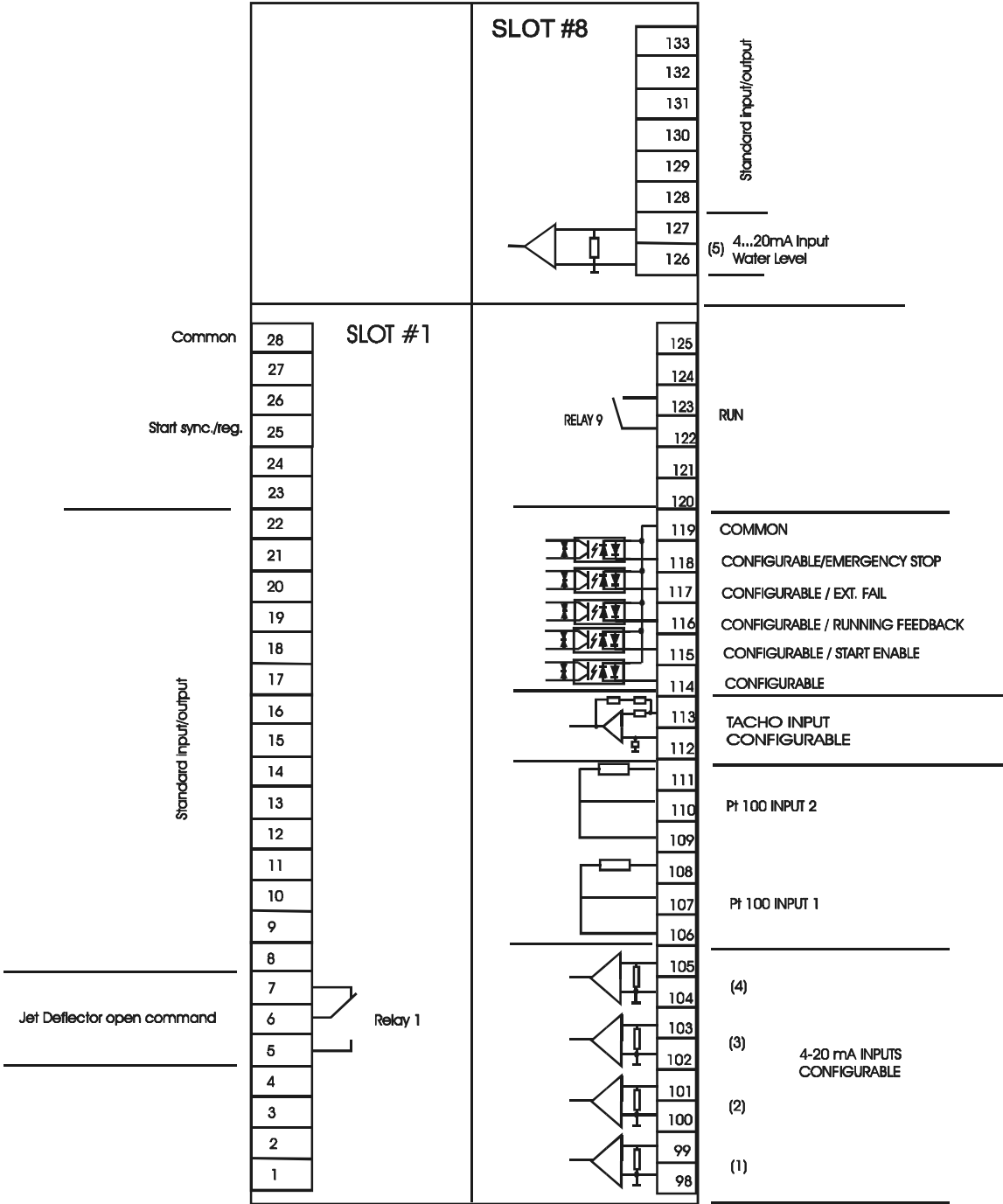
**Relay output turbine valve