Generator Paralleling Controller, GPC-3 Hydro
Start and stop sequences, water level control

- Application description
- Needed options
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- Functional description
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1. About this document

This chapter includes general user information about this document, concerning the general purpose, the intended users and the overall contents and structure.

**General purpose**

This document is an application note for DEIF’s Generator Paralleling Controller, the GPC. The document mainly includes functional descriptions for the application in question.

**Contents/overall structure**

The application note is divided into chapters, and in order to make the structure of the document simple and easy to use, each chapter will begin from the top of a new page. The following will outline the contents of each of the chapters.

**About this document**

This first chapter includes general information about this document. It deals with the general purpose of the application notes. Furthermore, it outlines the overall contents and structure of the document.

**Warnings and legal information**

The second chapter includes information about general legal issues and safety precautions relevant in the handling of DEIF products. Furthermore, this chapter will introduce note and warning symbols, which will be used throughout the document.

**Application description**

These chapters will include functional descriptions of the standard functions as well as illustrations of relevant application types. Diagrams and single-line representations will be used in order to simplify the information.
2. 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 document, 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

ℹ️ 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.
3. Application description

System overview
This document describes how to configure a GPC 3 Hydro for control of a Francis or Kaplan turbine generator with one speed control valve/wicket gate, controllable by relay output UP/DOWN signals. This means that Kaplan turbines with pitch and wicket gate control are not included.

For a Pelton turbine, an example with four nozzles is included.

Also included is control of a main shutoff/bypass valve, but no drain or fill valves.

This application note only covers the functionalities specific for a hydro turbine. For standard functions and options, please refer to the relevant documentation.

The system can be operated manually, semi-automatically or automatically.

Start and stop turbine
The GPC will control the start and stop of the turbine. This is done automatically or controlled by the operator.

Speed control
It is anticipated that speed control is carried out using relay outputs for speed increase/decrease (open/close valve(s)).

If analogue speed control is needed, electronic potentiometers (EPQ96-2) can be used to convert the relay signals to analogue.

Synchronise generator
Synchronisation of the breaker is done automatically, or it can be controlled by the operator.

Fixed power operation
The genset will use internal set point or analogue input for remote set point reference. The analogue input control is activated via a digital input. The signal is 0 to 10 V_{dc} = 0 to 100 % load.

Water level control with automatic start and stop
The genset produced power will be dependent on the level of the water reservoir. Decreasing water level => decreasing generator power. If the water level sinks below "stop level" value, the generator will be stopped. Restart will take place automatically when the water level has risen above the "start level" value.

Needed options
The GPCs must be equipped with the following options in order to carry out the controls and protection described in this application note:

- Option D1 to carry out power factor and voltage synchronisation control (for synchronous generator)
- Option M4 to carry out turbine start/stop and protection

All other available options can be applied as requested. Attention must be paid to governor (AVR) interface and required protections.
Digital input settings

Besides the usual settings for AC values (voltage, current, power and so on), a number of settings for inputs and M-Logic are needed to obtain the correct functionality. These settings are listed below.

The factory setting of digital input functions do not match a hydro turbine and must therefore be changed:

In the PC utility software (USW), the input settings are selected by clicking the icon in the top horizontal row of icons. You now have a list of selections and need to set the following:

