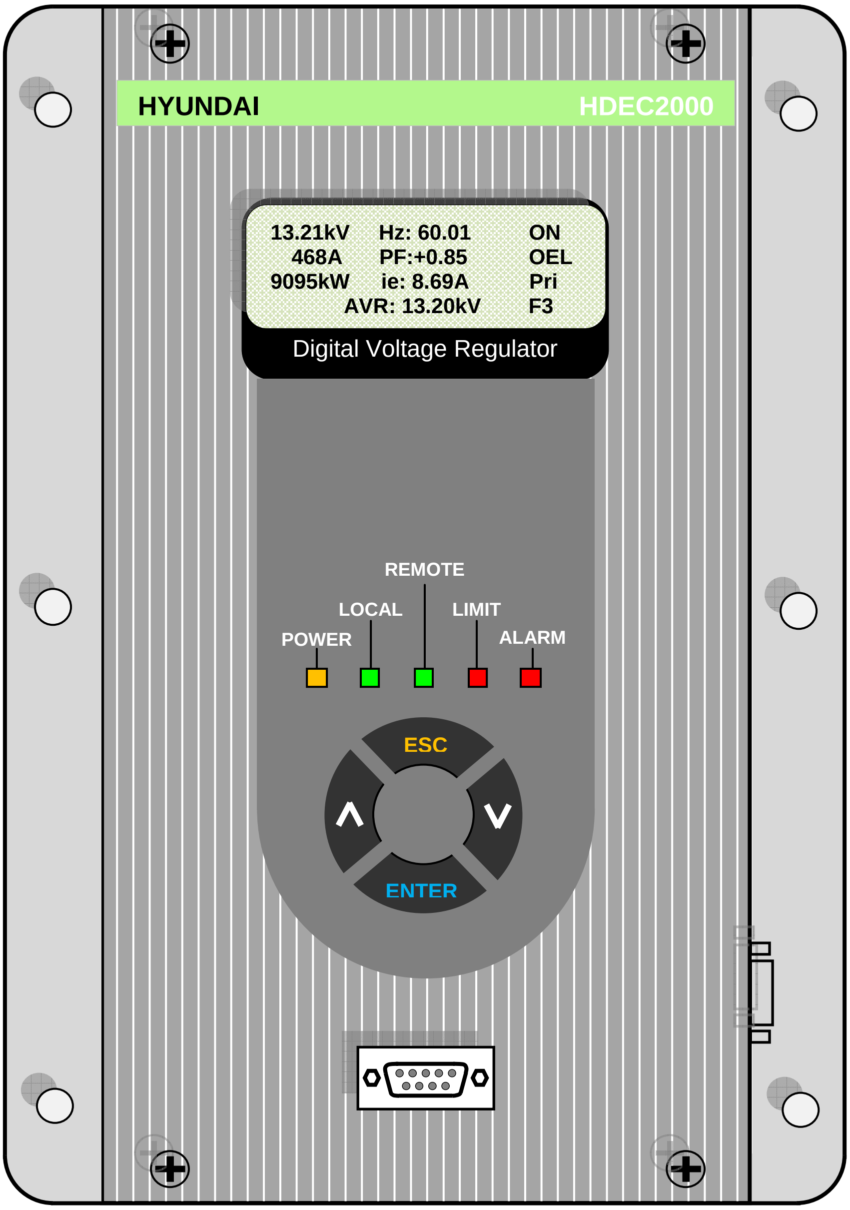
Digital Excitation Systems

HDEC 2000 User's Manual



Electro Electric Systems

We build a better future
HYUNDAI
HEAVY INDUSTRIES CO.,LTD.
www.hhi.co.kr

Important Notice

The examples and diagrams in this manual are included solely for illustrative purposes. Because of many variables and requirements associated with any particular installation, Hyundai Heavy Industries Co., Ltd cannot assume responsibility or liability for actual use based on the examples and diagrams.

Hyundai Heavy Industries Co., Ltd cannot accept any responsibility for damage incurred as a result of mishandling the equipment regardless of whether particular reference is made in this instructions or not.

The availability and design of all features and options are subject to modification without notice. Should further information be required, contact Hyundai Heavy Industries Co., Ltd.

Manufacturer’s Address
Electro Electric Systems, Hyundai Heavy Industries Co., Ltd
http://www.hyundai-elec.co.kr

Headquarters (Rotating Machinery Design Department):
#1, Jeonha-dong, Dong-gu, Ulsan, Korea
Telephone: +82 52 202 6612
Fax : +82 52 202 6995

Seoul Office (Rotating Machinery Sales Department):
Hyundai building, 140-2, Kye-dong, Chongro-gu, Seoul, Korea
Telephone: +82 2 746 7668
Fax : +82 2 746 7646

Service Inquiries: +82 52 202 6671

SAFETY PRECAUTION

GENERAL

Please read the following instructions given in this manual before installation, wiring, configuration and commissioning.

Please be advised regarding information, direction and etc before use. There are four different instructions explained in this manual regarding (danger), (caution), (important) and (note).

We use notes of safety considerations throughout this manual when necessary.

DANGER	This symbol indicates a danger resulting from mechanical forces or high voltage. If not avoided, either death or personal injuries will occur
CAUTION	This symbol indicates a dangerous situation. If not avoided, either personal injury or damage to the equipment will occur
IMPORTANT	This symbol indicates useful or critical information for successful application and understanding of the product
Note!	This symbol indicates useful information or tip for successful application

SAFETY INSTRUCTION

DANGER

- Before beginning any work, disconnect all power sources and verify that they are de-energized. Failure of these instructions may result in personal injury, death or equipment damage.
- This equipment must be grounded with no smaller than copper wire with $4mm^2$ cross section. The ground terminal is placed on the left side of the unit.
- This equipment operates with dangerous voltages. Never open any cover during operation. It can lead to death or injury to the persons.

CAUTION

- To avoid personal injury or equipment damage, only qualified personnel should install, wire, configure and commission for this equipment and its related components.
- Only specified size of cable and tools must be used for wiring and installation. If not, it causes damage to the equipment.
- Do not configure while the unit is in normal operate. It causes damage to the equipment or system.
- The excitation input voltage must be lower than the maximum permissible level. If not, it causes damage to the equipment.

IMPORTANT

- This manual covers the instruction of HDEC2000 unit for synchronous machine (generator and motor). However, the generator application may be used for most cases, so, many contents of this manual is expressed as the term of generator.
  Whenever the term generator is used, it is to be understood that it may be replaced by the term motor, if applicable. Likewise, whenever machine is used, it may be replaced by either generator or motor, if applicable.

