DESIGNER'S REFERENCE HANDBOOK



TCM-2, Thyristor Control Module 2

- Functional description
- Menu and on-screen setup
- Parameter settings
- Operation modes
- Mounting and wiring

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1. About this document

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

General purpose

This document is the Designer's Reference Handbook for DEIF's Thyristor Control Module 2, the TCM-2. The document mainly includes installation procedures, graphical user interface descriptions, functional description and a parameter introduction.

Please make sure to read this handbook before working with the TCM-2. Failure to do this could result in human injury or damage to the equipment.

Intended users

The handbook is mainly intended for the person responsible for installing the unit and for the person responsible for the unit setup and configuration. Technical knowledge about wind turbine generator connections and working conditions is assumed.

Contents/overall structure

The Designer's Reference Handbook 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 handbook as a document. It deals with the general purpose and the intended users of the Designer's Reference Handbook. 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 handbook.

General product description

The third chapter will deal with the unit in general and its place in the DEIF product range.

Installation instructions

This chapter includes the information needed to perform correct installation of the unit, e.g. mounting instructions, terminals, wiring, inputs etc.

User interface and LED description

This chapter deals with the graphical user interface, HMI and the LED functions.
Furthermore, information about the display including icon list is presented.

CAN communication

The TCM-2 offers a CAN interface both for control and monitoring. This chapter describes the monitoring function of the CAN messages sent from the TCM-2. The individual control functions are described in each mode of operation.

Mode 1 description

Here the functions for automatic control of one- and two-speed generators are described together with sequence diagrams for control signals. This mode is intended to be used on primary stall-regulated wind turbines.

Mode 2 description

This chapter describes the function where the TCM-2 is used as a slave module which receives commands for ignition angle, and output settings from an external controller through a CAN interface. The external controller has through the TCM-2 direct access to the ignition angle on the TCM-2. State variables are transferred to external controller through the CAN interface.

Mode 3 description

This chapter describes the CAN auto functions that can be accessed from the CAN interface

Generator coupling connections

This chapter introduces the generator coupling that the TCM-2 supports and the conditions to take into account when operating the TCM-2.

Detailed parameter description

This chapter includes a complete standard parameter list for setup.

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 handbook, are presented.

Legal information and responsibility

DEIF takes no responsibility for installation or operation of the TCM-2. 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 connection 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.

3. General product description

This chapter describes the overall product information about the unit in general and its place in the DEIF product range.

Introduction

The concept of the TCM-2 is to offer a cost-effective and an intelligent thyristor controller which adapts to the actual speed and acceleration of a given generator during synchronisation. The TCM-2 is used primarily in wind turbines for connecting asynchronous generators, but also in other applications such as water turbine applications or others which demand an effective generator cut-in sequence.

Type of product

The TCM-2 is a microprocessor-based controller designed to minimise the grid impact at cut in and out of a wind turbine asynchronous generator by interfacing directly to a 6-pulse thyristor bridge. The interface is designed as six highly insulated ignition pulse stages for generation of a 100 kHz/500 mA ignition current for at broad range of thyristors with a gate voltage between 0 and 5 V.

General product specifications

The TCM-2 is designed to provide 6 digital inputs, 6 digital outputs and an analogue input (0-10V) line. The TCM-2 is designed to withstand the harsh environment in a wind turbine. The TCM-2 integrates directly into the power cabinet, functioning as a stand-alone thyristor controller for wind turbines with 1- or 2-speed asynchronous generators controlled with few signals from an external PLC.

One input is dedicated to connecting a single-phased current measurement transformer (either 1Arms or 5Arms secondary mean current). This makes it possible to measure the actual thyristor current during operation.

The TCM-2 can be powered from either 18-36V DC or 19.2-30V AC. This flexibility makes it easy to integrate into a power switchboard cabinet.

Modes of operation
The TCM-2 can be configured to two different modes of operation.

Mode 1 - stand alone rpm-regulated wind turbine soft starter

In this mode, the TCM-2 handles the synchronisation of the generator with very few control signals given from an external controller. This mode can easily be adapted into an existing controller with very few changes or none in the existing application.

In this mode of operation, the TCM-2 performs all cut-in and cut-out operations for a single-speed or double-speed wind turbine generator, where its interface and the feedback to the control system is performed by a set of external analogue and digital signals.

For each generator stage, where the main generator is called **G1** and the secondary low-wind generator is called **G2**, there is a separate set of parameters to configure its operation, as well as one digital input signal to select the generator stage to operate.

The TCM-2 can easily also be set up to operate single-speed generator operation.

Mode 1 - TCM-2 control principle

The TCM-2 is a 6-pulse thyristor bridge ignition controller. The ignition angle is controlled in different ways according to different control functions in Mode 1.

1. Motor start function
2. Cut-in of asynchronous generator
3. Cut-down sequence for 2-speed asynchronous generator (G1->G2)
4. Over-synchronous cut-in on G2, small generator

Mode 2 - CANbus-controlled ignition pulse generator

TCM-2 can be directly controlled via CANbus. This makes it possible for other process control units to set the actual ignition angle for the thyristor bridge on a periodical base.

Thus, any control application based on a 6-pulse thyristor bridge can be implemented. Ignition angle and digital outputs can be set with CAN telegrams. In this mode, the TCM-2 holds no control functions but the ignition angle is only controlled from the external process through CAN commands and setpoints.

The TCM-2 continuously sends status CAN telegrams with all current settings to the external control system.

Mode 3 – CAN Auto function

TCM-2 can be used as a direct CAN auto mode where different synchronisation functions can be enabled by simple CAN protocol commands. The internal functions in the TCM-2 are fully configured to each application by a set of parameters.

The following can be performed in this mode.

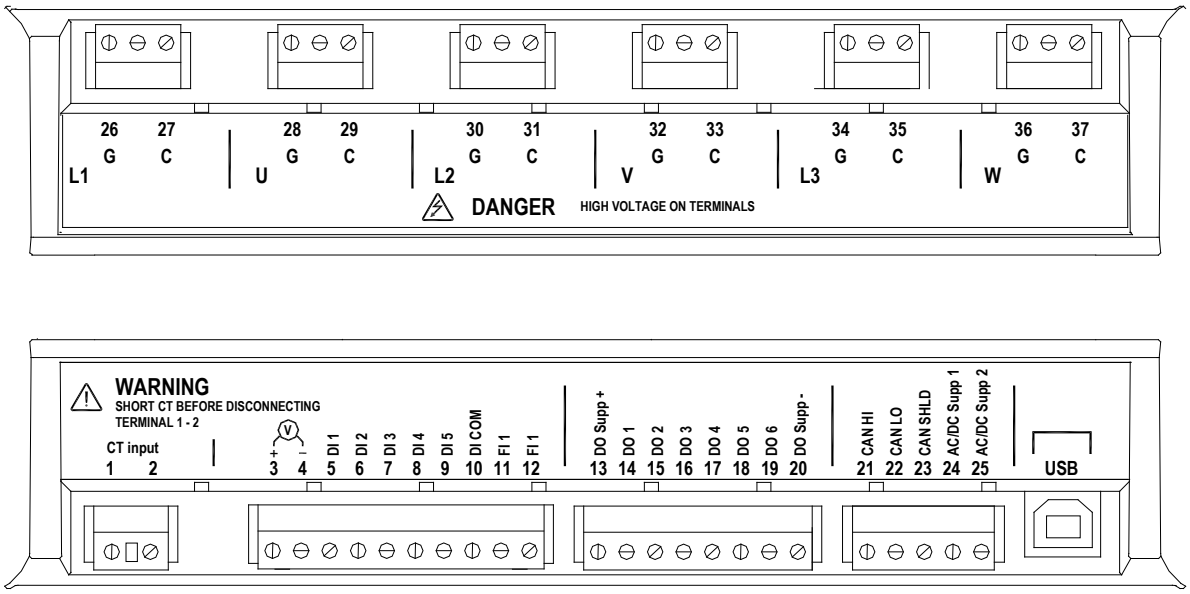
- Adjustable pitch synchronisation ramp for synchronising a fixed speed pitch-regulated wind turbine.
- Motor operation function with adjustable current settings

4. Installation instructions

The following section deals with all installation and mounting instruction. Examples show wiring of the TCM-2 to different modes of operation.

Terminals

Physical placement of terminal location:



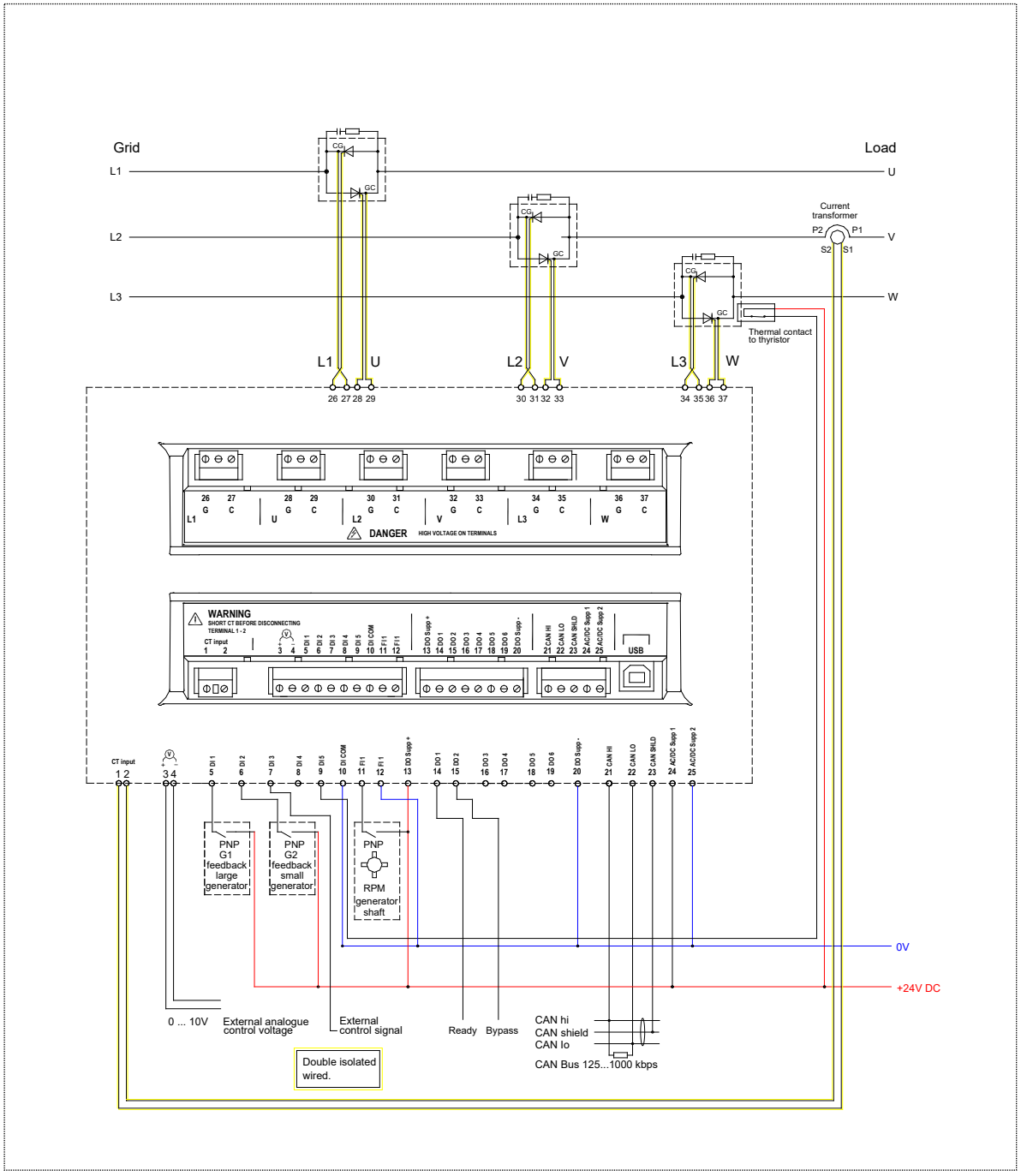
Terminal description

Detailed description of each terminal

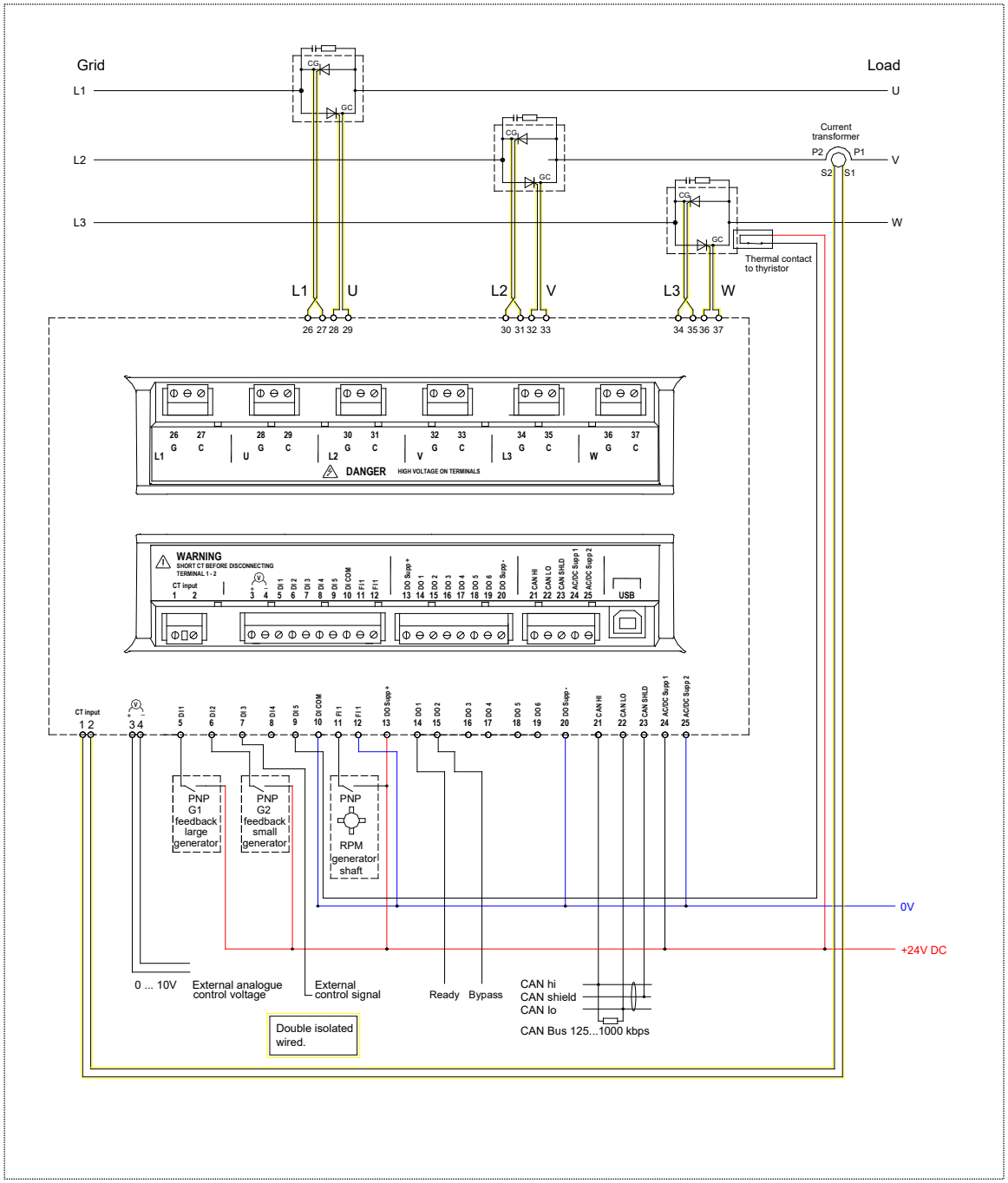
Note that the description only counts for operation mode 1. In mode 2, CAN operation, all inputs and outputs can be used per application need.