<table>
<thead>
<tr>
<th>Function</th>
<th>Input</th>
<th>Function</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shutdown override</td>
<td>Not used</td>
<td>Deload</td>
<td>Not used</td>
</tr>
<tr>
<td>Remote start</td>
<td>Not used</td>
<td>SWBD control</td>
<td>Not used</td>
</tr>
<tr>
<td>Remote stop</td>
<td>Not used</td>
<td>Alarm inhibit 1</td>
<td>Dig. input 23, term. 23</td>
</tr>
<tr>
<td>Remote GB on</td>
<td>Not used</td>
<td>Start sync/contr</td>
<td>Not used</td>
</tr>
<tr>
<td>Remote GB off</td>
<td>Not used</td>
<td>Local mode</td>
<td>Not used</td>
</tr>
<tr>
<td>Remote alarm ack.</td>
<td>Dig. input 24, term. 24</td>
<td>Remote mode</td>
<td>Not used</td>
</tr>
<tr>
<td>Remove starter</td>
<td>Not used</td>
<td>Fixed frequency</td>
<td>Not used</td>
</tr>
<tr>
<td>Reset ana gov output</td>
<td>Not used</td>
<td>P Load sharing</td>
<td>Not used</td>
</tr>
<tr>
<td>Man Gov UP</td>
<td>Not used</td>
<td>Fixed P</td>
<td>Not used</td>
</tr>
<tr>
<td>Man Gov Down</td>
<td>Not used</td>
<td>Frequency droop</td>
<td>Not used</td>
</tr>
<tr>
<td>Man AVR UP</td>
<td>Not used</td>
<td>Ext. Gov set point</td>
<td>Not used</td>
</tr>
<tr>
<td>Man AVR Down</td>
<td>Not used</td>
<td>Fixed U</td>
<td>Not used</td>
</tr>
<tr>
<td>Manual mode</td>
<td>Not used</td>
<td>Q load sharing</td>
<td>Not used</td>
</tr>
<tr>
<td>Battery test</td>
<td>Not used</td>
<td>Fixed Q</td>
<td>Not used</td>
</tr>
<tr>
<td>GB close inhibit</td>
<td>Not used</td>
<td>Fixed PF</td>
<td>Not used</td>
</tr>
<tr>
<td>Low speed</td>
<td>Not used</td>
<td>Voltage droop</td>
<td>Not used</td>
</tr>
<tr>
<td>Enable GB black close</td>
<td>Not used</td>
<td>Ext. AVR set point</td>
<td>Not used</td>
</tr>
<tr>
<td>Binary running detection</td>
<td>Not used</td>
<td>Start enable</td>
<td>Not used</td>
</tr>
<tr>
<td>Access lock</td>
<td>Not used</td>
<td>GB spring loaded</td>
<td>Not used</td>
</tr>
</tbody>
</table>

Functions Deload and Start sync/contr are controlled via M-Logic. Please refer to chapter 5.

Some of the “Not used” may be set to an input if the function is required.

Safe stop alarm

Since a turbine does not stop like a diesel engine (stops immediately when fuel supply is removed), the “Safe stop” fail class function is needed. The “Safe stop” is capable of taking the power off the generator, opening the breaker and stopping the turbine in order to prevent overspeed by tripping the generator breaker (fail class “Trip” or “Trip and stop” or “Shutdown”).

This is obtained by:

Setting the alarms in question to “Safe stop” as fail class.

When triggered, the safe stop will deload the generator, open the breaker and stop the turbine.
4. General setup

Relay parameters
- All relays used for speed/excitation control must be set to “Limit”, and the related timers to 0.
- Relays 121 (start) and 123 (stop) are not configurable.

Start timing
The start (crank) on timer setting (parameter 6183) is used for the initial opening of the control valve/guide vane/wicket gate/nozzle (which is dependent on the turbine type). This timer setting must be set so that the turbine starts spinning, but does not overspeed. The time can only be determined by testing. This may be combined with the setting “Remove starter” (parameter 6174).

Stop timing
Stopping of the turbine is based on closing the control valve/wicket gate/nozzle(s) to make the turbine come to a complete stop. The main valve will close also. This is timed based on:

1) Using the stop (stop coil) output to close valves
2) Using the RPM input to see if the turbines have stopped
3) Using the “Extended stop time” (parameter 6212) to hold the stop output long enough to make sure that valve/gate/nozzle(s) are really closed.

Magnetic pickup
A pickup connected to terminals 100-101 is needed to detect the turbine speed. This is essential for the setting of the excitation speed output (excitation ON).