DECLARATION OF CONFORMITY

We, the manufacturer,

HYUNDAI HEAVY INDUSTRIES CO., LTD
1, Jeonha-dong, Dong-gu, Ulsan, 682-792, Korea

declare under our sole responsibility that the following product;

Product: Digital Excitation Controller

Model: HDEC2000

to which this declaration relates is in conformity with the following EC directives and standards;

Applicable EC Directives:

Low Voltage Directive (2006/95/EC)

EMC Directive (2004/108/EC)

Applicable Standards:

EN 61010-1 (2001, Second edition)

EN 61000-6-2 (2005)

EN 61000-6-4 (2007)

Detailed specification of the test and declared product are shown in the following test reports;

Safety Test (according to LVD):

Test Report No.: 10-1333-0087

Issued Date: October 5, 2010

Test Laboratory: KTL (Korea Testing Laboratory)

EMC Test (according to EMCD):

Test Report No.: 10-2351-0076

Issued Date: June 23, 2010

Test Laboratory: KTL (Korea Testing Laboratory)

Place: Ulsan, Korea

Declared Date: November 15, 2010

Signature:

J.O. Kim / General Manager

Rotating Machinery Design Department, Electro Electric Systems

CONTENTS

SAFETY PRECAUTION

General 3
Safety Instruction 4

DECLARATION OF CONFORMITY 5

SECTION 1. GENERAL INFORMATION

Introduction 10
Features 10
System Description 12

SECTION 2. INSTALLATION AND HARDWARE

General 16
Mounting Requirements 16
Electrical Connections and Terminal Designation 18
Hardware Configuration 27

SECTION 3. FUNCTIONAL DESCRIPTION

Input and Output
- Digital Inputs 29
- Analog Input and Output 34
- Digital (Relay) Output 38
- Peripheral Device 39

Operational Function
- Regulation Mode and More 39
  - Controller and Control Gain 39
  - FCR Mode 40
  - AVR Mode 40
  - VAR Mode 40
  - PF Mode 40
  - Droop Compensation 41
  - Cross Current Compensation 41
  - Voltage Buildup 42
  - Ready Mode Function 42
  - Soft Start Function..43
  - Bump-Less Mode Transfer (Internal Tracking) 44

Limitation Functions 45
Generator Capability Curve 45
Under Frequency Limiter 45
Over Excitation Limiter 46
Under Excitation Limiter 48
Stator Current Limiter 49
Protective Function 50
Generator Over Voltage 51
Generator Under Voltage 51
Generator Over Current 51
Exciter Over Current 53
Loss of Field 53
Loss of Sensing 53
Loss of Power 55
Diode Fault Monitor 55
Output Short Circuit 56
Mode Mismatch 56

SECTION 4. CONFIGURATION
Introduction 58
Configuration Procedure 58
Software Installation and Communication 59
Setup 60
Configuration Tab 61
Generator Tab 63
AVR/ FCR Tab 65
VAR/ PF Tab 66
Startup/ Auxiliary Tab 67
Gain Tab 68
Digital IO Tab 74
Protection Tab 75
Limiter Tab 77
Monitoring and Control 78
Menu Navigation 81

SECTION 5. USER INTERFACE
Introduction 84
Operation 85
Mode of Operation....86

Functions of each Component 86
Display Pages of Monitor Mode 87
Setup Mode Functions 89

SECTION 6. COMMISSIONING

Introduction 92
Commissioning 92

SECTION 7. TROUBLE SHOOTING

Introduction 96
Trouble Shooting 96

Appendix A. Configuration Parameter 99
Appendix B. Mathematical Model 106
Appendix C. Specification 115

Revision History 120

This page intentionally left blank.

SECTION 1. GENERAL INFORMATION

INTRODUCTION

HDEC 2000 is an automatic voltage regulator for excitation control system of synchronous machine. The unit is designed on the basis of Hyundai's long period (more than 30 years) experience in design, manufacturing and testing of synchronous machine together with newest digital signal process techniques.

Besides automatic voltage regulation function, all regulation functions, limiting functions and most of protective functions for excitation system enable the HDEC 2000 unit to be used in a wide range of applications. All of these features are achieved by the combination of reliable hardware design and the optimized software technology.

FEATURES

HDEC 2000 unit has the following features and capabilities.

Control and Regulation Functions

- Four(4) excitation regulation modes
  - Automatic voltage regulation mode (AVR mode)
  - Manual field current regulation mode (FCR mode)
  - Reactive power regulation mode (VAR mode)
  - Power factor regulation mode (PF mode)
- Hardware voltage buildup function with no external control power
- Ready mode function for shunt power application with no control power.
- Soft start voltage buildup in AVR and FCR mode
- Secondary soft start function for non-standard application
- Over excitation limiting (OEL) and under excitation limiting (UEL) in AVR, VAR/PF regulation modes
- On-line and off-line OEL selection depending on generator current
- Stator current limiting (SCL) in AVR, VAR/PF regulation modes
- Standard mode and maximum flux mode under frequency (V/F) limiting
- Bump-less operating mode transfer (internal tracking)
- Auto-tracking between two HDEC 2000 units (master, backup redundant configuration)
  - Not activated now
- Parallel operation with reactive droop compensation or cross-current compensation

Protective Functions

- Generator over voltage
- Generator under voltage
- Generator over current (constant time and inverse time)
- Exciter over current (constant time and inverse time)
- Loss of filed (under excitation)
- Loss of sensing

- Loss of power
- Diode fault monitor for open and short rotating diode (DFM)
- Short circuit protection of excitation output (supported by hardware)
- Mode mismatch

Input and Output Interfaces

- No need external control power input basically
- Excitation power input (AC or DC)
- Single phase or three phase true rms generator voltage sensing
- Single phase generator current sensing (1 or 5 amperes nominal)
- Single phase 1A cross current loop input
  - No need additional (external) burden resistor and circuit breaker information
- Analog inputs (+/-10Vdc, 4 to 20mAdc or other standard signal) for remote control or PSS
- Seven(7) digital inputs (fixed function)
- Three(3) programmable digital inputs

- PWM excitation output power (rated 15A@60deg.C)
- Three(3) programmable relay outputs
- One(1) watchdog relay output