Term	Name	Function	Description
1-2	CT	Grid current measuring	CT secondary side
3-4	Ain	0-10V analogue signal	Control signal from controller
5	DI1	Digital input	Mode 1, G1 feedback signal
6	DI2	Digital input	Mode 1, G2 feedback signal
7	DI3	Digital input	Mode 1, Start signal from controller Mode 2, Enable thyristor output Mode 3, Enable thyristor output
8	DI4	Digital input	Not used
9	DI5	Digital input	Thyristor thermistor
10	DI COM	Digital common	Common 0V for digital inputs
11	FI 1	RPM input	Generator RPM signal
12	FI 2	RPM common	Common signal for generator RPM
13	DO Supp +	Digital output supply+	+9 - +36V DC
14	DO1	Digital output, NPN/PNP	Mode 1, Ready signal to controller
15	DO2	Digital output, NPN/PNP	Mode 1, Synchronisation OK signal
16-19	DO3-6	Digital output, NPN/PNP	Not used but available on CAN interface
20	DO Supp -	Digital output supply-	Common 0V for digital output
21	CAN HI	CAN-H	CAN interface
22	CAN LO	CAN-L	
23	CAN SHLD	CAN-GND	
24	AC/DC Supp 1	AC/DC supply+	18 – 36V DC, 19.2 – 30V AC
25	AC/DC Supp 2	AC/DC supply+	GND
26	-	Thyristor ignition pulse	Grid L1 thyristor gate
27	-	Thyristor ignition pulse	Grid L1 thyristor cathode
28	-	Thyristor ignition pulse	Generator L1 thyristor gate
29	-	Thyristor ignition pulse	Generator L1 thyristor cathode
30	-	Thyristor ignition pulse	Grid L2 thyristor gate
31	-	Thyristor ignition pulse	Grid L2 thyristor cathode
32	-	Thyristor ignition pulse	Generator L2 thyristor gate
33	-	Thyristor ignition pulse	Generator L2 thyristor cathode
34	-	Thyristor ignition pulse	Grid L3 thyristor gate
35	-	Thyristor ignition pulse	Grid L3 thyristor cathode
36	-	Thyristor ignition pulse	Generator L3 thyristor gate
37	-	Thyristor ignition pulse	Generator L3 thyristor cathode

Connections Mode 1 – double-speed generator application



Connections single speed generator application



Technical specifications

Aux. supply:	18-36V DC or 19.2-30V AC Max. 2 A
Operating temp.:	-25-+70°C (-13-+158° F)
Storage temp.:	-40…70°C (-40…158°F)
Climate:	97% RH to IEC 60068-2-30
Operating Altitude:	Max. 3,000 m
Vibration:	3…13.2 Hz, 2 mm_{P-P} 13.2…100 Hz, 0.7 g To IEC 60068-2-6
Shock:	50 g, 11 ms, half sine. To IEC 60068-2-27.
Protection class:	IP20 to IEC/EN 60529
Mounting:	Vertical or horizontal with thyristor terminals up or to the side for operation under full temp. range and protection class
UL/cUL R/C	For use on a flat surface of a type 1 enclosure.
Safety:	To EN 61010-1 overvoltage category III, 690V AC, pollution degree 23
UL/cUL R/C:	To UL508C and CSA 22.2 No. 14-05 overvoltage category III 600 V, pollution degree 2.
Material:	Plastic case, black, foil-covered. UL-94 V-0.
Connectors:	PHÖNIX Screw terminals 20 Arms
Weight:	Approx. 1 kg
EMC/CE:	To EN 61000-6-2/4
Thyristor ignition pulses:	500 mA current limited 100 kHz, dI/dt 1 A/us, Gate cathode voltage 0-5 V
Grid:	110V AC to 690V AC (phase-to-phase)
UL/cUL R/C:	110…600V AC
Frequency:	40-70 Hz
Digital inputs:	9-36V DC, app. 2.4 kOhm, input optically insulated, PNP or NPN selectable as a group.
RPM input:	9-36V DC, app. 2.4 kOhm, optically insulated, PNP or NPN.

1 to 12 pulses per turn, duty cycle > 20%

Analogue input: 0-10 V, 10 kOhm,
differential mode not galvanically insulated.

Current measurement input: -/1 or -/5 Arms AC

Accuracy: Class 1.0 to IEC/EN 60688

Current overload: 4 * in continuously
1020 * In for 10 s

Digital outputs: With external supply 9-36V DC, max 1.5 V voltage drop,
200 mA source/sink continuously

Wire size: AWG 30-12.

Terminal tightening torque: 5-7 lb-in (0.5-0.7 Nm)

UL markings:

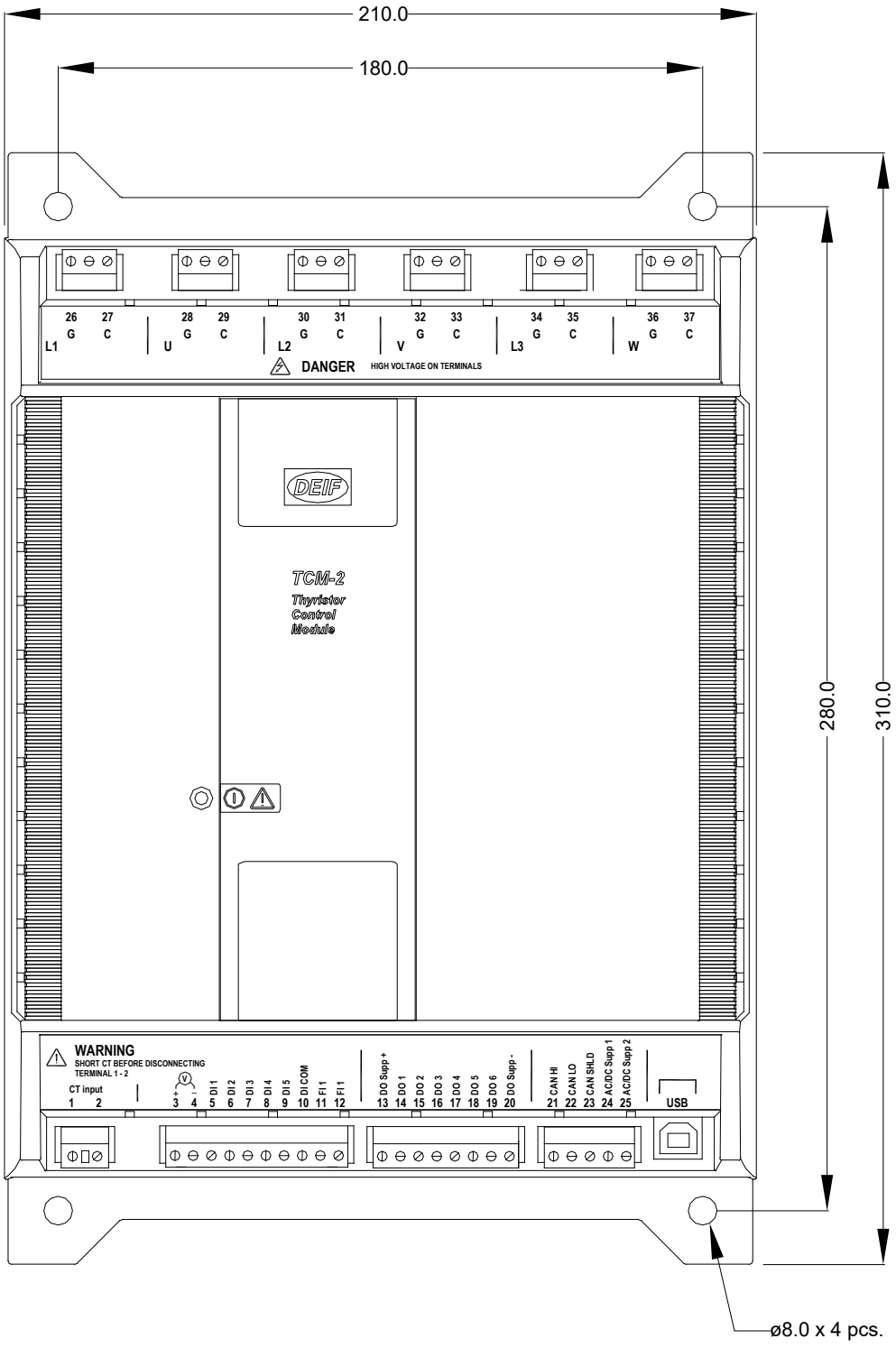
Installation: To be installed in accordance with the NEC (US) or the CEC (Canada).

Approval: CE & UL/cUL-recognised to UL508C and CSA 22.2 No. 14-10.

These controllers are intended to be used in industrial control panels where the suitability of the combination has been determined by Underwriters Laboratories.

Dimensions

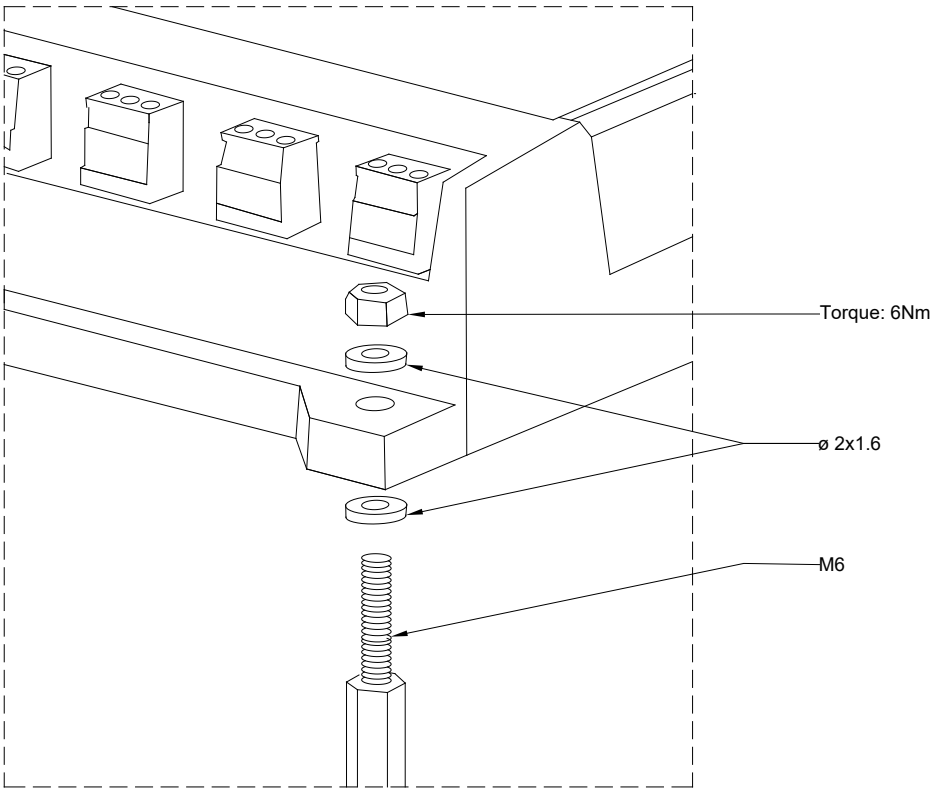
Units in mm



Mounting

The TCM-2 housing is designed to protect the electronics inside. It is easy to install the module using standard tools and parts.

Adaptor plates for mounting the TCM-2 in existing switchboard cabinets are available on request.



5. User interface and LED description

This chapter introduces the graphical user interface implemented in the TCM-2. The user interface is designed for easy setup of modes and parameter. The LED signals the current state of the TCM-2.

Connecting to the TCM-2 via USB cable

Install the TCM-2 utility software and connect the USB cable. The latest version can be requested at www.deif.com.

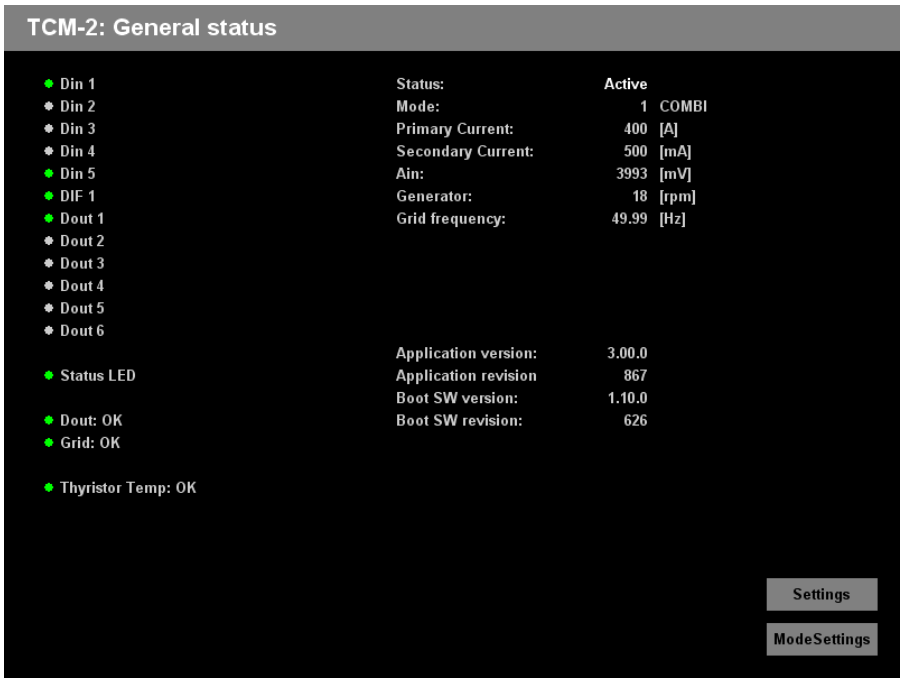
HMI pages

The user interface is built on graphical pages with easy overview and operation.