control**
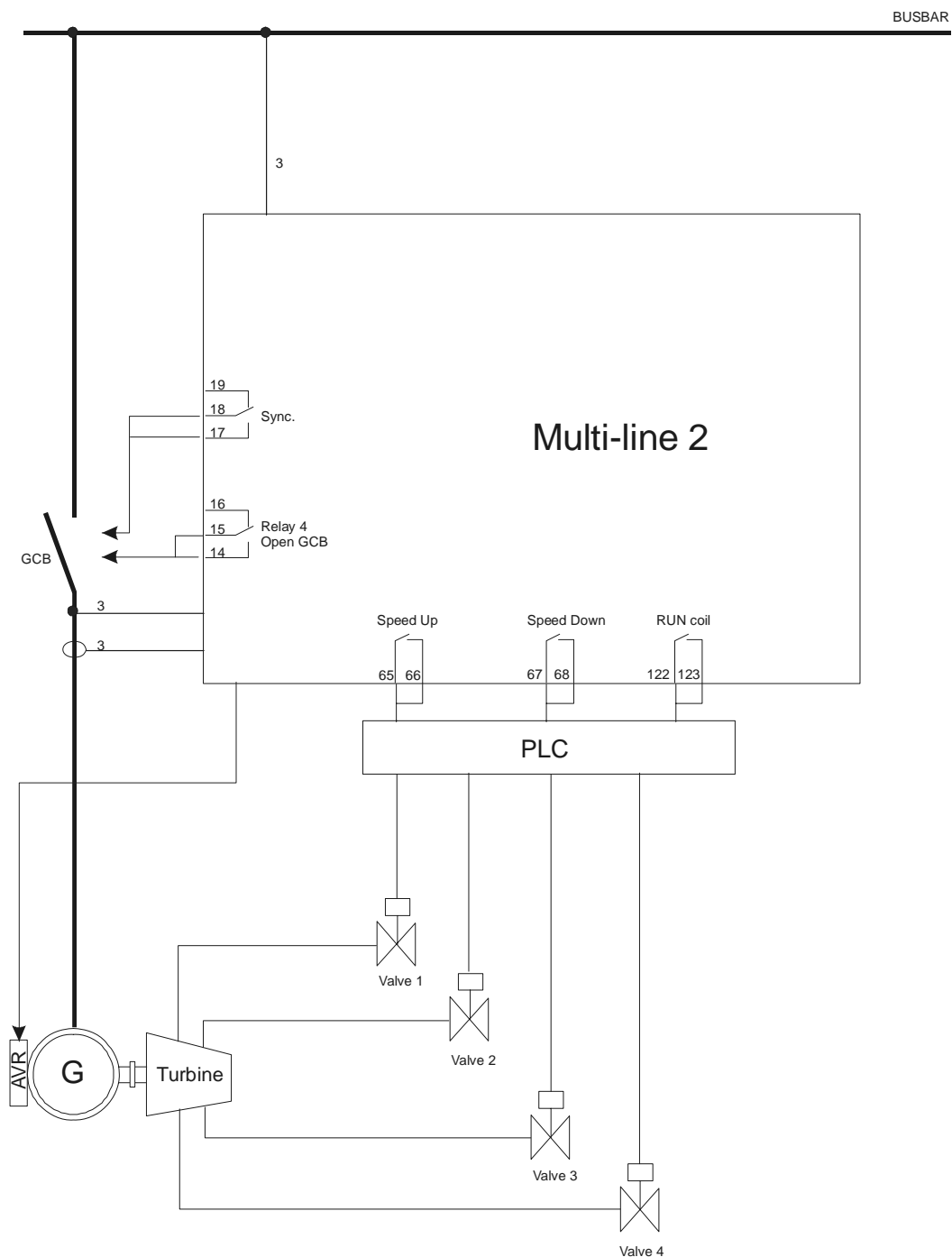