Monitoring Parameters via Front Panel Display

- Generator voltage
- Generator current and CCC loop current
- Active power
- Frequency
- Power factor and CCC loop power factor
- Excitation current and voltage
- DC link voltage and PWM duty
- Auxiliary analogue input voltage
- Open and short circuit diode ripple

- Excitation on/off information
- Operational limitation messages
- Master, backup (primary, secondary) unit condition
- Active operating mode and setpoint of active operating mode
- All fault conditions
- Firmware version number

Monitoring Item via Front Panel LED

- Processor on/off (controller on/off)
- Local and remote control mode
- Setpoint limitation and operational limiter information

- Alarm/Fault conditions

Communication Port

- RS-232 port for factory setup and site configuration
- CAN port for redundant system (not supported now)
- RS-485 port for remote access (read only now)

Setup Software Capability

- Setup parameter configuration
- Remote control
- Estimation of PID control gains for all regulation and limitation mode
- Real time monitoring

SYSTEM DESCRIPTION

The key function of HDEC2000 unit is the automatic voltage regulation of synchronous generator through excitation current control by means of PID (proportional, integral, derivative) control algorithm. To perform it, the unit provides control software and some different kinds of hardware devices such as PWM IGBT stage, DIOs, measuring devices (AIs), and communication interfaces etc, and the unit also provides most of functions required by user's application. Simplified Overall IO and internal architecture of HDEC2000 unit are shown in Figure 1-1.

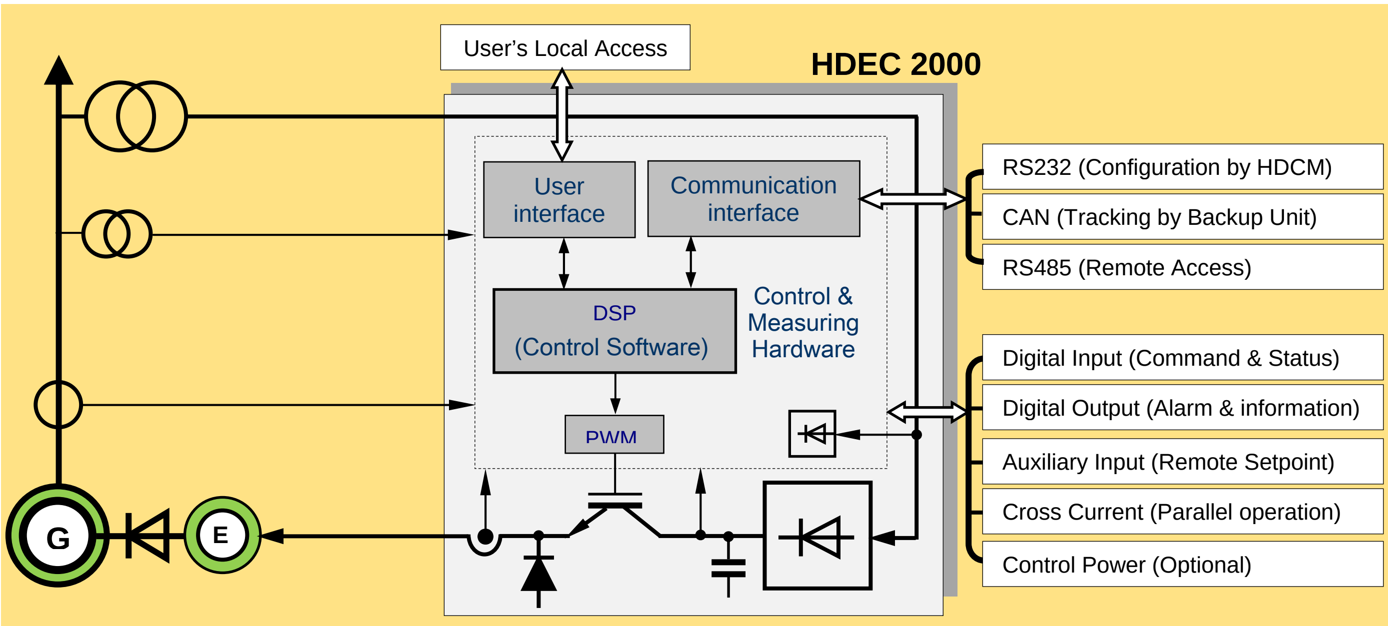


Figure 1-1 Simplified Overall IO and internal architecture of HDEC2000

Control Software and Function Blocks

Control Software containing function blocks is the brain or the heart of HDEC2000 unit. The software controls all of hardware which performs its own task of self diagnosis, measurement, regulation, limitation function, protective function, monitoring and communication. Control software is an executable codes set and stored in nonvolatile Flash memory.

The function blocks especially perform major regulation functions and limitation functions, and a part of control software. The most of function blocks are designed based on excitation system models of IEEE421.5 standard.

Excitation Power Flow

Excitation input power is normally supplied from the excitation transformer connected with generator output terminals or supplied from a permanent magnet generator (PMG). Some case, excitation input power may be supplied from external utility. Excitation output power of HDEC2000 unit is supplied to excitation winding of main machine or exciter machine after rectification and smoothing process through power module (switching IGBT) controlled by regulation output signal (PWM duty) of software function block of HDEC2000 unit.

Control Power

No external control power is normally required for HDEC2000 unit since the control power is internally supplied from excitation input power. For few special application, either ac or dc power source may be supplied externally. Control power is used as driving power of each component in the HDEC2000 unit. See Section 3 (Functional Description) and Appendix C (Specification) for more detailed information.

Sensing Input and Auxiliary Input

The voltage and current sensing signals for HDEC2000 unit are measured from sensing transformer installed on generator or generator external cubicle. Both of single phase or three phase voltage sensing configuration is supported by HDEC2000 unit. In case of current sensing system, single phase sensing is available and cross current loop sensing is also available. Excitation voltage and excitation current signals are sensed by measuring device installed internally.

For remote control application by analogue signal, +/-10Vdc, 4 …20mA or other standard signal is available and the HDEC200 unit also provides the control capability by the analog signal.

Digital Input and Output

Most of control Tasks such as excitation on/off, Auto/Manual and Setpoint Adjust are achieved via digital input signal. The HDEC2000 unit provides seven digital inputs for predefined functions and three digital inputs for programmable functions. Digital inputs can be controlled with dry contactor or PLC open collector signal. The HDEC2000 unit provides three programmable output relays and one watchdog relay also.