Excitation speed
The excitation speed output can be made using the running detection setting (parameter 6173) and then selecting a relay in the run status setting (parameter 6160).

Main valve/deflector
If a main valve and/or deflector is present, it may be controlled via M-Logic:

If no shutdown/trip alarms are present and start input is activated: Open main valve/disengage deflector.

If shutdown/trip alarm is present or start input is not activated: Close main valve/engage deflector.
**Water level-dependent running**

If water level is measured, this can be used for control of start, stop and output power.

**Start**

The start water level can be set using one of the two alarm levels present for each analogue input. Combine this with an M-Logic line activating the “Start sync/contr” to start the turbine and synchronise.

**Stop**

The stop point can be made with the other alarm level for the water level input in question, but in order to save this for a low level alarm/shutdown, it is better to use one of the overload alarms (parameters 1450 to 1490) where the setting range is -200...0...+200 % load. Remove the “high alarm” tick box setting to make the alarm trigger on a low value.

**Water level-dependent power**

To make the generator output power be dependent on the water level, the power derate function can be used (parameter 6260).

This function creates a straight line relation between an analogue input value and generator power output.

Example, start, stop and water level dependent power:
The turbine will start at water level 35 % and stop at generator power 5 %. 100 % output is reached when the water level reaches 80 %.

Set parameter 6264 proportional to ON (increase power by increasing signal).

Parameter 6263 derate slope is set in %/(P)/mA.

The example uses multi-functional input 120 set to 4 to 20 mA, and the alarm no. 1 (120.1) to start the generator and generator overload 1, set to low alarm, to stop the generator.

Parameter 6266 derate limit is set to 0 % (power).
5. M-Logic settings

M-Logic is used to create functions otherwise not obtainable. The settings are done via the PC utility software.

**Water level-dependent start/stop with main valve control**

The following inputs are used:

- Digital input 25: AUTO start command
- Digital input 52: Main valve open/deflector disengaged
- Multi-input 120 alarm 120.1: Water level for start

Logic 15:
Set start sync/control (activates regulators), based on digital input 25.

Logic 16:
When start activates (no matter why), the open main valve command is set. Here it is important to note that the first part of start, the start prepare, must have a timer run (setting 6168) that is longer than the time it takes to open the main valve to ensure that the main valve is open before the start sequence commences.

The relay 5 is used in this example to control the main valve. The logic holds the main valve open until the cooling time starts. Here the cooling time (setting 6211) can be set to 1 sec., the detection is only there to break the self-hold of relay 5.

Logic 17:
Monitors that the main valve actually opens when the command is set. If no start is active, or if terminal 54 is ON, the alarm inhibit 2 is activated. This can be used for digital input 54 alarm (setting 3220) inhibit, so that it only triggers if the start sequence is in progress. The alarm timer must be set to the same value as for start prepare (logic 16). The alarm must be set to “not high alarm” (high alarm tick box not ticked off).

Logic 18:
REMOTE start based on water level. The logic 18 only triggers if the unit is in REMOTE control, that is if the operator selects LOCAL, logic 18 is ignored. In this example, the water level limit is set in alarm 102.1. Remember to set outputs A and B to “Limit”, otherwise an alarm will be triggered.

Logic 19:
REMOTE stop based on generator low power output. This can also be based on an analogue input limit, for example Alarm 102.2. Remember to set outputs A and B to “Limit”, otherwise an alarm will be triggered.
### Logic 15
**AUTO regulators ON**

<table>
<thead>
<tr>
<th>Event A</th>
<th>Operator</th>
<th>Event B</th>
<th>Operator</th>
<th>Event C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dip Input No25 inputs</td>
<td>OR</td>
<td>Dip Input No25 inputs</td>
<td>OR</td>
<td>Not used</td>
</tr>
</tbody>
</table>