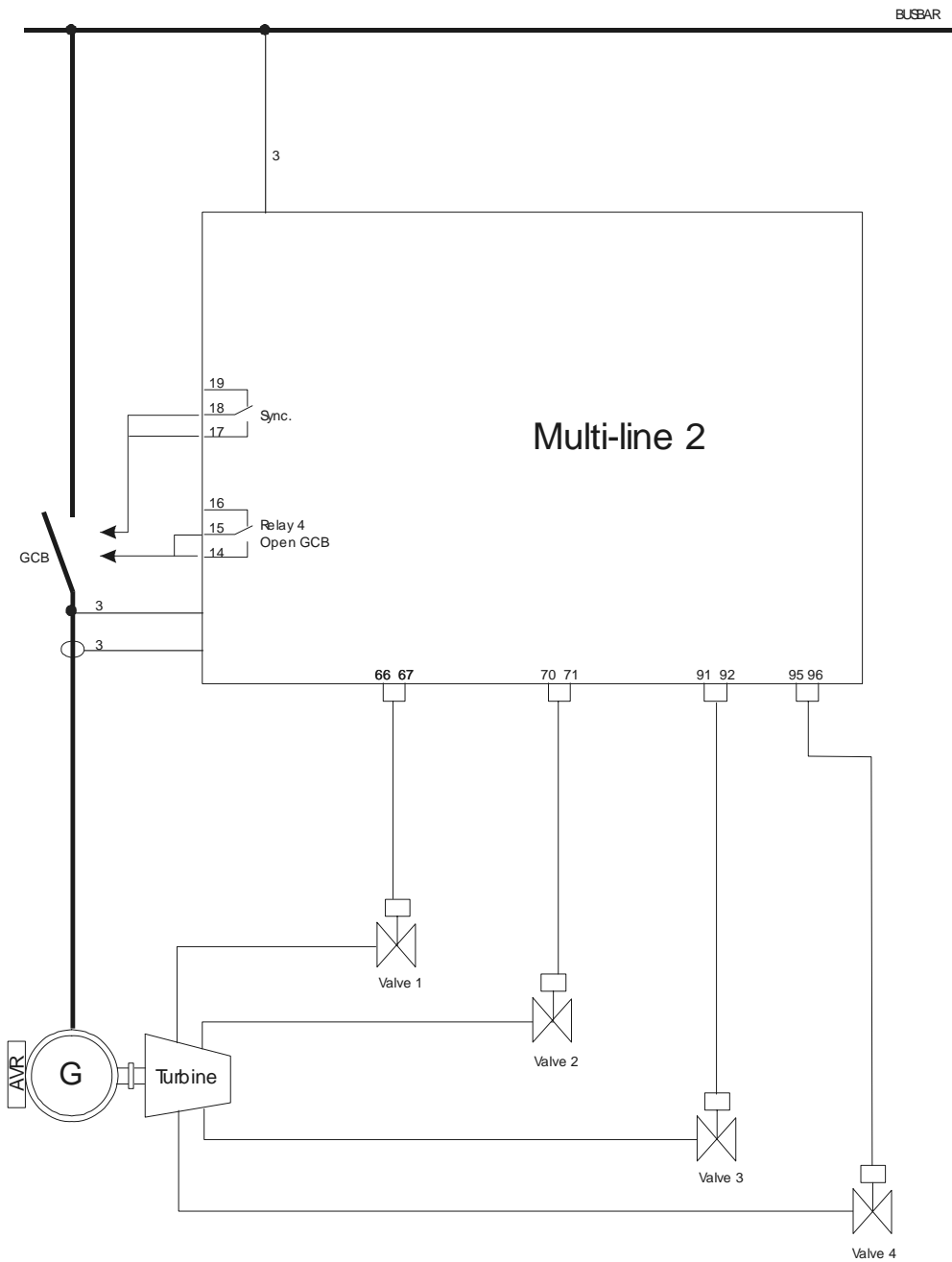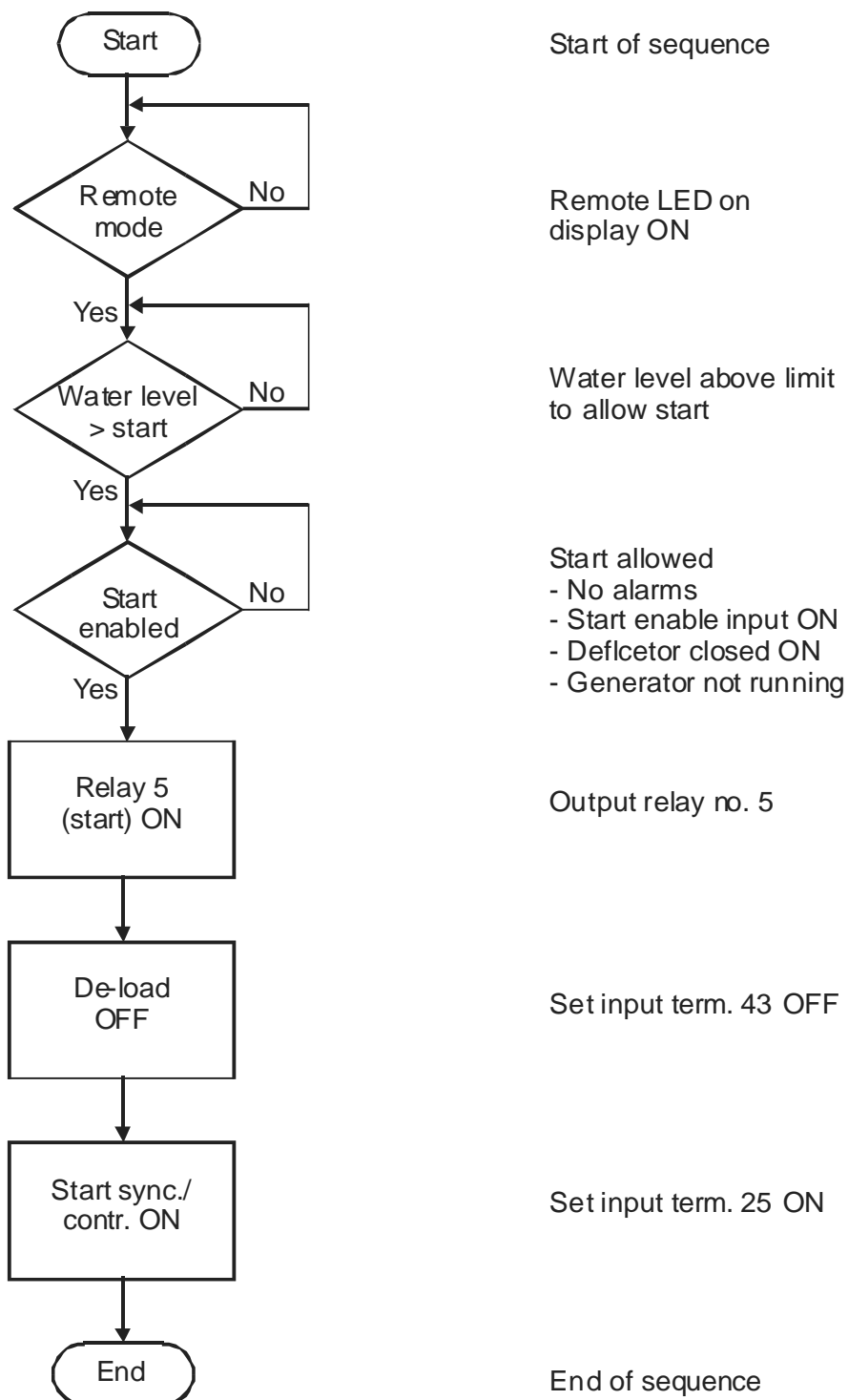