Communications

Three communication ports are provided for initial configuration in the factory (or commissioning in site), for data exchange between HDEC2000 units for redundant system and for remote access. The communication ports consist of RS232 (COM0), CAN (COM1) and RS485 (COM2) ports.

User Interface

The HDEC2000 unit provides three kinds of user interface devices which consist of front panel LCD display, LED lamps and key pad (buttons). Most of operating information such as analogue signals, limitation information and fault events are displayed on the LCD display panel. And the unit also provides the capability for configuration of important parameters and some useful operational functions.

Configuration and monitoring Software

The Configuration and monitoring software for HDEC2000 unit called HDCM is connected through RS232 communication port on the front panel. The HDCM software provides very useful functions such as parameter configuration, setpoint adjustment, control gain estimation and real time measurement for factory setup and site commissioning.

This page intentionally left blank.

SECTION 2. INSTALLATION AND HARDWARE

GENERAL

This section mainly describes mounting requirement and electrical connection contains hardware configuration.

The Unit should be unpacked carefully by using of suitable tools without the use of force and the unit should be inspected visually to check any damage caused during transport.
If any damage is found after unpacking, the complaints for defects resulting from inappropriate transport are to be addressed immediately to the receiving station or the last carrier.

If the unit is not installed immediately, the unit must be stored at indoor areas which are dry and dust-free environment.

! CAUTION	**The unit is visible damaged. The safe operation is not possible. The unit must not be installed.**

MOUNTING REQUIREMENTS

The unit is designed for rack mounting or wall mounting. The unit is installed in mounting place by means of six mounting holes and screws.

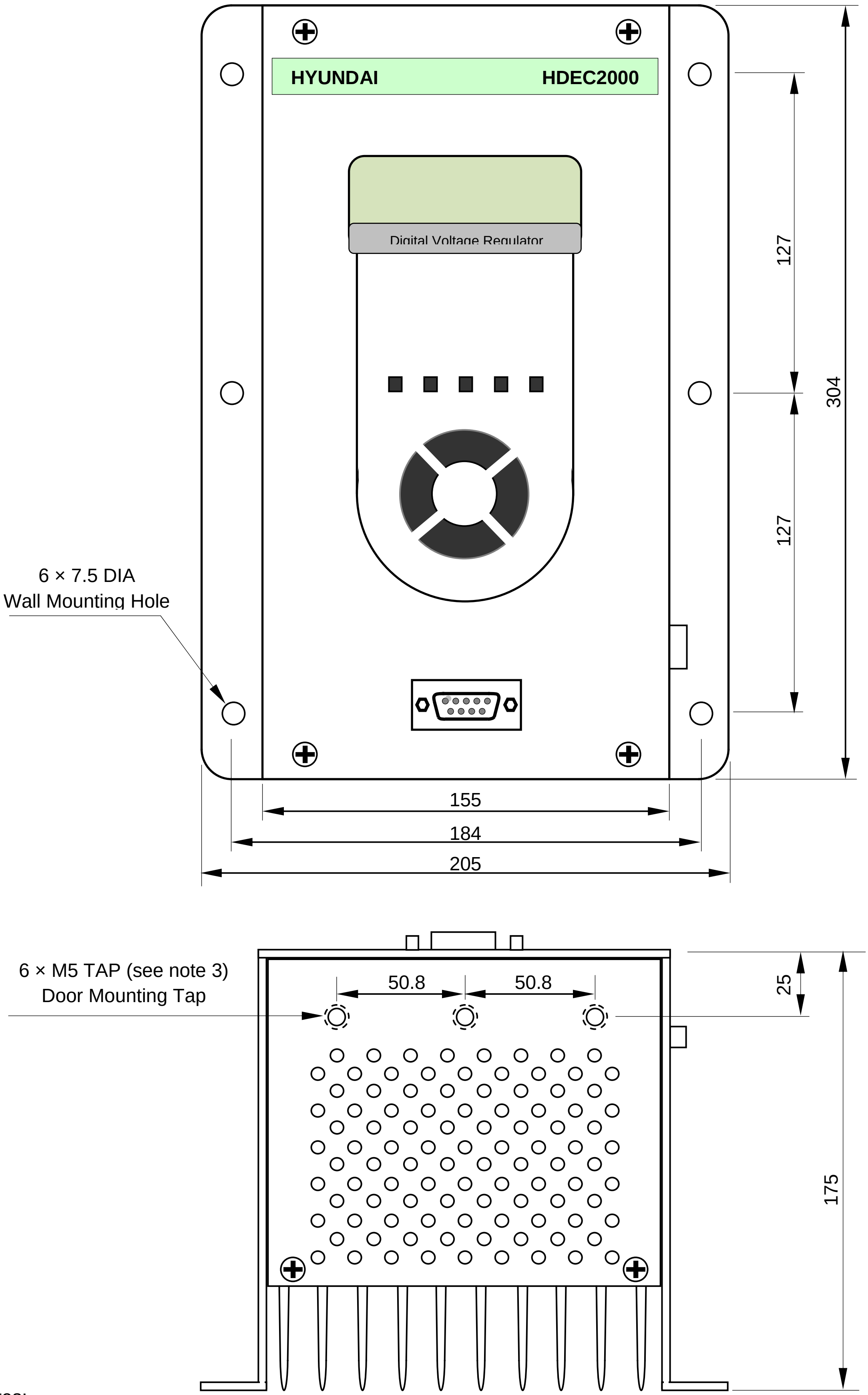
The unit must be installed with the satisfaction of following requirements for safety operation.

- The unit must be installed at indoor areas which are dry and dust-free environment.
- The ambient temperature of installation site must not be exceeded to specification requirement.
- The unit must be mounted vertically for optimum cooling.
- Minimum 100mm free spaces of top and bottom plane are required for enough cooling.
- Minimum 80mm free spaces of left and right plane are required for enough cooling.
- Especially, most of terminal blocks are located on the left plane, wider free spaces must be considered for the handling of connection tools.

Note!
When wall mounting method is adopted, If HDEC2000 unit is installed on the limited area or if security of working space is difficult, the HDEC2000 unit may be mounted on left plane of the cubicle. It is helper to secure handling space for working tool.

Alternative, the door mounting method may be adopted by using of suitable bracket.

The outline dimensions for installation are shown in Figure 2-1.



Notes:
1. Weight = 4.5 kg
2. Dimensions are in mm
3. The earlier version (hardware) does not provide the door mounting taps in bottom and top plane.