General status

Here the status, mode and general information can be seen. Digital input and output status is shown together with analogue input measurements and current measurements.

- **Din**, shows the state of the digital inputs
- **Dout**, shows the state of the digital outputs
- **Status LED**, is the same as the LED on the front of the TCM-2
- **Grid**, is OK if the TCM-2 gets measurements from the grid
- **CAN RPDO**, timeout indication on CAN interface (can be disabled as option and only visible in CAN operation mode)



From the page, additional settings menu can be selected:

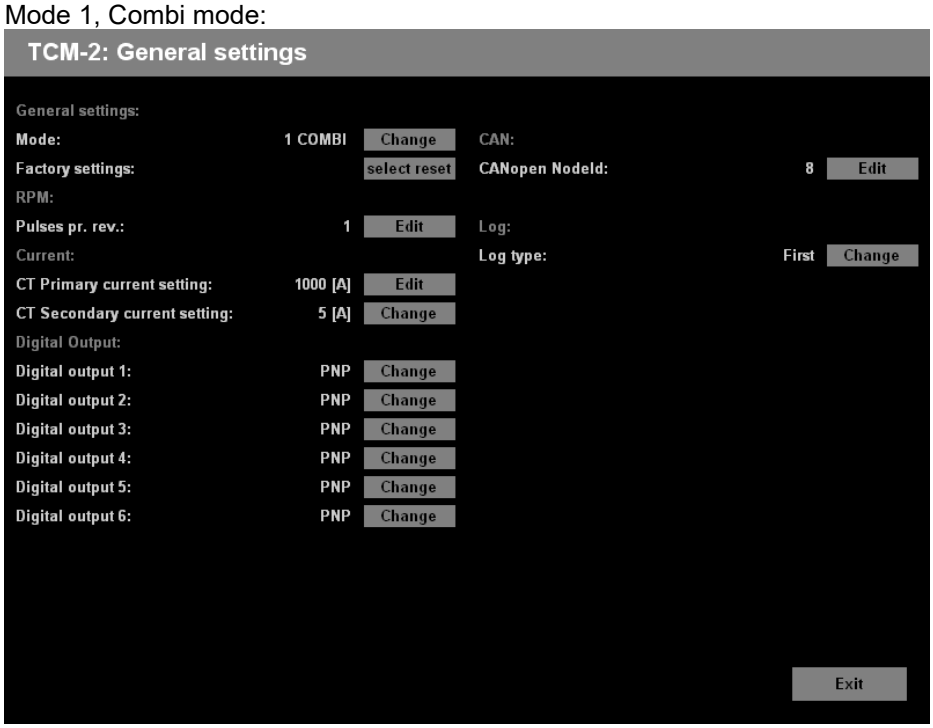
- **Settings**, is the common settings menu, here the operation mode is set
- **ModeSettings**, Mode 1 parameter settings. This menu will only be available when "Mode 1" is selected in the **Settings** menu

General Settings

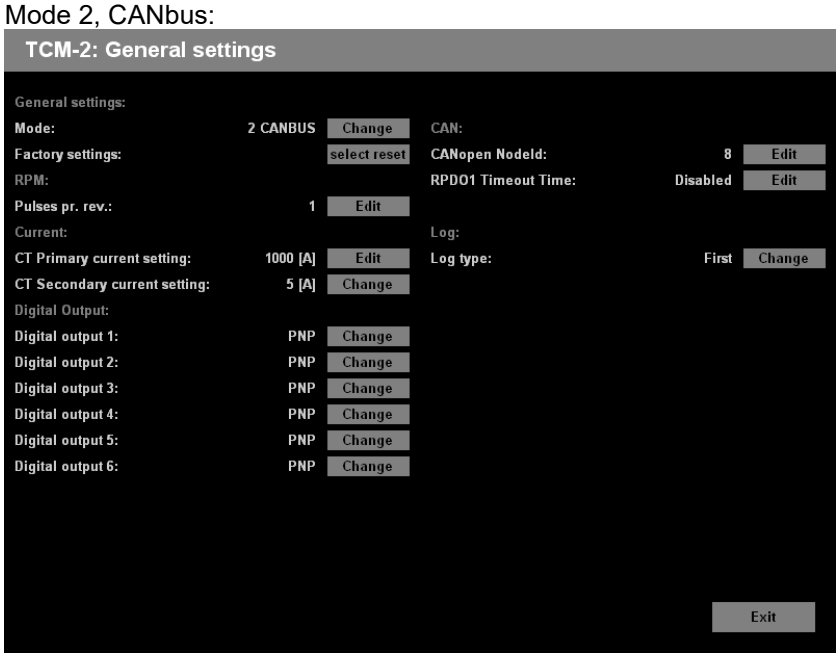
These are the general settings for the TCM-2:

- **Mode of operation**, 1 COMBI, 2 CANbus or 3 CAN auto
- **Pulses pr rev**. the number of pulses from the generator on one turn
- **CT primary current setting:** ratio on current transformer – primary site
- **CT Secondary current setting: r**atio on current transformer – secondary site
- **Digital output 1-6**, set the digital output to either NPN or PNP
- **RPDO1 timeout**, disable or set specific timeout
- **Log type,** select whenever saving first or newest log.

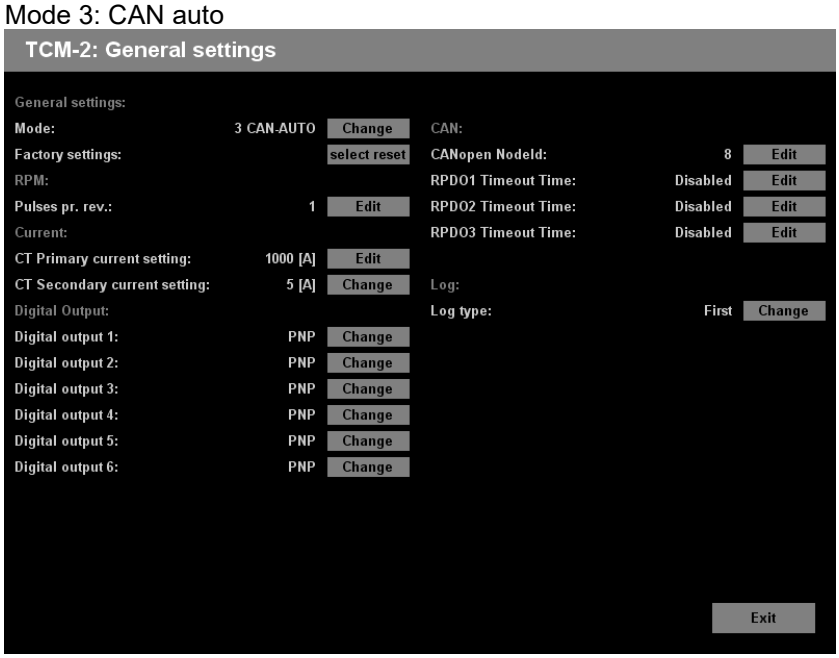
Mode 1, Combi mode:



Mode 2, CANbus:



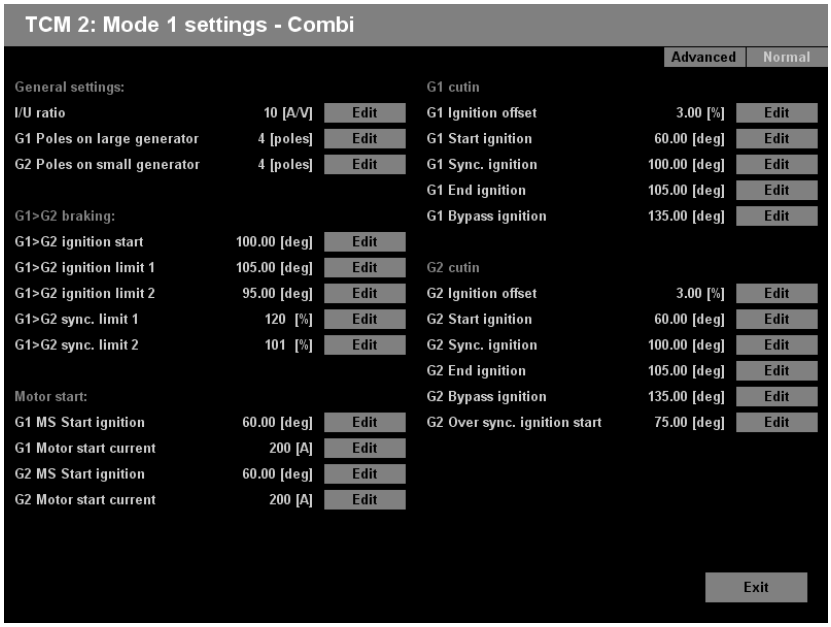
Mode 3: CAN auto



Mode 1 parameter settings

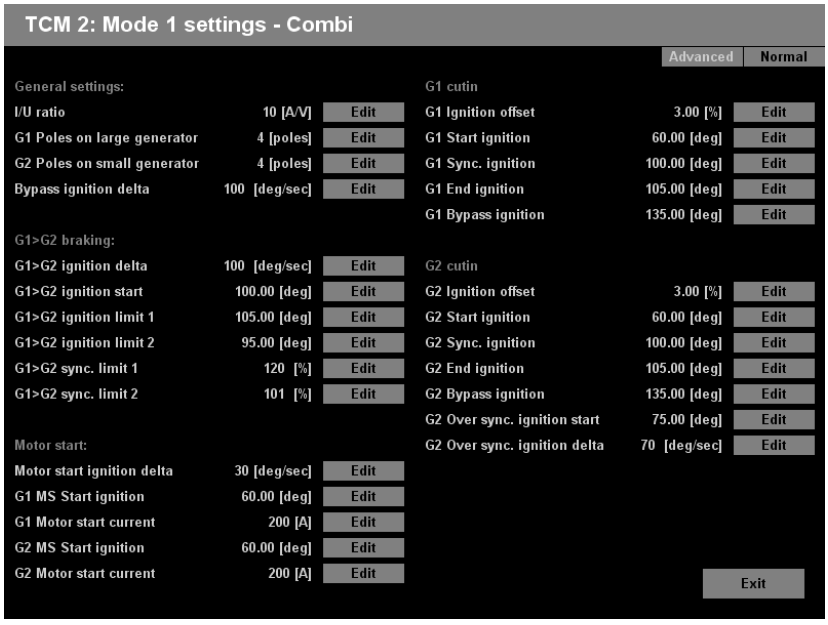
In this page, the settings for Mode 1 can be adjusted to the actual turbine and generator model. These settings also have to be adjusted to gain optimal performance.

Normal settings page



Advanced settings page

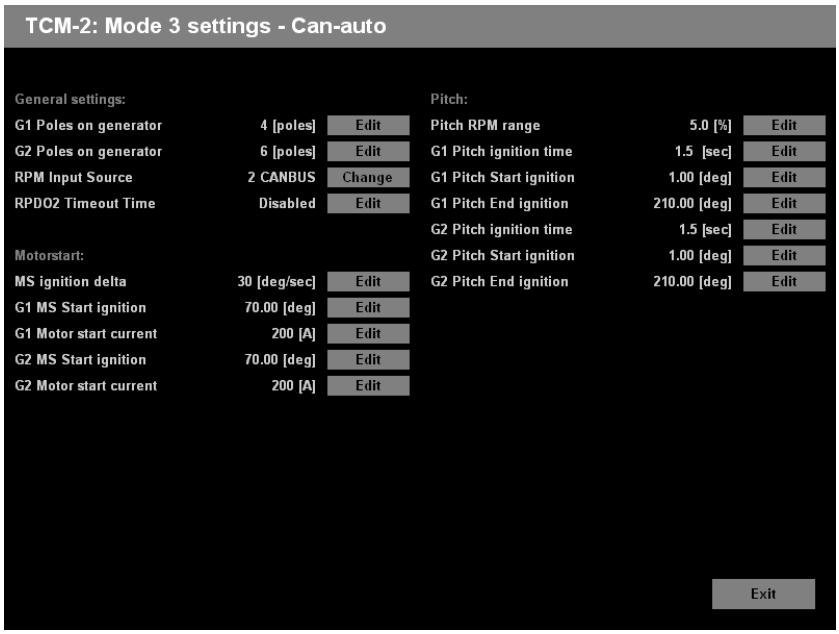
In the advanced page, it is possible to set special parameters for optimising the ignition times such as ***Bypass Ignition Delta***. These parameters are not necessary to change, and default values can be used.



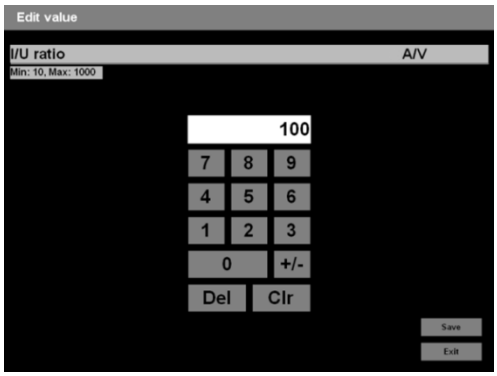
To edit a parameter, press **Edit** and a numerical keyboard will appear.

Mode 3 parameter settings

In this page, the settings for Mode 3 can be adjusted to the actual turbine and generator model. The settings are used by the TCM-2 to control the internal functions activated by the CAN messages used in Mode 3.



Parameter editor example



Note: in the left corner, Min and Max settings for the specific parameter are stated.

LED status signals

The TCM-2 status LED in the front has certain pattern indication status OK or an error.

LED state	Description
Green On	No errors, TCM-2 is ready to operate
Red flashing fast	High temperature
Red flashing slow	Error in output stage, no supply/short circuit or other error related to the output stage
Red: 1 long flash + 1 short flash	Phase missing or phase sequence wrong
Red: 1 long flash + 2 short flash	Net frequency high, above 70 Hz or low, below 40 Hz
Red: 1 long flash + 3 short flash	No net, frequency unstable or below 30Hz
Red: 1 long flash + 4 short flash	No RPM signal detecting during operation
Red: 1 long flash + 5 short flash	CAN timeout

6. CAN communication

The TCM-2 supports CAN protocol communication in all modes for receiving additional information of internal values and states and also to manage the internal parameters by CAN messages.