The GPC has only one set of relay outputs for speed control. If more than one control valve is used, an external switching between the valves must be made (when valve 1 is fully open, valve 2 starts opening, when valve 2 is fully open, valve 3 starts opening etc., and the other way round when closing the valves). Usually a PLC is used for this.

**Analogue output turbine valve control**

# 7. Flowcharts

## Water level dependent start flowchart

| Flowchart | Description |
|-----------|-------------|
| **Start** | Start of sequence |
| **Remote mode** — No | Remote LED on display ON |
| **Water level > start** — No | Water level above limit to allow start |
| **Start enabled** — No | Start allowed<br>- No alarms<br>- Start enable input ON<br>- Deflcetor closed ON<br>- Generator not running |
| **Relay 5 (start) ON** | Output relay no. 5 |
| **De-load OFF** | Set input term. 43 OFF |
| **Start sync./ contr. ON** | Set input term. 25 ON |
| **End** | End of sequence |

## Water level dependent (generator power) stop flowchart

| Flowchart | Description |
|---|---|
| Start | Start of sequence |
| Remote mode — No | Remote LED on display ON |
| Gen. power < stop — No | Generator power equal to or below stop point |
| GB ON — No | Generator breaker is closed |
| De-load ON | Set input term. 43 ON - Ramp down power |
| GB OFF — No | Wait for generator breaker to open. |
| Start sync./ contr. OFF | Set input term. 25 OFF to stop generator |
| Gen. stopped — No | Wait for running status to be OFF |
| End | End of sequence |

DEIF A/S reserves the right to change any of the above