Figure 2-3 Outline Dimensions (Front and Bottom View)

ELECTRICAL CONNECTIONS and TERMINAL DESIGNATION

The HDEC2000 unit provides many kinds of functions. In case of standard application, some or fewer functions may be used only, so all input and output terminals may not be used. Electrical connection is depending on system design and application.

Incorrect wiring may result damage to HDEC 2000 unit and system. Wiring must be carefully performed by qualified personnel.

Even though shield cable using is not forced for all connections, we recommend that user may use shield cables for all connections to preventing troubles caused by electromagnetic and electrical noise.

Specified shield cable must be used and shield wire must be connected with its own ground terminal for especially designed signal.

Connections between shield wire and protective earth are depending on policy of signal ground design. User should follow specified connection guides existed for especially designed signal.

Connections for Communication

RS232 port (Front) connection

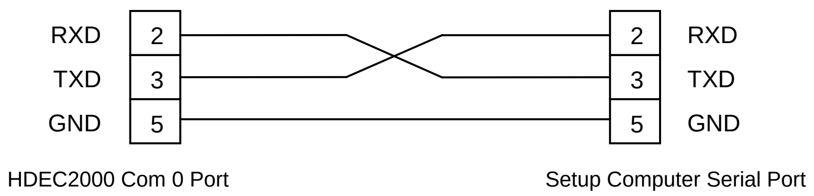


Figure 2-2 Front Panel Com-0 Port Cable Connection

The HDEC2000 unit is connected with the configuration device (setup computer) via RS232 (COM0) serial port (D-sub connector) on the bottom side of front panel. The RS232 port is only used for factory setup and commissioning purpose. RS232-USB converter may be used if no serial port is present in user’s computer. Wiring diagram for COM0 port is shown in Figure 2-2. For more information, see section 4 (Configuration).

CAN port (Right panel) connection

The HDEC2000 unit is connected with other HDEC2000 unit via CAN (COM1) port (D-sub connector) on the bottom side of right panel. The COM1 communication port provides data exchange between two HDEC2000 units for redundant configuration. The Function for redundant configuration is not supported now. Signal assignment for each pin of COM1 connector is planned later.

Connections for External devices (Left panel Connection)

All of the terminal blocks are on the left plane, and all connections with external system are connected on the left panel. Applicable kinds of cable and cross sections are listed in Table 2-1 to Table 2-5.

Note!

Two (or one) cross sections for connection cables are listed in each Table (Table 2-1 to Table 2-5). Two numbers in the cross section column mean the useable cross section range. First number indicates the minimum cross section and bottom number indicates the maximum cross section. **However, Accepted cross section of connecting cable is depending on the shape, straight length and the diameter of used connection ferrule.**

CAUTION

We strongly recommend that only one cable may be connected with one terminal, except COM2 (RS485) shield wire terminal. Even though, not recommended, If user wants to connect two cables with same terminal, the inserting depth of ferrules, connection looseness and the accepted cross sectional area of terminal should be considered.

Auxiliary analogue input

Auxiliary input signal provides for remote control of generator voltage or other parameters via analogue signal. The permissible input range for current terminal is 4 …20mAdc or 0 …20mAdc, and the permissible input range of voltage terminal is +/-10Vdc or 0 …10Vdc. The shielded cable must be used, and shield wire is connected on A3 (Labeled GND) terminal, but shield wire is not connected with protective earth.

Table 2-1 Designation of Analogue Input Terminal Block

Block	Number(Label)	Cross section	Function Description and Remark
A	A1(I+)	$0.75mm^2$ $1.5mm^2$	Auxiliary analogue current positive
	A2(I-)		Auxiliary analogue current negative
	A3(GND)		Auxiliary analogue shield
	A4(V+)		Auxiliary analogue voltage positive
	A5(V-)		Auxiliary analogue voltage negative
	A6(E1)	$1.0mm^2$ $1.5mm^2$	Phase A generator voltage sensing
	A7(E2)		Phase B generator voltage sensing (omitted for 1-phase sensing)
	A8(E3)		Phase C generator voltage sensing
	A9(CTC 1AMP)	$1.5mm^2$ $2.5mm^2$	Phase B Cross current
	A10(CTC COM)		Phase B Cross current common
B	B1(CTB 1AMP)	$2.5mm^2$ $4.0mm^2$	1A phase B generator current sensing
	B2(CTB 5AMP)		5A phase B generator current sensing ($4.0mm^2$ is recommended)
	B3(CTB COM)		Phase B current sensing common

Notes for cross sectional area of CT cables: See Figure 2-3 and Figure 2-4 for more information.

1) Between cross-current CT (or generator B-phase CT) and user supplied terminal block: 2.5 …$4.0mm^2$

2) CCC loop wiring (interconnection cable between cubicle to cubicle): $4.0mm^2$

3) Between HDEC2000 unit and user supplied terminal block:

- Only one CT (secondary 1Aac) is used for Droop and CCC: 1.5 …2.5 mm^2
- Two CTs are used independently: 2.5 …$4.0mm^2$ for B-phase CT, 1.5 …2.5 mm^2 for CCC CT
- If CCC function is used, this cable should be as shorter as possible.