This section describes the common CAN interface available for all three modes of operation.

CAN Protocol

TCM-2 CANbus description

To control the TCM-2 in CAN mode, a set of CAN messages are described.

TCM-2 CANbus uses an 11 bit identifier with a baud rate of 125 kbps.

TCM-2 Node ID = 0x08. (Adjustable).

Short description of supported CAN messages

The general supported CAN messages are sent from the TCM-2 to the external controller.

Process data objects(PDO):

The process data protocol handles transmissions of real time data. The message format is:

CAN-ID	Data0	Data1	Data2	Data3	Data4	Data5	Data6	Data7

Here, the CAN-ID is the communication object identifier consisting of a function code + node id. This could for example be 0x180 + node id from slave to master.

Sent telegrams from the TCM-2	
CAN ID	Description
0x180 + node ID	Status PDO
0x280 + node ID	Measurement 1 PDO
0x380 + node ID	Measurement 2 PDO

Detailed description of each message sent from TCM-2

ID 0x180 + node ID: Status PDO

Sent every 20 ms.

Data byte	Description	Type	Unit	Range	Description
0	Actual Mode	Byte	Enum	1 – 2	TCM-2 mode of operation
1	Status Code	Byte	Enum		TCM-2 overall status
2	Error Code	Byte	Enum		Last error description
3	Reserved	-	-	-	No use
4	Binary input 0-5	Byte	Bits	0 – 63	Value of input bits
5	Binary output	Byte	Bits	0 – 63	Value of output bits
6	Control state	Byte	Enum		Current control state
7	TCM-2 State	Byte	Enum	-	Current TCM-2 state

Actual Mode	Description
1	Mode 1, RPM-controlled soft starter
2	Mode 2, CAN mode
3	Mode 3, CAN auto

Status code	Description
-3	Initialisation error
-2	General error state
-1	Not ready
0	Status ready
1	Active

Error code	Description
-100	Unknown error
-30	CAN time out
-21	RPM Range error
-20	RPM missing in active state
-10	Output state error, supply missing, overload
-6	Thyristor hot
-5	Phase missing
-4	Low frequency
-3	High frequency
-2	No grid available
-1	Phase sequence error
0	No error

Control state mode 1	Description
-1	Error
0	Ready
1	Select cut-in strategy
10	Motor start ramp-up
11	Motor start regulate current
12	Motor start ramp-down
20	Cut-in first ramp
24	Cut-down ramp-down
25	Over-synchronous cut-in
30	Cut in prepare first ramp
31	Cut in run first ramp
32	Cut in run second ramp
33	Cut in run final ramp
50	Synchronising completed

Control state mode 2	Description
-1	Error
0	Ready
1	Active

Control state mode 3	Description
-1	Error
0	Ready
1	Select Function
10	Motor start current ramp-up
11	Generator current control loop
12	Generator current ramp-down
15	Pitch ram init checking for speed
16	Pitch ramp active
17	Pitch ramp Done
18	Pitch Ramp Bypass
50	Synchronising completed

TCM-2 State	Description
-1	Error
0	Ready
3	Mode 1 Combi
5	Mode 2 CAN
7	Mode 3 CAN auto

All states and error codes are priorities with the lowest number as the highest priority, and only the highest priority's code will be transferred.

ID 0x280 + node ID: Measurement 1 PDO:

Sent every 20 ms

Data byte	Description	Type	Unit	Range	Description
0	-	-	-	-	-
1	-	-	-	-	-
2	Current RMS. LSB	Word	mA	0 – 5000	Secondary current
3	Current RMS MSB	-	-	-	-
4	Analogue voltage LSB	Word	mV	0 – 10000	Analogue input voltage
5	Analogue voltage MSB				
6	IgnitionAngle LSB	Word			Actual ignition angle to Thyristors
7	IgnitionAngle MSB	Word	0.1 deg	0 – 2100	

ID 0x380 + node ID: Measurement 2 PDO:

Sent every 20 ms

Data byte	Description	Type	Unit	Range	Description
0	Generator period time LSB	Integer 32	us		Generator rotational speed raw measurement. Only measures RPM from terminals
1	Generator period time				
2	Generator period time				
3	Generator period time MSB				
4	Generator RPM signal LSB	Word	RPM	0 – 2000	Generator RPM-calculated value. Only measures RPM from terminals
5	Generator RPM signal MSB				
6	-				
7	-				

Transmission of configuration parameters

The CAN protocol supports setup of parameters. By this, it is possible to implement a TCM-2 parameter handler in an external controller or PLC.

Transmission protocol

The client sends Service Data Objects (SDO) to the server (TCM-2 module) via a CAN telegram. The TCM-2 module acknowledges this with another SDO. .

In general, when configuring the CMD field to "set request", the SDO (value in data field) is written to the device which now responds with an acknowledge SDO. And when reading an SDO in the device, a read request SDO is sent to the device which responds with an SDO containing the value.

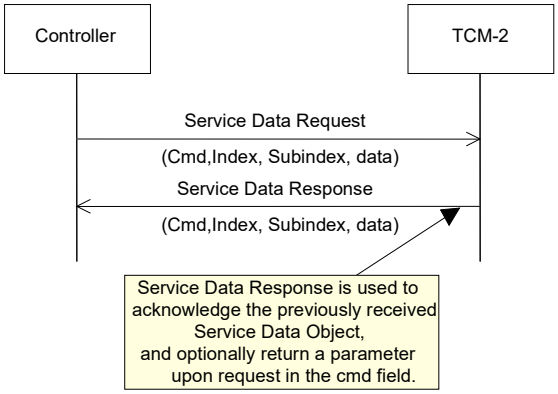


Figure 1: Download of configuration parameters

Service data objects - SDO:

This is the protocol that is used to read and write the parameters in the TCM-2 module (the parameter structure is considered as an object dictionary in the TCM-2 module).

Service Data Request/Response message format:

CAN-ID	CMD	Index LSB	Index MSB	Sub index	Data0	Data1	Data2	Data3

- CAN-ID is the CAN device identifier. In general, this would be 0x600 + nodeid from CAN master and 0x580 + nodeid from CAN slave (TCM-2).
- The Cmd indicates whether it is a set/read command and the number of valid bytes that are present.
- Index is the index in the "object dictionary". (2 byte).
  Parameters start with index 0x2000. (16 bit unsigned integer).
  Parameters are described further in the last chapter, where "ID" corresponds to the index.
- Sub index is the object dictionary sub index.
  This value is not used. This byte has to be set to 0x00.
- Data is the value.
  These 4 bytes indicates the parameter value. Note: the parameter here is only 2 byte.

The CMD field specifies how to interpret the current SDO. The interpretation of the different bits depends on the scenario. The four different formats are described in the following subsections.

Parameter set request

CMD field in SDO request:

Bit 7, 6, 5	Bit 4	Bit 3,2	Bit 1	Bit 0
ccs	x	n	e	s

- ccs field is used to indicate if it is a set or read request.
  ccs = 2, indicates a read request.
  ccs = 1, indicates a set request.
- X is not used.
- n indicate number of byte in data field that is not valid.
- e indicates if it is an expedited transfer.
  e = 0 indicates normal transfer.
  e = 1 indicates expedited transfer
- s indicates if data size is indicated.
  s = 0 data size is not indicated.
  s = 1 data size is indicated.

CMD field in SDO response:

Bit 7, 6, 5	Bit 4-0
scs	x

- scs field is used to indicate if it is a set or read response.
  scs = 3, indicates a set response.
- X is not used.

Example of a set request

Example 1: "Digital output 1" needs to be configured to the value "1" in the TCM-2 via CANbus.

This particular parameter has the index ID 0x2004. According to note in the parameter section, this parameter is **one byte long**. This gives that index MSB (Byte 2) equals 0x20, index LSB (Byte 1) equals 0x04 and value (Byte 4) equals 0x01. Let us assume that the TCM-2 has the "node ID" 8, which gives the CAN ID 0x608. Sub index (Byte 3) is always zero.

The following CAN telegram must be sent to the TCM-2.

CANID 0x608	BYTE 0 0x2B	BYTE 1 0x04	BYTE 2 0x20	BYTE 3 0x00	BYTE 4 0x01	BYTE 5 0x00	BYTE 6 0x00	BYTE 7 0x00

The TCM-2 will return this document in order to acknowledge the "set" operation.

CANID 0x580	BYTE 0 0x60	BYTE 1 0x04	BYTE 2 0x20	BYTE 3 0x00	BYTE 4 0x00	BYTE 5 0x00	BYTE 6 0x00	BYTE 7 0x00

Parameter read request

CMD field in SDO request:

Bit 7, 6, 5	Bit 4-0
ccs	x

- ccs field is used to indicate if it is a set or read request.
  ccs = 2, indicates a read request.
- X is not used.

CMD field in SDO response:

Bit 7, 6, 5	Bit 4	Bit 3,2	Bit 1	Bit 0
scs	x	n	e	s

- scs field is used to indicate if it is a set or read response.
  scs = 2, indicates a read response.
- X is not used.
- n indicates number of byte in data field that is not valid.
- e indicates if it is an expedited transfer.
  e = 0 indicates normal transfer.
  e = 1 indicates expedited transfer
- s indicates if data size is indicated.
  s = 0 data size is not indicated.
  s = 1 data size is indicated.

Example of a read request

Example 2: "Magnet ignition (G2)" needs to be read in TCM-2 via CANbus.

This particular parameter has the index ID 2021. According to note in parameter section, this parameter is **two byte long**. This gives that Index MSB (Byte 2) equals 0x20, and Index LSB (Byte 1) equals 0x21. Let us assume that the TCM-2 has the "device ID" 8 which gives the CAN ID 0x608. Sub index (Byte 3) is always zero. Magnet ignition has the value "100.00".

The following CAN telegram must be sent to the TCM-2.

CANID	BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
0x608	0x40	0x21	0x20	0x00	0x01	0x00	0x00	0x00

The TCM-2 will return this telegram in order to acknowledge and deliver the value of the indicated parameter.

CANID	BYTE 0	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7
0x580	0x4B	0x21	0x20	0x00	0x10	0x27	0x00	0x00

The returned value can be found in byte 4 and 5 (2 byte value). The returned value is 0x2710 which equals "100.00".

7. Mode 1 description

In Mode 1, the TCM-2 works as an rpm-controlled soft cut-in for stall-regulated, one- or two- speed wind turbines. The advanced rpm-regulated soft cut-in calculates the optimum cut-in sequence and time from a set of adjustable parameters. In Mode 1, an external controller does not need to control the thyristor block, but only interface to the TCM-2 as stated in this chapter, then the TCM-2 will synchronise the generator and signal this to an external controller which can then engage the bypass contactor.

Mode 1 connections with existing controller supplying 0-10 V reference signal

In this setup, it is possible to use the TCM-2 in Mode 1 with existing wind turbine controller supplying a 0-10 V reference signal as start signal. As an alternative, one digital input can also be used as start signal if no analogue signal is available.

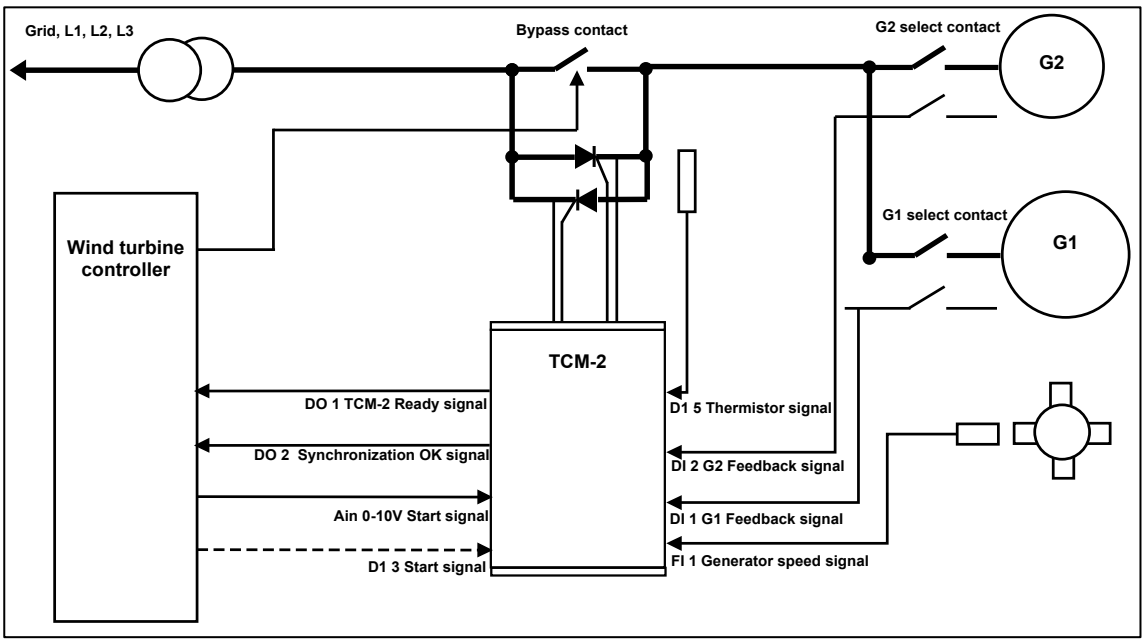


Figure 2: Mode 1 principle diagram

The general CAN information messages sent from the TCM-2 is described in Chapter 6.

The following can be performed in mode 1:

- **Motor start:** G1 and G2 motor operation with controllable current separately for both generator stages. Generator speed must be below 50% of nominal speed to activate motor operation. If the generator speed exceeds 66% of the nominal speed during motor start, the motor start is stopped, and the TCM-2 will prepare the under synchronous rpm-controlled cut-in.

- **Under synchronous rpm-controlled cut-in:** G1 and G2 under synchronous rpm-controlled cut-in at low and high wind speed for both generator stages when rpm is between 50% and 100% of nominal. Each generator stage has individual parameter sets.

- **G2 over synchronous cut-in**: at low wind when rpm is above synchronous speed up to 10% of G2 nominal speed.

- **G1 to G2 cut-down:** with generator breaking with G2 from highly over synchronous operation to normal operation.

Detailed description of each control function

Motor start function

The generator speed must be below 50% of the nominal speed to active the motor start function. If the speed increases to 66% of the nominal speed, then the TCM-2 will stop the motor start and prepare for the under synchronous rpm-controlled cut-in, which is the next stage.

The ignition angle during motor start is controlled in the following way: the external analogue signal is interpreted as a setpoint for the desired generator current under motor start, and the relation between the parameters are given in a small example below.