Enable this rule: ❑

**Output:**
- Start sync/Control command
- Delay (sec): __s__

### Logic 16
**Open main valve and hold (main valve opening time must be lower than start prepare (setting 0/10))**

<table>
<thead>
<tr>
<th>Event A</th>
<th>Operator</th>
<th>Event B</th>
<th>Operator</th>
<th>Event C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start activated Events</td>
<td>AND</td>
<td>Dip Input No25 inputs</td>
<td>AND</td>
<td>Cost down active Events</td>
</tr>
</tbody>
</table>

Enable this rule: ❑

**Output:**
- Relay 5: Relays
- Delay (sec): __s__

### Logic 17
**Main valve open monitoring: inhibit 2 blocks input 52 alarm (setting 32220 = main valve not open)**

<table>
<thead>
<tr>
<th>Event A</th>
<th>Operator</th>
<th>Event B</th>
<th>Operator</th>
<th>Event C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start activated Events</td>
<td>AND</td>
<td>Dip Input No25 inputs</td>
<td>AND</td>
<td>Not used</td>
</tr>
</tbody>
</table>

Enable this rule: ❑

**Output:**
- Inhibit 2: Inhibits
- Delay (sec): __s__

### Logic 18
**REMOTE start on water level high**

<table>
<thead>
<tr>
<th>Event A</th>
<th>Operator</th>
<th>Event B</th>
<th>Operator</th>
<th>Event C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote Modes</td>
<td>AND</td>
<td>Multiple Input 102.1 Limits</td>
<td>OR</td>
<td>Not used</td>
</tr>
</tbody>
</table>

Enable this rule: ❑

**Output:**
- Remote start and close GB: 1
- Delay (sec): __s__

### Logic 19
**REMOTE stop on water level low (power output low)**

<table>
<thead>
<tr>
<th>Event A</th>
<th>Operator</th>
<th>Event B</th>
<th>Operator</th>
<th>Event C</th>
</tr>
</thead>
<tbody>
<tr>
<td>G &gt; 1: Limits</td>
<td>AND</td>
<td>Remote Modes</td>
<td>AND</td>
<td>Running Events</td>
</tr>
</tbody>
</table>

Enable this rule: ❑

**Output:**
- Remote open GB and stop: C
- Delay (sec): __s__
M-Logic for Pelton turbine
The Pelton turbine control is in this example for a turbine with four nozzles arranged in cascade (activates one by one).

The following is assumed for control of four nozzles with increase/decrease relay speed signals to the nozzles:

<table>
<thead>
<tr>
<th>Relay</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>57</td>
<td>Activate nozzle 1</td>
</tr>
<tr>
<td>59</td>
<td>Activate nozzle 2</td>
</tr>
<tr>
<td>61</td>
<td>Activate nozzle 3</td>
</tr>
<tr>
<td>63</td>
<td>Activate nozzle 4</td>
</tr>
<tr>
<td>65</td>
<td>Speed increase</td>
</tr>
<tr>
<td>67</td>
<td>Speed decrease</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dig IN</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>Nozzle 1 open feedback</td>
</tr>
<tr>
<td>45</td>
<td>Nozzle 1 closed feedback</td>
</tr>
<tr>
<td>46</td>
<td>Nozzle 2 open feedback</td>
</tr>
<tr>
<td>47</td>
<td>Nozzle 2 closed feedback</td>
</tr>
<tr>
<td>48</td>
<td>Nozzle 3 open feedback</td>
</tr>
<tr>
<td>49</td>
<td>Nozzle 3 closed feedback</td>
</tr>
<tr>
<td>50</td>
<td>Nozzle 4 open feedback</td>
</tr>
<tr>
<td>51</td>
<td>Nozzle 4 closed feedback</td>
</tr>
</tbody>
</table>

The M-Logic setup for four nozzle Pelton turbine can be seen on the next page.
Cascade control outputs for Pelton turbine

- **Logic 1**: INCREASE NOZZLE 1 (RED). Increase N07; Activate N1; D48: N1 open feedback
  - Event A: Relay 65: Relays
  - Event B: Dig. Input No44: Inputs
  - Event C: Delay (sec.)