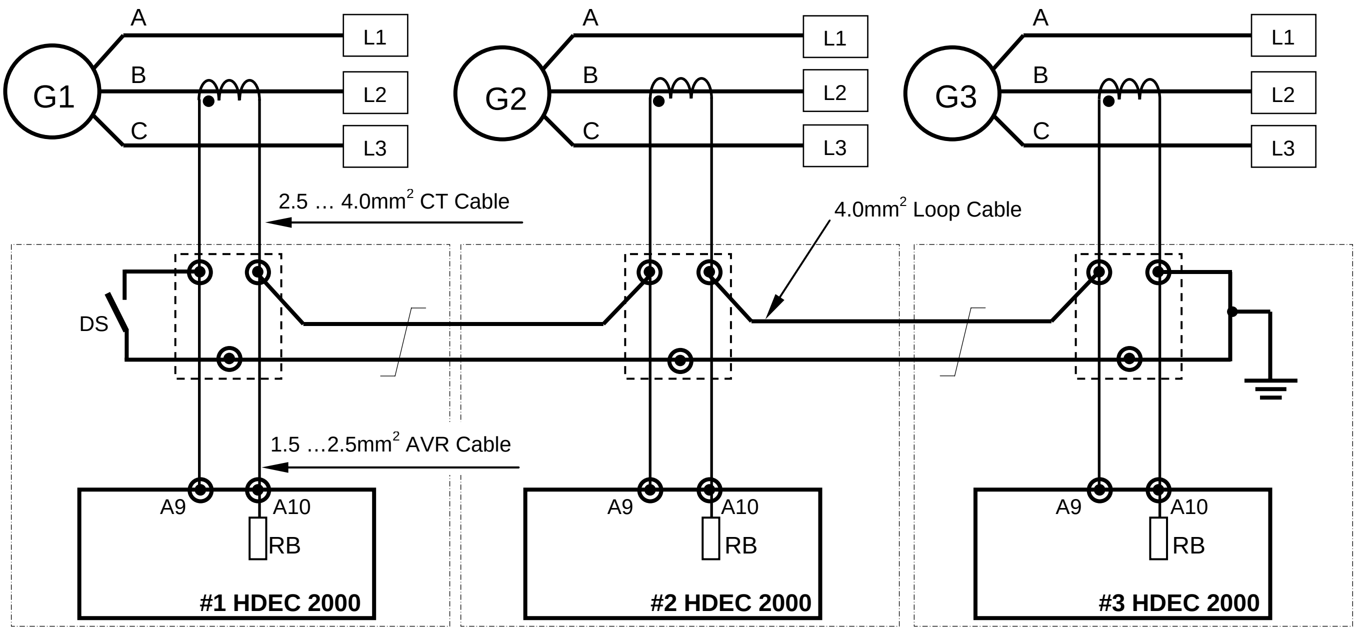
Generator voltage sensing Input

The HDEC2000 unit supports both single-phase and three-phase voltage sensing system. Three phase sensing cables of A, B, C phase are connected on A6, A7, A8 (Labeled E1, E2, E3) in consecutive order. In case of single phase sensing system, A6, A8 (Labeled E1, E3) terminals are used for A-phase and C-phase, respectively.

Generator current sensing Input

The HDEC2000 unit provides two kinds of current input terminals. Both are connected with current transformers installed on generator B-phase.

The first one is provided for parallel operation by mean of reactive droop compensation. And the accepted input current is either 1Aac or 5Aac. The B1 (Labeled 1AMP) terminal is used for 1Aac CT input, the B2 (Labeled 5AMP) terminal is used for 5Aac CT input and the B3 (Labeled COM) terminal is commonly used for both current range.



Notes:

1) Only one point ground is accepted if CCC circuit is grounded.
2) RB: internal burden resistor of HDEC2000 unit for CCC function
3) DS: Optional CCC Disable Switch (CCC function is disabled if this switch is opened)
4) Additional auxiliary contact of generator circuit breaker is not required.

Figure 2-3 Basic Circuit for CCC (*Cubicle Installation, CCC Function Only****)***

The second one is provided for parallel operation by mean of reactive differential compensation (cross current compensation, normally called CCC). And the accepted input current is maximum 1Aac. The terminals A9 and A10 (Labeled 1AMP, COM) are used.

Especially, the cross section of cables (interconnection cables between user supplied terminal blocks of each cubicle) for loop wiring should be as large as possible for best accuracy of load sharing. Basic circuit for CCC is shown in Figure 2-3 for cross current compensation.

If the both input current of reactive droop compensation and cross current compensation are designed with same 1Aac, only one CT may be used for both reactive droop compensation and cross current compensation. Figure 2-4 shows typical wiring diagram for CCC with single and two CT(s) respectively.

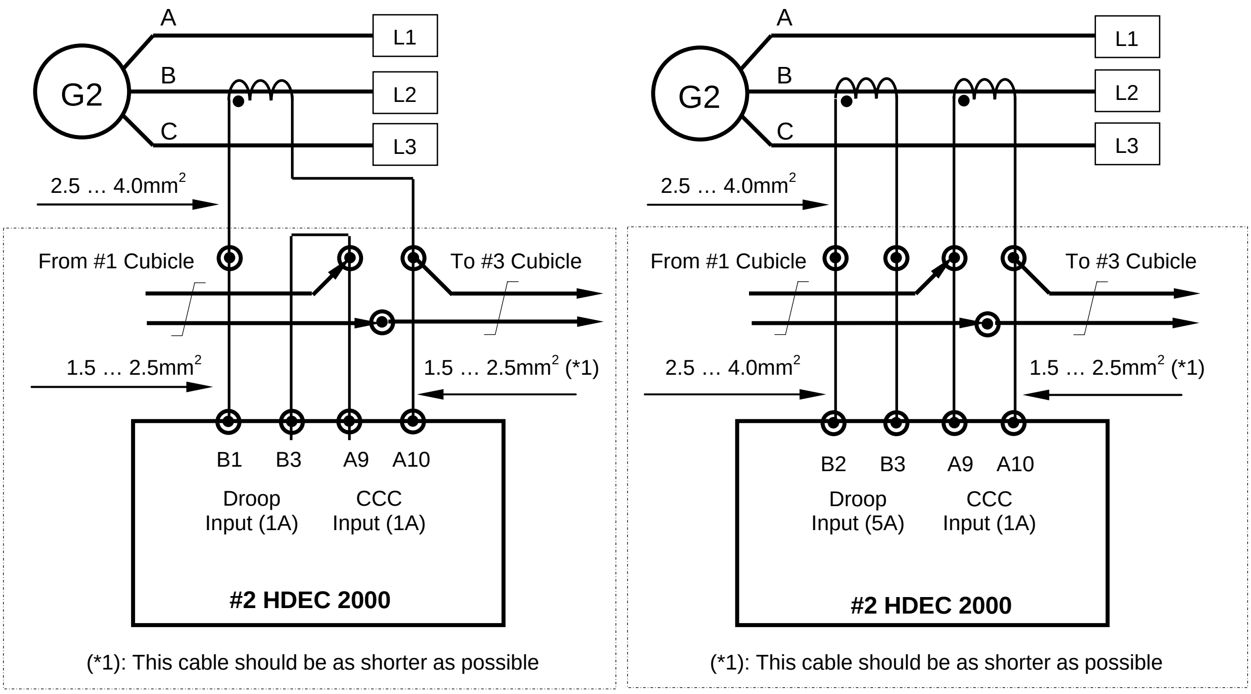


Figure 2-4 Typical Wiring Diagram for Droop and CCC *(Left: Single 1A CT, Right: 5A CT for droop and 1A CT for CCC)*

Digital input (Command and Status) and Digital (Relay) output

The HDEC2000 unit provides seven digital inputs for predefined functions and three digital inputs for programmable functions. And the unit also provides three programmable output relays and one watchdog relay.