The current for the motor start must be selected on e.g. 200 A, and the analogue signal to be applied can be calculated as:

Analogue signal = 200 A/800 A*10 V = 2.5 V to be applied from the external controller

Because theTCM-2 needs to transfer the voltage signal to a current level, the parameter **I/Uratio** needs to be set. In this example: 200 A/2.5 V = 80 A/V.

When the external controller applies the voltage, the TCM-2 will control the current on the generator. Please note that the TCM-2 is only measuring a single-phase current and deviations from external 3-phase measurement equipment is most likely.

If the TCM-2 is installed on an existing wind turbine, the relation between the applied 0-10 V signal and expected current could differ, and the parameter "I/Uratio" should be set to an appropriate value for correct regulation.

If DI3 is used as start signal, the parameter setting "Motor Start current G1" or "Motor Start current G2" is used as reference.

Cut-in of asynchronous generator

During cut-in of an asynchronous generator (this is also valid for a 2-speed generator), the ignition angle follows a 3-step ramp, where the duration of each ramp is dynamically adapted to the apparent rpm and acceleration of the generator shaft. This principle allows a cut-in sequence which adapts to different low-, medium- and high-wind operations.

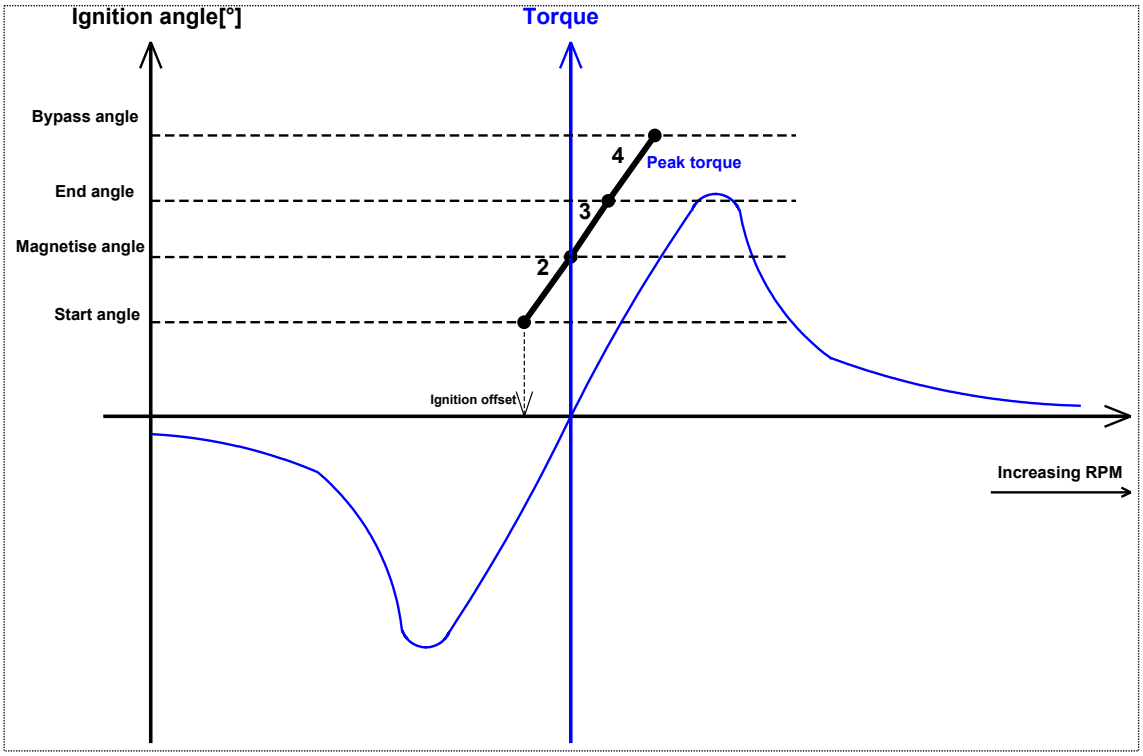


Figure 3 Principal cut in ramp mode 1

By modifying the individual parameters, it is possible to change the individual ramp sequence.

Control logic between TCM-2 and external controller:

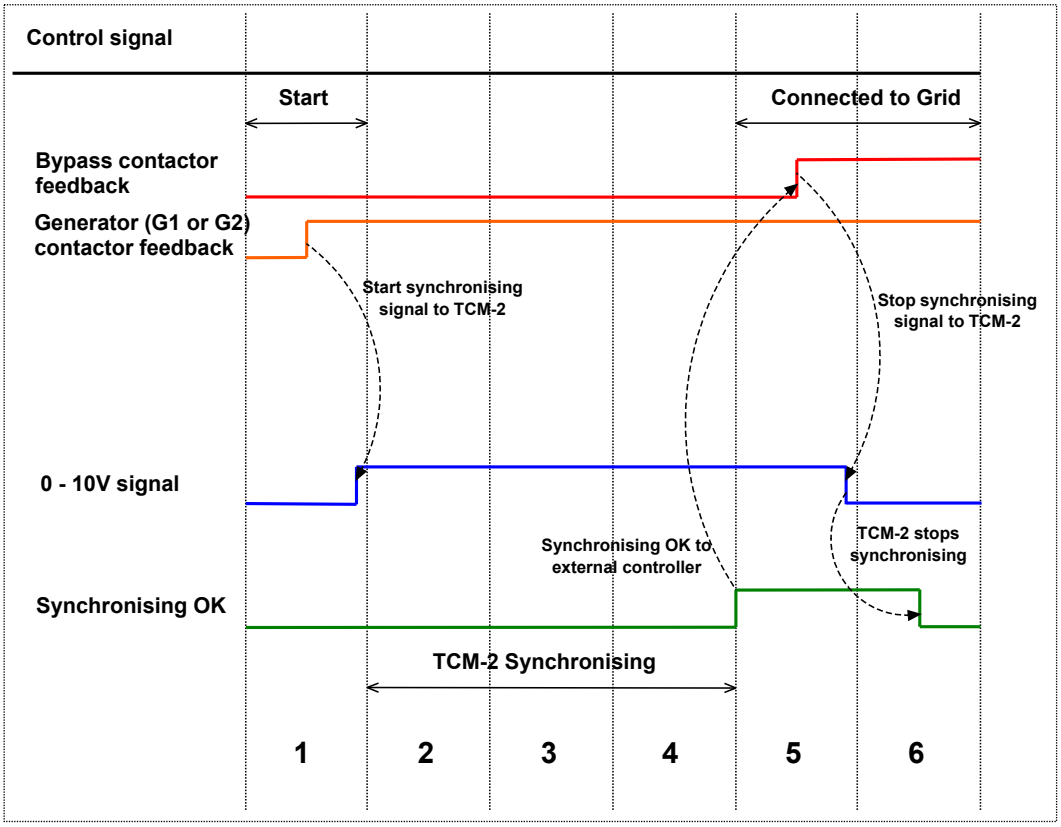


Figure 4 Control logic cut-in

1. Start cut-in sequence

The external controller sets the actual generator to cut-in (only double speed) and sets the analogue signal to a value above 1V to activate the TCM-2 cut-in sequence.

2. 1st ramp

The TCM-2 starts opening the thyristors from the "**Start Ignition"** to the **"Sync.Ignition angle"** parameter until the speed is synchronous. The **"Ignition offset"** settles when the ignition should begin. However, this offset will be adjusted adaptively by the TCM-2 according to the RPM and acceleration of the generator.

3. 2nd ramp

The second ramp is used after synchronous speed and fully opens the thyristor bridge until "**End Ignition"** is reached.

4. 3rd ramp

The last ramp is to select when the TCM-2 shall send the synchronisation OK signal. When the "**Bypass Ignition"** is reached, the signal synchronisation OK is set to indicate that the bypass contactor can be activated by the external controller.

When the TCM-2 is used for a 2-speed generator, the principle applies to both generator stages, but each of them can be set by a separate parameter setup for the ignition ramp for the two generators.

5. Connect bypass from external controller

The external controller should engage the bypass contactor and deactivate the ON signal to the TCM-2

6. Deactivate TCM-2

The external controller disables the TCM-2 by setting the analogue signal to 0V, and the TCM-2 is in ready state.

Cut-down sequence for 2-speed asynchronous generator (G1-G2)

The cut-down procedure is only relevant for 2-speed generators, where the small generator is used in over synchronous operation as an electrical brake. By setting the parameters so a high ignition angle is avoided when the small generator transfers over the peak torque towards the synchronous speed, a soft brake sequence can be set up.

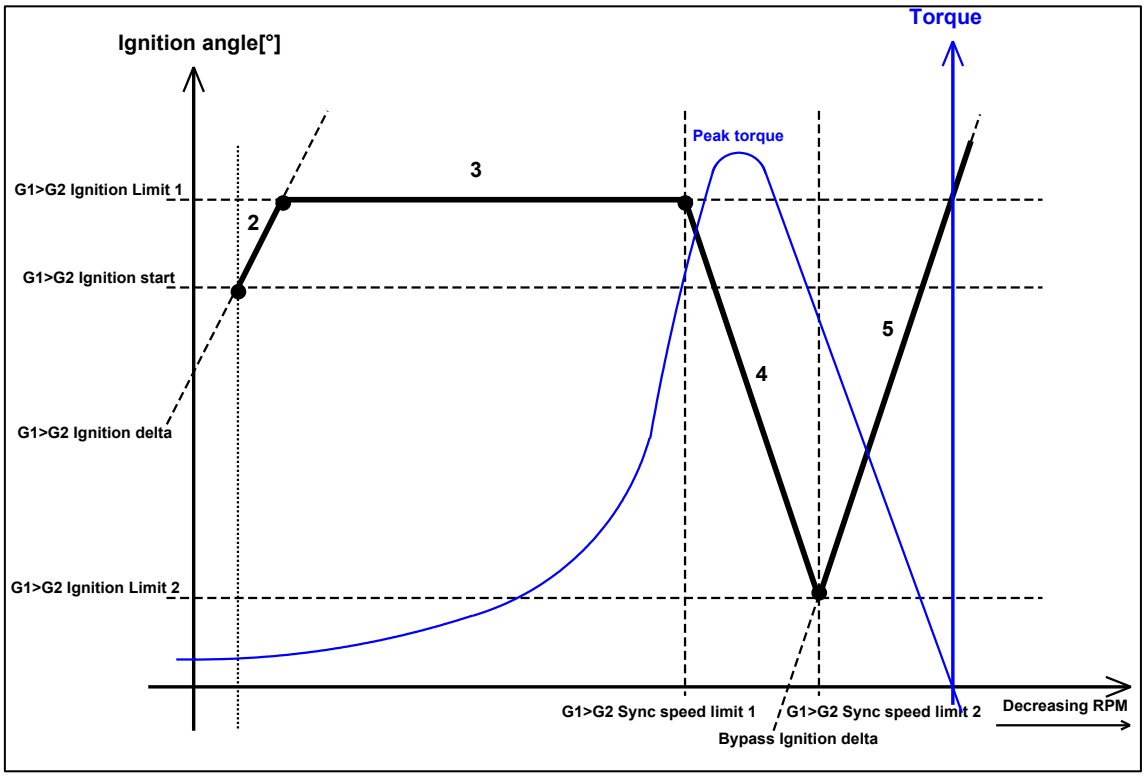


Figure 5 Principal cut down ramp G1 -> G2

The figure above is seen from going from the high-speed generator, G1, to the low-speed generator, G2.

Control logic between external controller and TCM-2

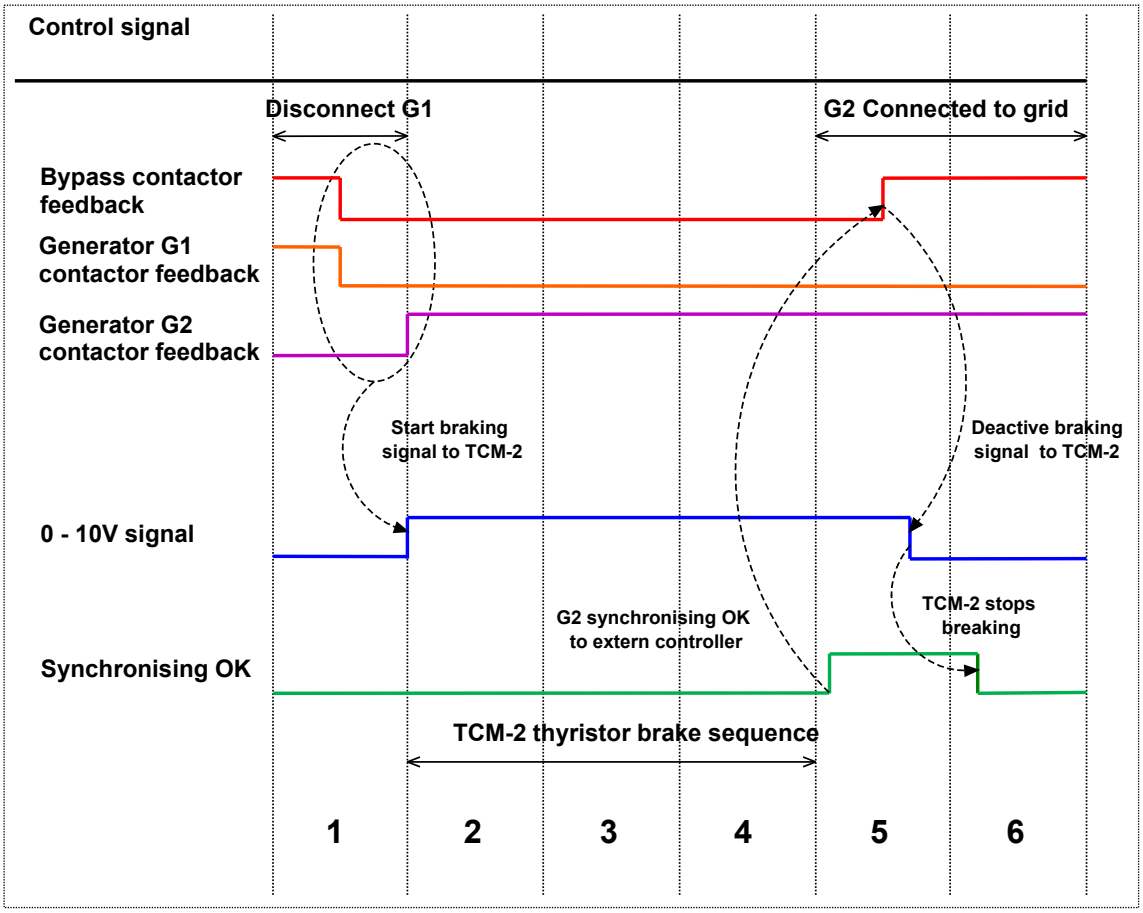


Figure 6 Control logic braking sequence

Description of each step going from large generator G1 to small generator G2

1. Disconnect G1

The external controller disconnects the bypass contactor, and the G1 contactor. Selects the G2 to synchronise and activates the TCM-2 by setting the analogue signal to a value above 1V to start the sequence.