- **Logic 2**: INCREASE NOZZLE 2 (RED). Activate N0: D48: N2 open feedback
  - Event A: Relay 65: Relays
  - Event B: Dig. Input No44: Inputs
  - Event C: Delay (sec.)

- **Logic 3**: INCREASE NOZZLE 3 (RED). Activate N0: D48: N3 open feedback
  - Event A: Relay 65: Relays
  - Event B: Dig. Input No44: Inputs
  - Event C: Delay (sec.)

- **Logic 4**: INCREASE NOZZLE 4 (RED). Activate N1; D48: N4 open feedback
  - Event A: Relay 65: Relays
  - Event B: Dig. Input No44: Inputs
  - Event C: Delay (sec.)

- **Logic 5**: DECREASE NOZZLE 4 (PS). Decrease D48: N4 closed feedback
  - Event A: Relay 65: Relays
  - Event B: Dig. Input No44: Inputs
  - Event C: Delay (sec.)

- **Logic 6**: DECREASE NOZZLE 3 (D48: N3 closed feedback)
  - Event A: Relay 65: Relays
  - Event B: Dig. Input No44: Inputs
  - Event C: Delay (sec.)

- **Logic 7**: DECREASE NOZZLE 2 (D48: N2 closed feedback)
  - Event A: Relay 65: Relays
  - Event B: Dig. Input No44: Inputs
  - Event C: Delay (sec.)

- **Logic 8**: DECREASE NOZZLE 1 (D48: N1 closed feedback)
  - Event A: Relay 65: Relays
  - Event B: Dig. Input No44: Inputs
  - Event C: Delay (sec.)
Stop and start control outputs for Pelton turbine

<table>
<thead>
<tr>
<th>Logic 9</th>
<th>SHUTDOWN STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event A</td>
<td>Operator: Trip-stop; Fall class: OFF</td>
</tr>
<tr>
<td>Enable this rule</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Logic 10</th>
<th>N1 shutdown stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event A</td>
<td>Operator: Virtual Event 1: Virtual 1</td>
</tr>
<tr>
<td>Enable this rule</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Logic 11</th>
<th>N2 shutdown stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event A</td>
<td>Operator: Virtual Event 1: Virtual 1</td>
</tr>
<tr>
<td>Enable this rule</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Logic 12</th>
<th>N3 shutdown stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event A</td>
<td>Operator: Virtual Event 1: Virtual 1</td>
</tr>
<tr>
<td>Enable this rule</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Logic 13</th>
<th>N4 shutdown stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event A</td>
<td>Operator: Virtual Event 1: Virtual 1</td>
</tr>
<tr>
<td>Enable this rule</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Logic 14</th>
<th>START</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event A</td>
<td>Operator: Granting Events</td>
</tr>
<tr>
<td>Enable this rule</td>
<td></td>
</tr>
</tbody>
</table>
6. Wiring

These wirings only comprise the DC lines. The AC lines are described in the GPC installation instructions.

The wiring shows the necessary control circuits to carry out the task. It is assumed that all controls (except breaker commands) are carried out using 24 Vdc.

**Francis/Kaplan turbine plant control wiring**

For Kaplan turbine: The relation between turbine wicket gate (guide vane) opening and runner pitch is not controlled by the GPC.
Pelton turbine plant control wiring

The wiring is mainly to enable the cascade control made in M-Logic to operate, distributing the signals between the nozzles.
In the above example, the four nozzles are driven by 24 V\textsubscript{dc} pilot motors. The drive can also be 230 V\textsubscript{ac} motors or hydraulic pilot valves for hydraulically controlled nozzles. The important thing is to choose relays, whose contacts can carry the voltage/current needed.

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