The information for terminal designation of digital input is shown in Table2-2, and information for terminal designation of output relays is shown in Table 2-3. For more information, see section 3 (Functional Description).

Table 2-2 Designation of Digital Input Terminal Block

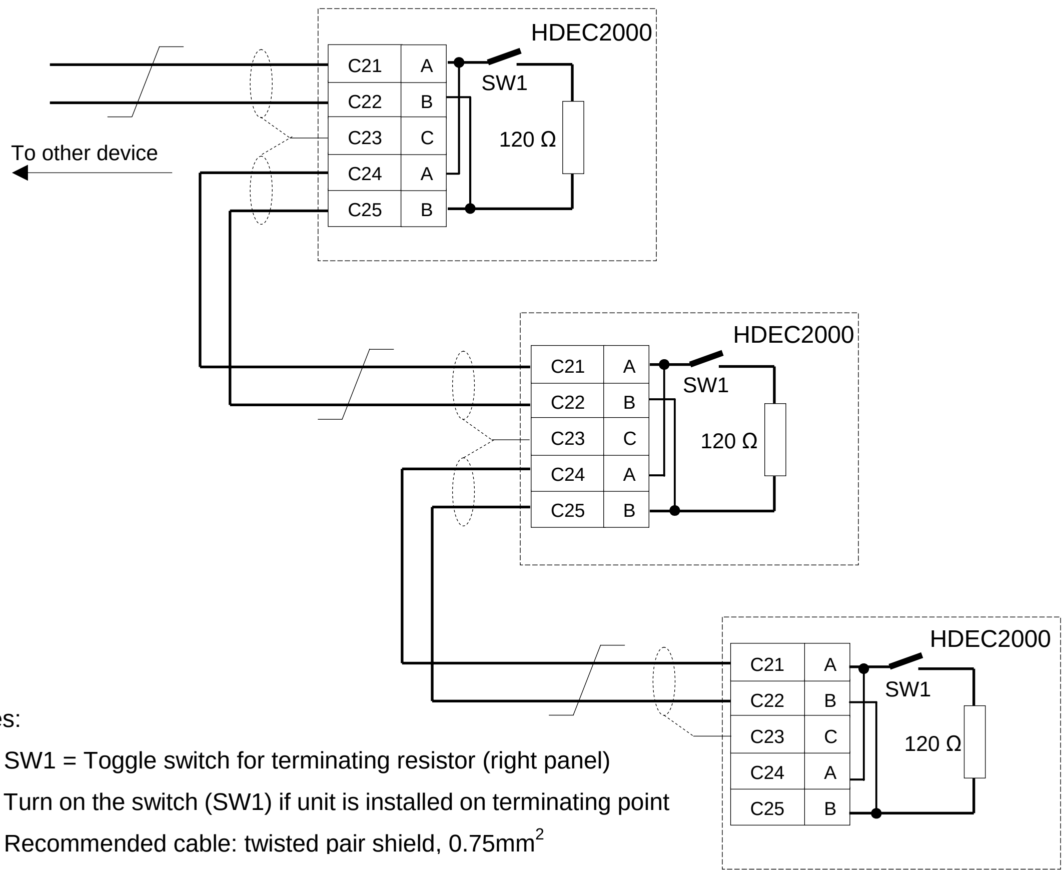
Block	Number(Label)	Cross section	Function Description and Remark
C	C1(Stop/Start)	$0.75mm^2$ $1.5mm^2$	Excitation on command
	C2(Auto/Manual)		Manual select command
	C3(RAISE)		Setpoint raise command (Momentary contactor)
	C3(LOWER)		Setpoint lower command (Momentary contactor)
	C5(GCB)		Grid circuit breaker status (Normally opened auxiliary contact)
	C6(MCB)		Machine circuit breaker status (Normally opened auxiliary contact)
	C7(AREST)		Alarm reset command
	C8(PROG-1)		Programmable digital input #1

Block	Number(Label)	Cross section	Function Description and Remark
	C9(PROG-2)		Programmable digital input #2
	C10(PROG-3)		Programmable digital input #3
	C11(COM)		Digital input common,
	C12(COM)		(C11 and C12 terminal blocks are internally jumped together)

Table 2-3 Designation of Digital (Relay) Output Terminal Block

Block	Number(Label)	Cross section	Function Description and Remark
C	C13(RLY-1)		Programmable output relay #1
	C14(RLY-1)		
	C15(RLY-1)		Programmable output relay #2
	C16(RLY-2)	$0.75mm^2$	
	C17(RLY-2)	$1.5mm^2$	Programmable output relay #3
	C18(RLY-3)		
	C19(WTCHD)		Watchdog relay output
	C20(WTCHD)		

RS485 communication



Notes:

1) SW1 = Toggle switch for terminating resistor (right panel)
2) Turn on the switch (SW1) if unit is installed on terminating point
3) Recommended cable: twisted pair shield, $0.75mm^2$

Figure 2-5 Typical RS485 Wiring Diagram

The RS485 port provides for remote access via MODBUS™ protocol. The shielded twist pair cable must be used for connections between HDEC2000 units and other communication devices. Both shielded wires of communication link cables must be connected on C23 (Labeled C) terminal together and not connected to protective earth directly. Terminal designation is shown in Table 2-4 and typical wiring diagram is shown in Figure 2-5.

If the HDEC2000 unit is installed on the end point of RS485 connections, the toggle switch (SW1) for terminating resistor may be turned on (closed). In order to turn on the toggle switch for terminating resistor, push up the lever of the swith-1 (SW1) installed on right panel. If the terminating resistor of other communication device installed on the opposite end RS485 connections is not matched with HDEC2000 unit, then open the switch, and install the new terminating resistor on the C24, C25 terminals (Labeled A, C). For more information of remote access, see separated MODBUS communication manual.

Table 2-4 RS485 Designation of Communication Terminal Block

Block	Number(Label)	Cross section	Function Description and Remark
C	C21(A)	$0.75mm^2$ $1.5mm^2$	RS 485 data line A
	C22(B)		RS 485 data line B
	C23(C)		RS 485 shield ground
	C24(A)		Same as E21 terminal
	C25(B)		Same as E22 terminal

Control power

No external control power is required in most application for HDEC2000 unit. If the HDEC2000 unit requires the external control power, applicable cables and terminals are followed referring to Table2-5. For more information about the kind(s) of external sources and range, see Appendix C (Specification).