2. 1st Ramp

After disconnection of the big generator in a situation with low power, the small generator is connected and magnetised current, where a suitable braking force is established on the generator. Adjust the **G1>G2IgnitionLimit1** to achieve an acceptable braking current.

3. 2nd ramp

This ramp angle is kept constant during the second phase in order to reduce the speed of the generator and approach the synchronous speed. Here the small generator is running typically at 30-50% over synchronous speed and will start loosing speed toward the synchronous speed for G2.

4. 3rd ramp

This ramp angle is reducing the ignition angle linearly from the parameter **G1>G2IgnitionLimit1** to the parameter **G1>G2IgnitionLimit2** so the peak torque point of the G2 generator is crossed with a minimum opening of the thyristors to reduce the current through the generator.

5. 4th ramp

When the generator in the previous ramp has reduced the speed of the generator close to synchronous speed, the ignition angle is ramped up to full connection in order to gain full connection and operate the small generator. The synchronisation OK signal is sent to the external controller.

6. Connect bypass from external controller

The external controller should set the bypass contactor and deactivate the analogue ON signal to the TCM-2 which then enters ready state.

Over-synchronous cut-in G2

The over-synchronous cut-in on G2 can be used when the small generator is running over synchronous speed up 110%. To cut in the small generator, a 2-step connection ramp is fired to synchronise the generator.

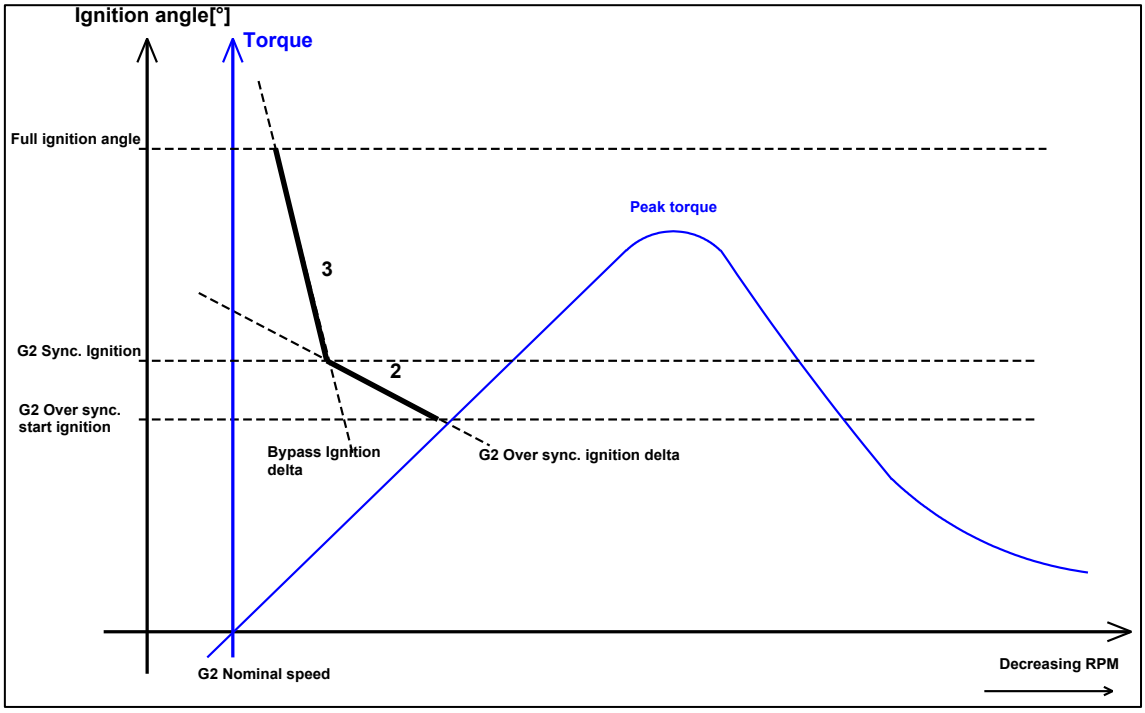


Figure 7 Principal over-synchronous cut-in ramp G2

Control logic between main controller and TCM-2

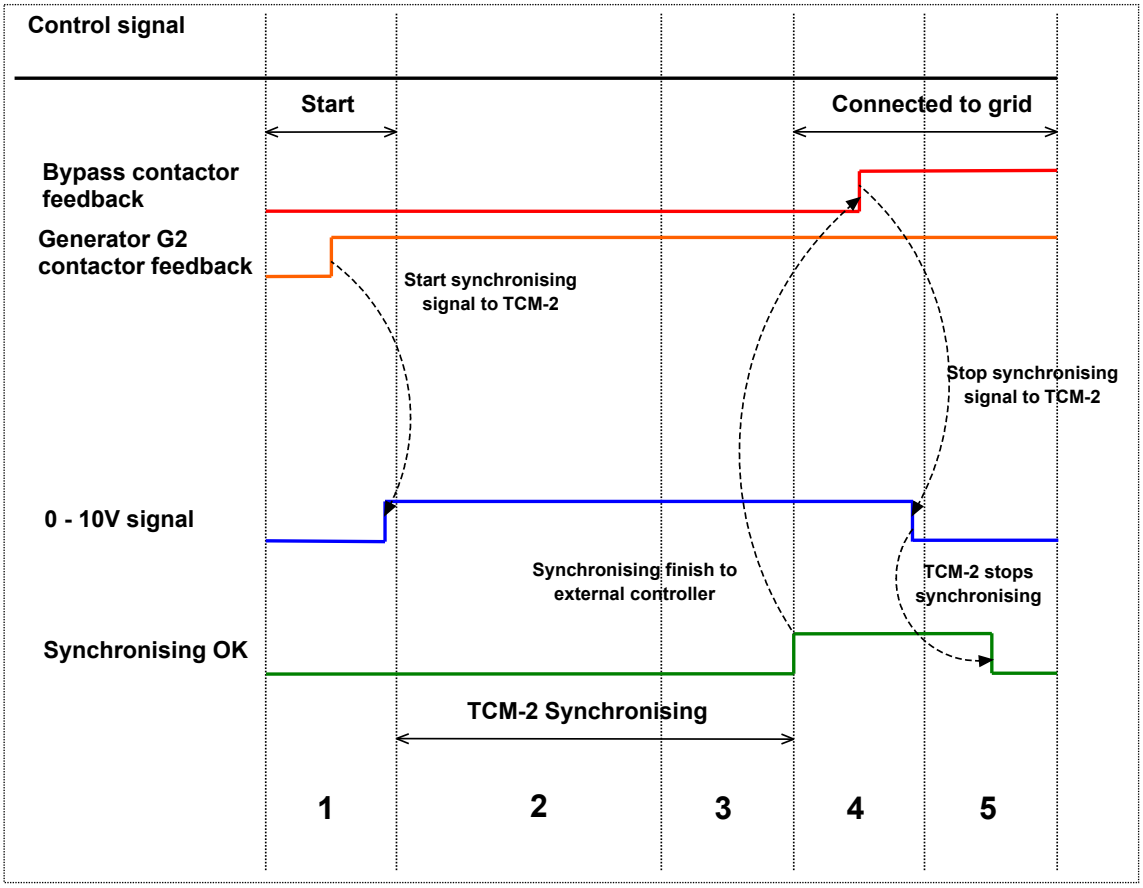


Figure 8 control logic over-synchronous cut-in G2

1. Activate TCM-2

The external controller activates the G2 contactor and sets the analogue signal to a value above 1V.

2. Cut-in ramp

The TCM-2 starts a linear ramp from "**G2 Over sync. Ignition start"** to "**G2 End Ignition".**

3. Bypass ramp

Ramp up to "**G2 End Ignition"** and signal the synchronisation OK signal to main controller.

4. Connect bypass from external controller

The external controller should set the bypass contactor and deactivate the ON signal to the TCM-2.

5. Deactivate TCM-2

The external controller disables the TCM-2 by setting the analogue signal to 0 V, and the TCM-2 stops and goes to ready state.

8. Mode 2 description

In this mode, the TCM-2 is connected to an external main controller or PLC through the CANbus Interface.

Here the TCM-2 continuously receives certain CAN telegrams, which directly control the actual ignition angle and the six digital output signals.

The maximum frequency for changing the ignition is three times the actual grid frequency, so for each new period in each phase L1, L2, L3 of the grid, the ignition is changed and adapted to the new setpoint.

The six digital outputs can be directly controlled by CAN telegram, while the actual value for the six digital inputs, the analogue input ,the RMS value for the phase current and all other internal measurements, states are transmitted once per period of the grid so that the PLC can monitor all states and functions of the TCM-2.

Mode 2 overview connection as controlled ignition pulse generator

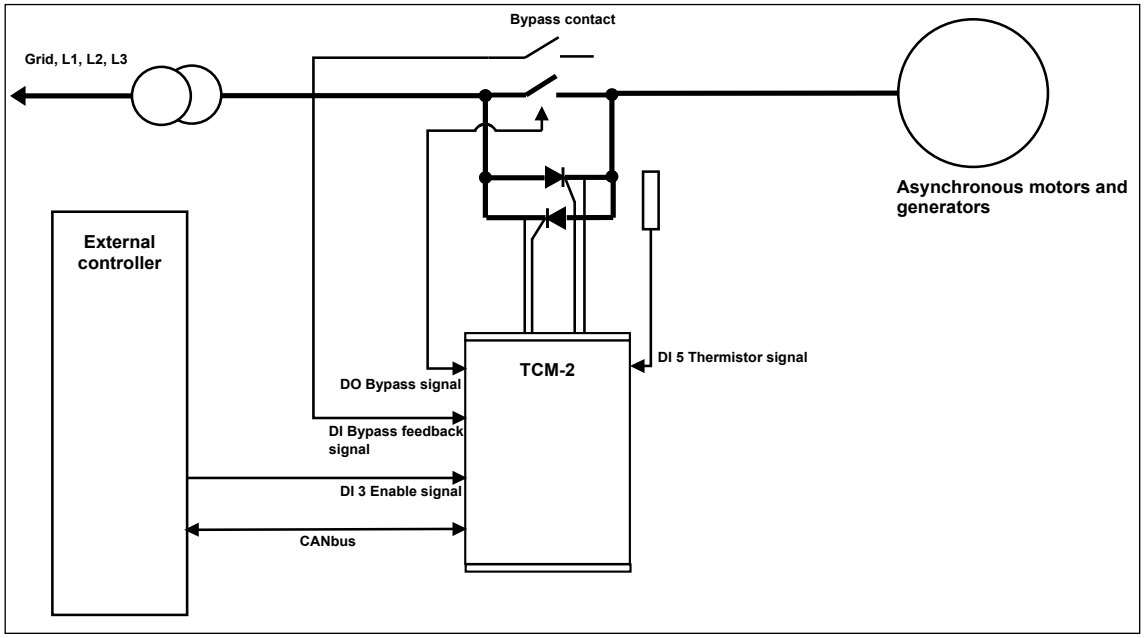


Figure 9 CANbus principle diagram

In Mode 2, the TCM-2 can be set up to different kinds of applications.

DI3 enable signal is set to HIGH to enable the ignition output to the thyristors.

CAN protocol

In mode 2 the external controller has full control of the ignition angle.

Please note, that the current CT information is entered correctly for using the current parameter information

Description of all telegrams supported in mode 2

Received telegrams from external controller	
CAN ID	Description
0x200 + node ID	Control PDO

Detailed description of each message sent from TCM-2

To control the TCM-2 in mode 2, the following control PDO is used as control interface.

Control telegram from controller to TCM-2

ID 0x200 + node ID: control telegram

Data byte	Description	Type	Unit	Range	Description
0	Control	Byte	Bits	0-1	TCM-2 will only accept the rest of the data if this byte is set to 1
1	Digital output 1-6	Byte	Bits	0-63	Set digital outputs
2	-				-
3	-				-
4	Ignition angle LSB	Word	0.1 deg	0-2100	Ignition angle setpoint high byte
5	Ignition angle MSB				Ignition angle setpoint low byte
6	-				-
7	-				-

The control message must be sent at 20 ms update frequency to operate the TCM-2.

The general CAN information messages sent from the TCM-2 is described in Chapter 6.

9. Mode 3 description

In this mode, the TCM-2 can use a CAN auto function to enable internal TCM-2 functions for controlling the cut-in ramp sequence through the CAN interface.

Mode 3 connection overview as CAN auto function

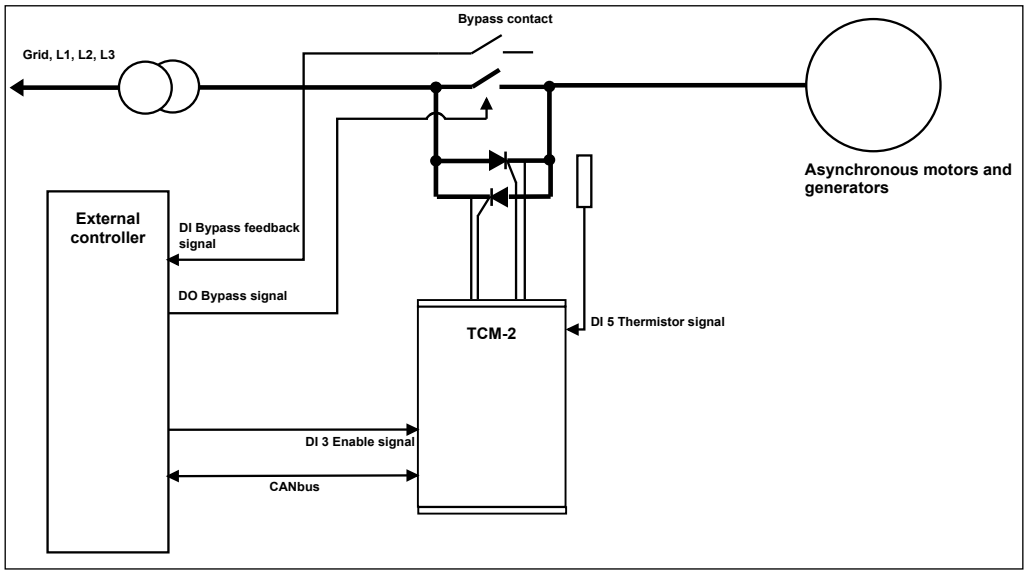


Figure 10 Mode 3 connection principle

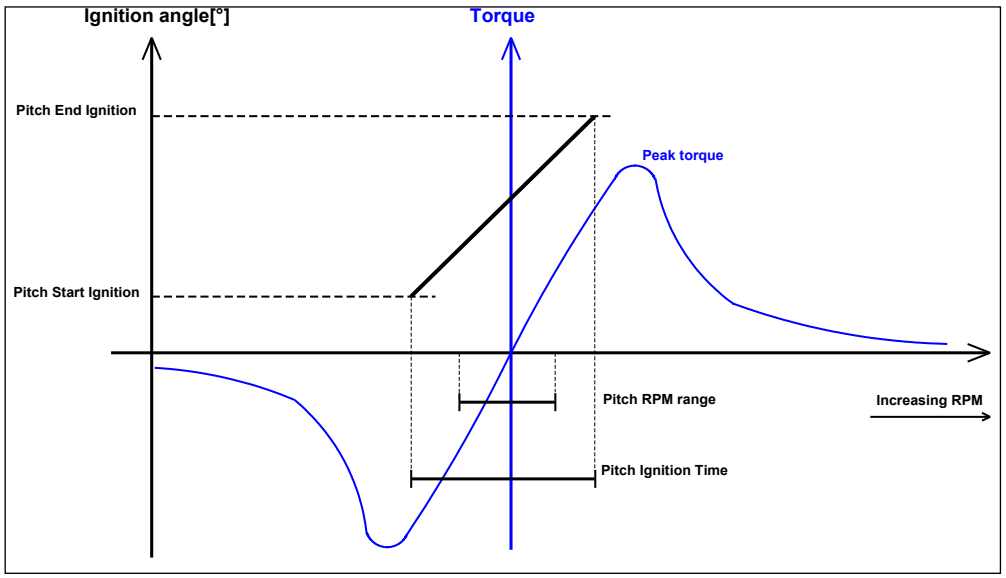
In Mode 3, the TCM-2 can be used for synchronising an asynchronous generator by simple CAN functions and controllable by simple adjustable parameters. The connection between the operational principle and parameters are illustrated in the following figure.

Figure 10 is describing the required communication signals between external controller and the TCM-2. The TCM-2 digital input and output can also be used for the bypass contact operation and feedback through the CAN interface.

Mode 3 function principles

In the following principles, the two functions available in mode 3 are described.

Pitch Ramp function – Pitch-controlled cut-in function

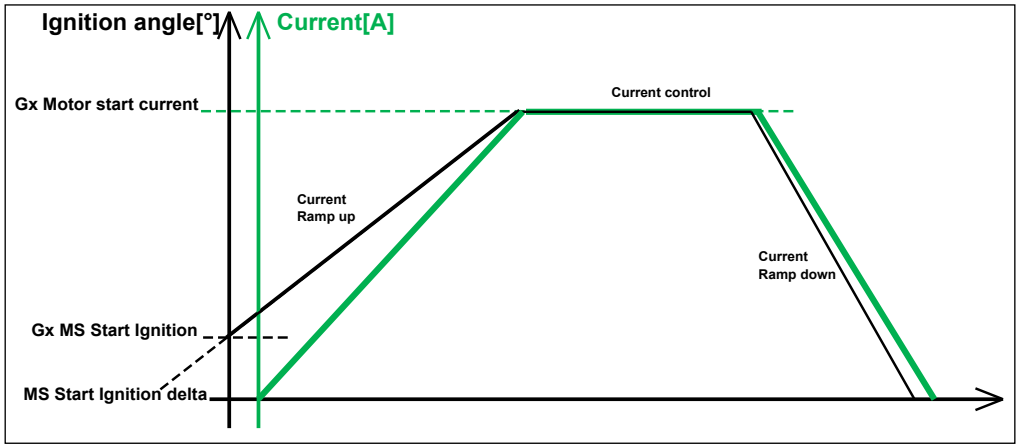


The function Pitch Ramp(15) is controlled by the parameters

Pitch RPM Range
Gx Pitch Ignition time
Gx Pitch Start Ignition
Gx Pitch End Ignition

By these parameters, the synchronising ramp can be adjusted according to the relevant generator and application.

Motor start function – current-controlled start function



The function Motor start (10) is controlled by the parameters

Gx Motor Start current
Gx MS Start Ignition
MS start Ignition Delta

CAN protocol

In mode 3, the external will use CAN messages to select the internal control function.

Please note, that the current CT information is entered correctly for using the current parameter information

Description of all telegrams supported in Mode 3

Received telegrams from external controller	
CAN ID	Description
0x400 + node ID	Function select PDO

Detailed description of each message sent from TCM-2

Detailed description of the function select message sent from external controller

ID 0x400 + node ID: Function select message

Data byte	Description	Type	Unit	Range
0	Function Index (L)	Word	Internal function	See table
1	Function Index (H)			
2	Function Data (G1/g2)	Byte	Generator	0 = not used 1 = G1 2 = g2 4..255 = not used
3	<reserved >	Byte		
4	<reserved>	Byte		
5	<reserved>	Byte		
6	<reserved>	Byte		
7	<reserved>	Byte		

The CAN auto function can be selected by using the following function indexes.

Function Index	Function Data	Function name	Description
15 (0x000F)	Generator selection	Pitch Ramp	Enable the automatic ramp function usable for pitch-regulated turbines or similar. The function is controlled by the ignition and timing parameters especially for mode 3
10 (0x000A)	Generator selection	Motor start	Enable the motor start current control function.
100 (0x0064)	Not used but use 0x00	State Ready	Interrupts any other current activities and forces the TCM-2 into ready state.
125 (0x007D)	Not used but use 0x00	Clear Error	Clear the error state and go to ready state. This function is used at power-up and if an internal error has been active and forced the TCM-2 out of an active state.

The general CAN information messages send from the TCM-2 is described in Chapter 6.

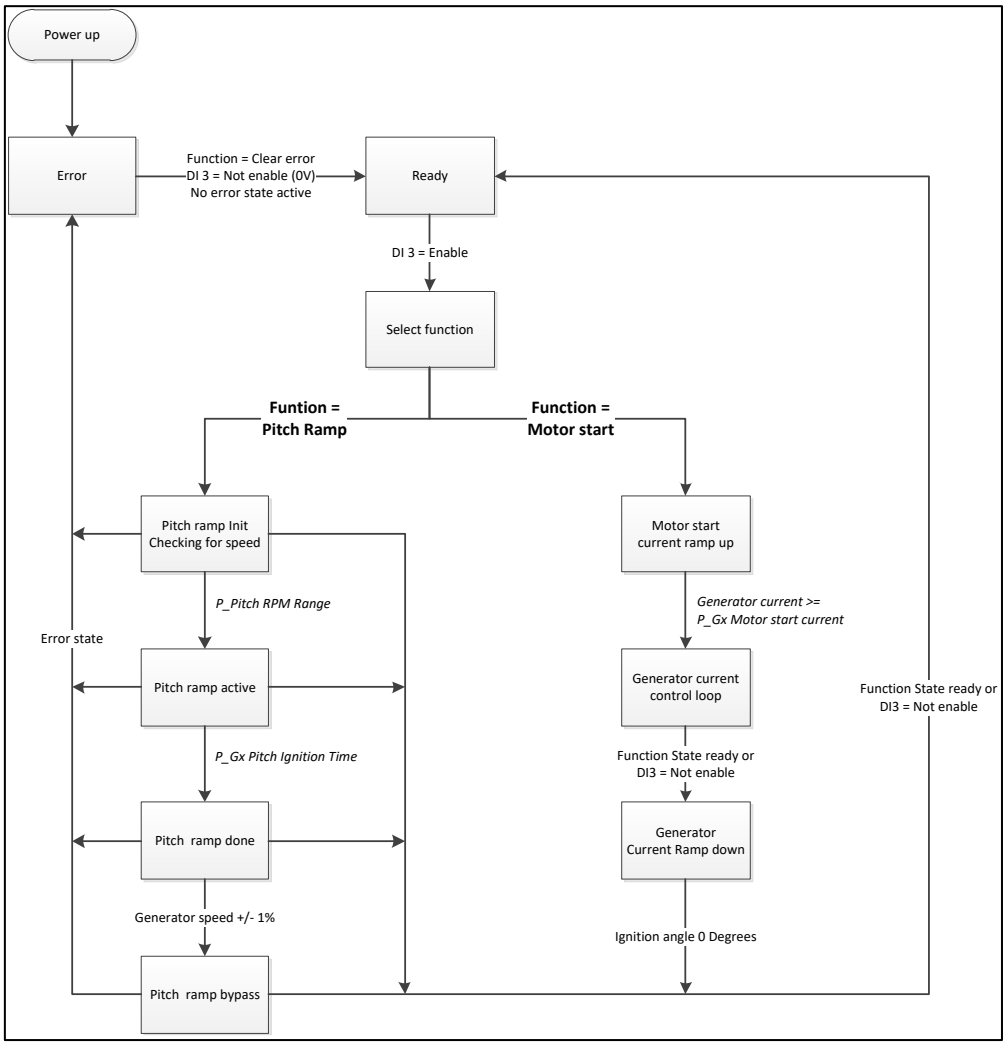


Figure 11 Mode 3 state principle diagram

When running the built-in functions, the external controller can follow each state of operation by the CAN measurement PDOs.

The states can be controlled by the above functions. As an example, when the pitch ramp function has been completed and the TCM-2 is in ignition ramp bypass state, the external controller should send the state ready function (100) to complete the synchronisation and return to the ready state.

At any time if the external controller sets the Enable signal DI 3 = 0 V, the TCM-2 will abort any ignition angle on the thyristor bridge and return to the ready state.

10. Generator coupling connections

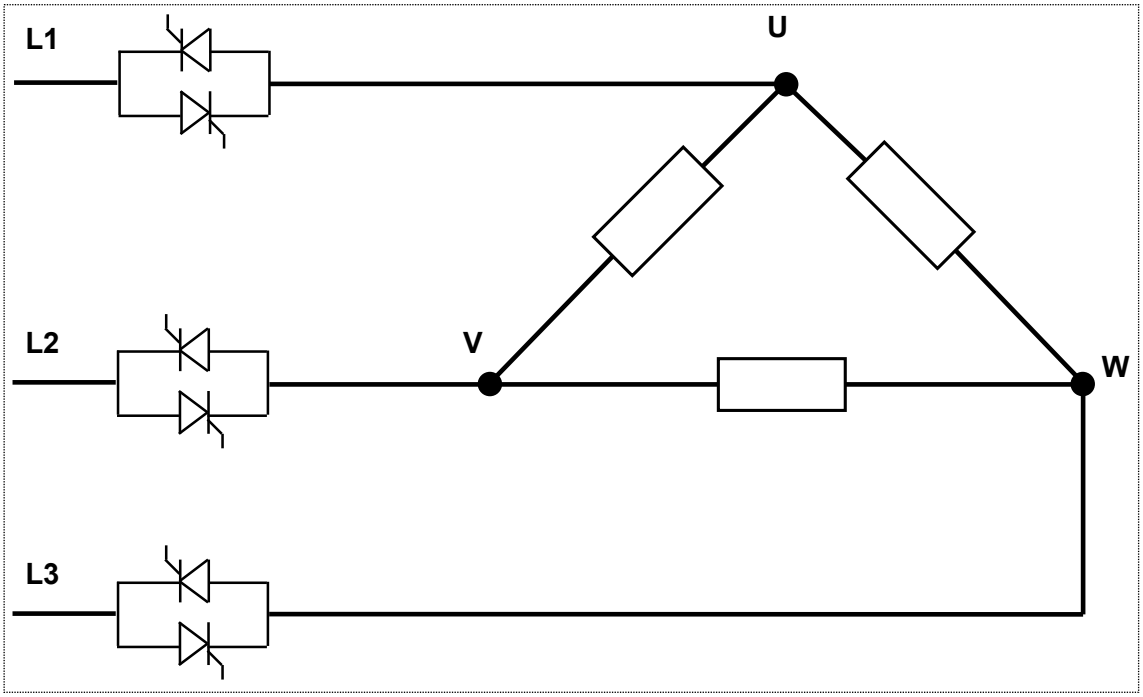
When installing the TCM-2, the connection of the generator to the grid is important to identify in order to set up the parameters correctly or when setting ignition angles in CAN control mode.

Two different ways of how to connect a 6-pulse thyristor bridge with a 3-phase asynchronous generator have been observed in the market for wind turbines with direct grid-connected asynchronous generator. They will be called "standard delta coupling" and "low-current delta coupling".

In the following, the coupling is described, and the ignition angles should be supplied to the TCM-2 by CAN interface to control the current flow. In Mode 2, the TCM-2 mode 1 settings must be adjusted according to the actual generator coupling method.

Standard delta coupling

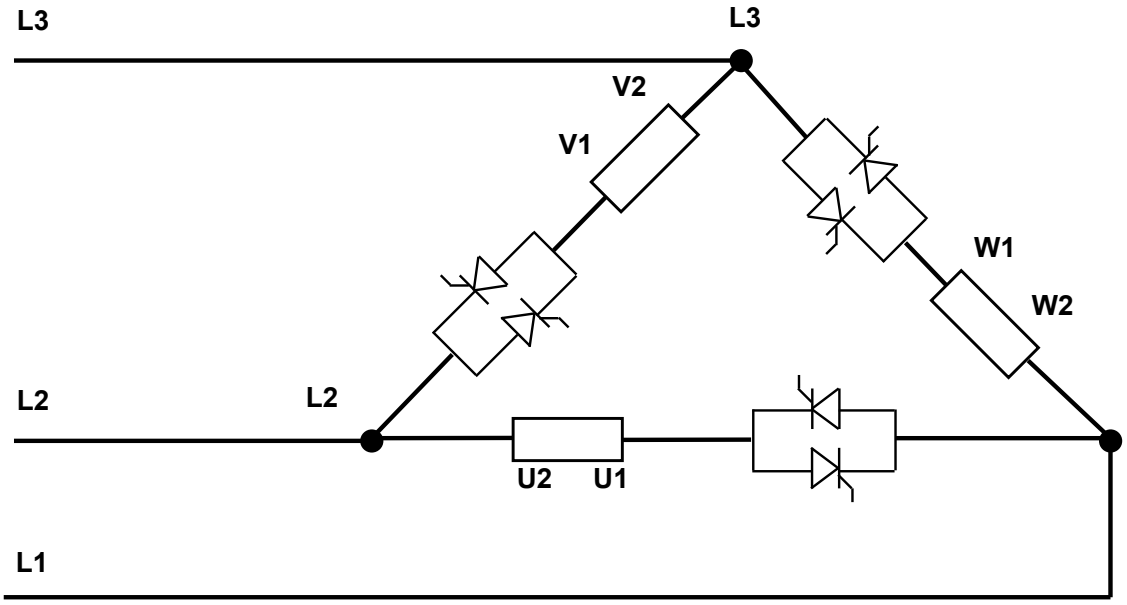
The "standard delta coupling" is shown in the diagram below:



Minimum ignition angle to start control of current flow is 60 deg.
Maximum possible ignition angle to fully open 180 deg.

Low current coupling type 1

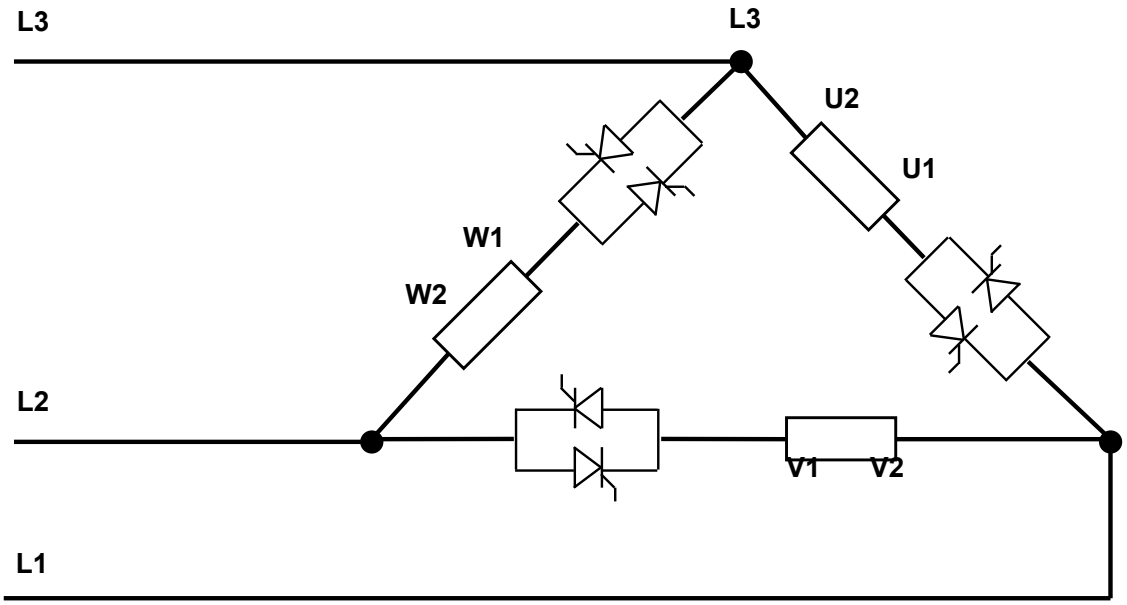
The "low current coupling" type 1 is shown in the diagram below. Note here that the thyristor pair is located in each coil of the generator, which is different than the "standard delta" coupling where the thyristors are mounted directly at the busbar.



Minimum ignition angle to control current flow 60 deg.
Maximum possible ignition angle to fully open 180 deg.

Low current coupling type 2

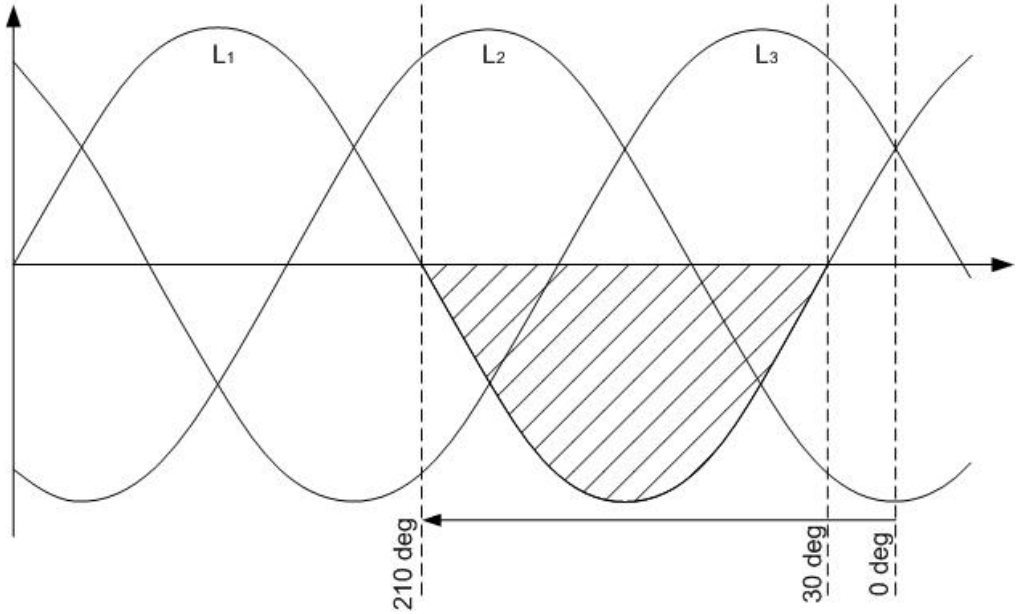
By changing U2 to L3, V2 to L1 and W2 to L2, another version 2 of this coupling can be realised, which has different ignition angles.



Minimum ignition angle to control current flow is 0 deg.
Maximum possible ignition angle to fully open 180 deg.

Ignition angle definition

The ignition angle for the TCM-2 is to be interpreted as in the below picture.



Note: The ignition angle is calculated from the crossing point of the individual phases. Thus seen from the phase to neutral, there is an offset of 30 degrees.

11. Detailed parameter description

This chapter includes a complete standard parameter list for setup. Therefore, this chapter is to be used for reference, when information about specific parameters is needed.

Parameter groups

Two groups of parameters are available. General settings which applies to both modes of operation and Mode 1 settings which applies to Mode 1 only.

Setup

Parameters must be set up in the HMI screen or by CAN interface as described in a previous chapter.

Parameter description

Name	ID(Hex)	Unit	Min.	Max.	Default	Description
General settings:						**These settings are mandatory to setup in both modes of operation**
Pulses per rev.	2000	int	1	12	1	Number of pulses on the generator shaft per revolution, given by the rpm sensor on the digital input 5
Mode	2001	enum	1	3	2	Selection between autonomous operation or direct control via CANbus Mode 1: Autonomous operation Mode 2: CANbus by external controller
Not used	-	-	-	-	-	-
CT Secondary current setting	2003	A	1	5	1	Either 1 A or 5 A secondary current on CT
Digital output 1	2004	enum	NPN	PNP	PNP	Signal level of the 6 digital outputs NPN : 0V = OFF, 24V = ON PNP : 24V = OFF, 0V = ON
Digital output 2	2005	enum	NPN	PNP	PNP	Signal level of the 6 digital outputs NPN : 0V = OFF, 24V = ON PNP : 24V = OFF, 0V = ON
Digital output 3	2006	enum	NPN	PNP	PNP	Signal level of the 6 digital outputs NPN : 0V = OFF, 24V = ON PNP : 24V = OFF, 0V = ON
Digital output 4	2007	enum	NPN	PNP	PNP	Signal level of the 6 digital outputs NPN : 0V = OFF, 24V = ON PNP : 24V = OFF, 0V = ON
Digital output 5	2008	enum	NPN	PNP	PNP	Signal level of the 6 digital outputs NPN : 0V = OFF, 24V = ON PNP : 24V = OFF, 0V = ON
Digital output 6	2009	enum	NPN	PNP	PNP	Signal level of the 6 digital outputs NPN : 0V = OFF, 24V = ON PNP : 24V = OFF, 0V = ON
CT Primary current setting	200A	A	1	5000	1000	Ratio (primary current/secondary current) of the current transformer, which is connected to the TCM-2 current measurement input in Mode 1
Log type	200B	enum	0	1	0	Decide "First" or "newest" log saved. 0: First log - 2 logs available 1: Newest log – 1 log available
Reserved	200C-					

	200E					
RPM Input Source	200F	enum	1	2	2	Select RPM signal from CANbus or from terminals. Only in Mode 3: CAN auto. 1: Terminal 2: CANbus

Name	ID(Hex)	Unit	Min.	Max.	Default	Description
Mode 1 settings:						
G1 start ignition	2010	deg	0	210	60.00	The value for the start ignition of the large generator. DEPENDS ON THE COUPLING. See more detailed description of different coupling forms under section 5.
G1 Sync ignition	2011	deg	0	210	100.00	The value for the ignition, where the generator is magnetised and running exactly at synchronous speed
G1 End ignition	2012	deg	0	210	105.00	The value of the ignition, where the large generator is connected and can be held stable.
G1 Bypass ignition	2013	deg	0	210	135.00	The value of the ignition, where the bypass contactor can be connected.
G1 Ignition offset	2014	%	0,01	20	3.00	Ignition offset to adjust the start time of the ignition ramp.
G1 Poles on large generator	2015	poles	2	16	4	Number of poles of the large generator.
Reserved	**2016-201F**					
G2 Start ignition	2020	deg	0	210	60.00	The value for the start ignition of the small generator. DEPENDS ON THE COUPLING.
G2 sync. ignition	2021	deg	0	210	100.00	The value of the ignition, where the small generator is connected and can be held stable.
G2 End ignition	2022	deg	0	210	105.00	The value of the ignition, where the small generator is connected and can be held stable.
G2 Bypass ignition	2023	deg	0	210	135.00	The value of the ignition, where the bypass contactor can be connected.
G2 Ignition offset	2024	%	0,01	20	3.00	Ignition offset to adjust the start time of the ignition ramp.
G2 Poles on small generator	2025	poles	2	16	4	Number of poles of the small generator.
G2 Over sync. ignition start	2026	deg	0,01	210	75.00	Sets the start ignition for an over-sync. cut-in on G2
G2Over sync. ignition delta	2027	deg/s	1	1000	70	Sets how fast the ramp is increased to the bypass ignition for an over-sync. cut-in on G2
Reserved	2028 – 202F					

Name	ID(Hex)	Unit	Min.	Max.	Default	Description
G1>G2 ignition start	2030	deg	0,01	210	100.00	Start ignition angle for the cut-down (G1->G2) procedure with the small generator
G1>G2 ignition delta	2031	deg/s	1	1000	100	Speed for the ramp up of the ignition under the first step of cut-down, until ignition reaches cut-down ignition limit 1
G1>G2 ignition limit 1	2032	deg	0,01	210	105.00	The ignition, which settles the current in the small generator during the second phase of cut-down (constant ignition phase)
G1>G2 ignition limit 2	2033	deg	0,01	210	95.00	The ignition value, which is applied at the end of phase 3 of a cut-down.
G1>G2 sync. limit 1	2034	%	100	1000	120	The speed factor of G2 where the ignition is starting to ramp down.
G1>G2 sync. limit 2	2035	%	100	1000	101	The speed factor for starting final bypass ramp to fully connect generator
Bypass ignition delta	2036	deg/s	1	1000	100	Settles the speed, how fast the final ramp under connection of either small or big generator is performed.
Reserved	2037					
I/U ratio	2038	A/V	1	500	10	Transfer function from the analogue 0-10V signal from the external controller to the current seen on the on the primary side. The function is depending on the primary CT parameter setting.
Reserved	**2038-203F**					
MS ignition delta	2040	deg/s	1	10000	30	Settles the speed, how fast the current during motor start is ramped up, valid for both generator stages
Reserved	2041 – 2042	-	-	-	-	-
G1 MS Start ignition	2043	deg	0,01	210	60.00	Start ignition angle for the motor start function on G1
G2 MS Start ignition	2044	Deg	0,01	210	60.00	Start ignition angle for the motor start function on G2
G1 Motor start current	2045	A	1	5000	200	The desired current on the Primary side of the CT for motor start with the large generator (G1). This parameter is used when the DI3 is used as control signal
G2 Motor start current	2046	A	1	5000	200	The desired current on the Primaryide of the CT for motor start with the small generator (G2). This parameter is used when the DI3 is used as control signal
Reserved	**2047-204A**	**-**	**-**	**-**	**-**	**-**
Can settings:						
RPDO1 Timeout Time	2050	ms	0	10000	0	Timeout between CAN messages on PDO1 (0x200 + NodeID) Resolution 10ms 0 = disables the timeout function
RPDO2 Timeout Time	2051	ms	0	10000	0	Timeout between CAN messages. on PDO2 (0x300 + NodeID) Resolution 10ms 0 = disables the timeout function
RPDO3 Timeout	2052	ms	0	1000	0	Timeout between CAN messages. on

Time				0		PDO3 (0x400 + NodeID) Resolution 10ms 0 = disables the timeout function
Reserved	**2053-2054**	**-**	**-**	**-**	**-**	**-**
CANopen NodeId	2055		1	127	8	CANopen NodeID

Name	ID(Hex)	Unit	Min.	Max.	Default	Description
Mode 3 settings:						
G1 Poles on generator	2070	poles	2	16	4	Number of poles of the small generator.
G2 Poles on generator	2071	poles	2	16	4	Number of poles of the small generator.
Reserved	**2072-2075**					
MS ignition delta	2076	deg/s	1	10000	30	Settles the speed, how fast the current during motor start is ramped up, valid for both generator stages
G1 MS Start ignition	2077	deg	0.01	210	70.00	Start ignition angle for the motor start function on G1
G2 MS Start ignition	2078	Deg	0.01	210	70.00	Start ignition angle for the motor start function on G2
G1 Motor start current	2079	A	1	5000	200	The desired current on the Primary side of the CT for motor start with the large generator (G1). This parameter is used when the DI3 is used as control signal
G2 Motor start current	207A	A	1	5000	200	The desired current on the Primaryide of the CT for motor start with the small generator (G2). This parameter is used when the DI3 is used as control signal
Reserved	**207B-207F**					
Pitch RPM range	2080	0.1%	0	100	5	Select RPM-range Allowed deviation from synchronous generator speed.
Reserved	**2081**					
G1 Pitch ignition time	2082	0.1 s	0.1	100	1.5	Time of Ramp on G1
G2 Pitch ignition time	2083	0.1 s	0.1	100	1.5	Time of Ramp on G2
G1 Pitch start ignition	2084	deg	0.01	210	1.00	Start ignition of Ramp on G1
G2 Pitch start ignition	2085	Deg	0.01	210	1.00	Start ignition of Ramp on G2
G1 Pitch end ignition	2086	Deg	0.01	210	210.00	End ignition of Ramp on G1
G2 Pitch end ignition	2087	deg	0.01	210	210.00	End ignition of Ramp on G2