IMPORTANT	**In case of shunt power application, if the residual voltage is too low (e.g. lower than 6Vac when measured at excitation input terminals), the external control power must be supplied for voltage buildup. The pre-excitation power may be supplied alternative.**

Excitation power Input and Output

Three kinds of Excitation input power (Shunt, PMG and external Utility) are available. In case of three phase source, all three terminals E1, E2, E3 (Labeled A, B, C) are used out of turn. In case of single phase or dc source is supplied, any two terminals out of three may be used.

Excitation power output of the HDEC2000 unit is connected with excitation winding, F1, F2 (Labeled F+, F-) terminals are used for Excitation power output. HDEC2000 unit can supply maximum 15Adc through power module (IGBT) controlled by PWM duty.

The shield cables may be used for both excitation input and output power, however not forced. The shield wires of both sides and both powers (input and output) must be grounded. Table 2-5 shows terminal designation and cable cross sections for excitation power.

Chassis Ground

DANGER

This equipment must be grounded with no smaller than copper wire with $4mm^2$ cross section. The ground terminal is placed on the left side of the unit, and the terminal number is G4 (Labeled GND).

Table 2-5 Designation of Control Power and Excitation Power Terminal Block

Block	Number(Label)	Cross section	Function Description and Remark
D	D1(L)	$1.0mm^2$	Control power input Hi
	D2(N)	$1.5mm^2$	Control power input Lo
E	E1(A)		Phase A excitation power input
	E2(B)		Phase B excitation power input
	E3(C)	$2.5mm^2$	Phase C excitation power input
	E4(GND)	$4.0mm^2$	Chassis Ground (**Must be grounded with protective earth**)
F	F1(F+)		Excitation power output positive
	F2(F-)		Excitation power output negative

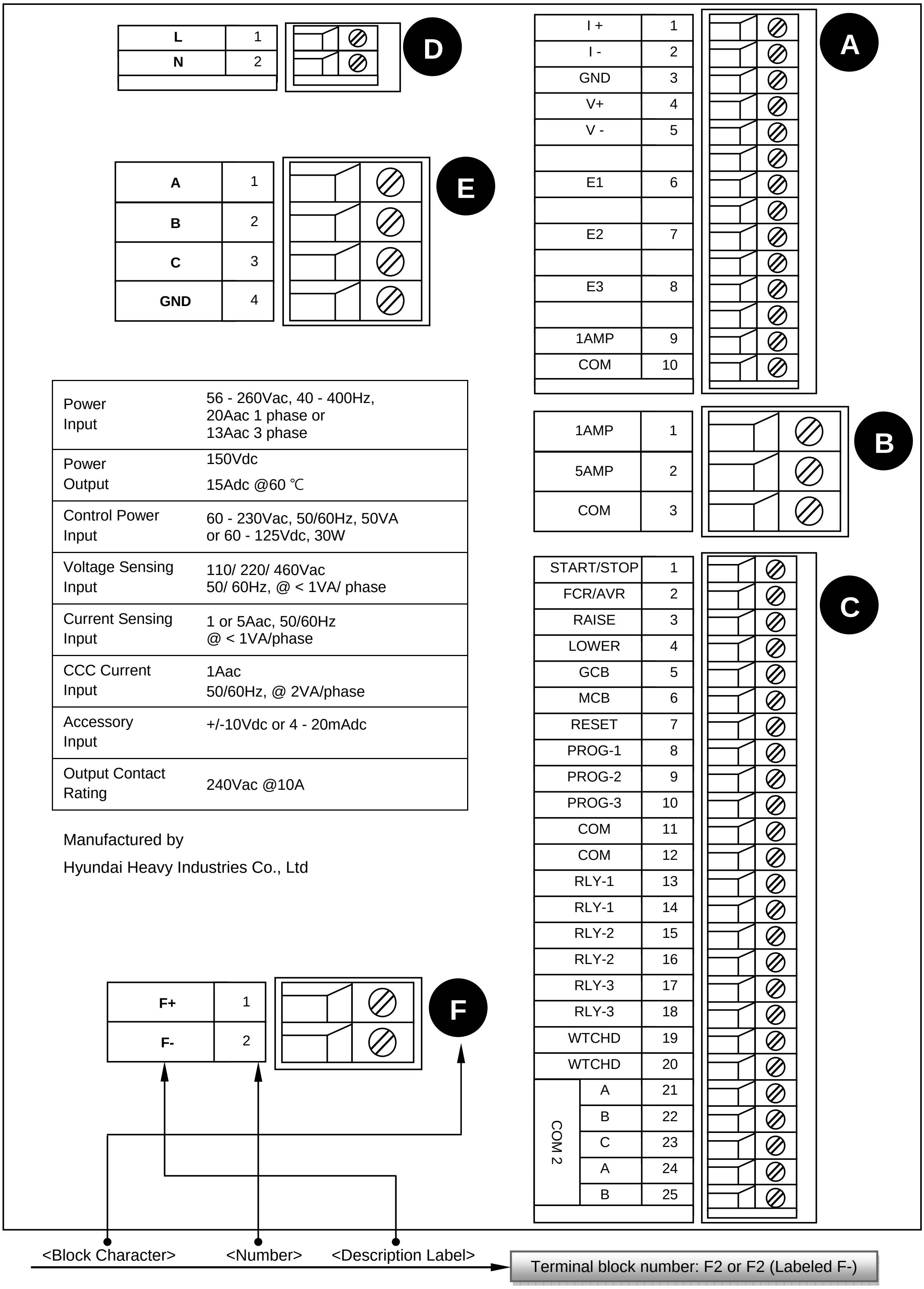
Terminal Block Arrangement and Electric Wiring Diagram

Terminal block arrangement of Left panel is shown in Figure 2-6, and typical wiring diagram of HDEC2000 unit is shown in Figure 2-7.

Be careful of terminal block number, the expression of terminal block number of HDEC2000 unit (this manual) is followed.

- Terminal block numbers consist of three parts called <Block Character>, <Number> and <Description Label>
- <Number> is written at the front panel side, and the <Description Label> is written at the rear side when viewed from left side
- Only <Block Character> and <Number> are written with no space and without <Description Label>, in normal case… Ex: F2
- Sometimes <Description Label> is written with the character “Labeled” and parenthesis at the end of terminal number … Ex: F2 (Labeled F-)

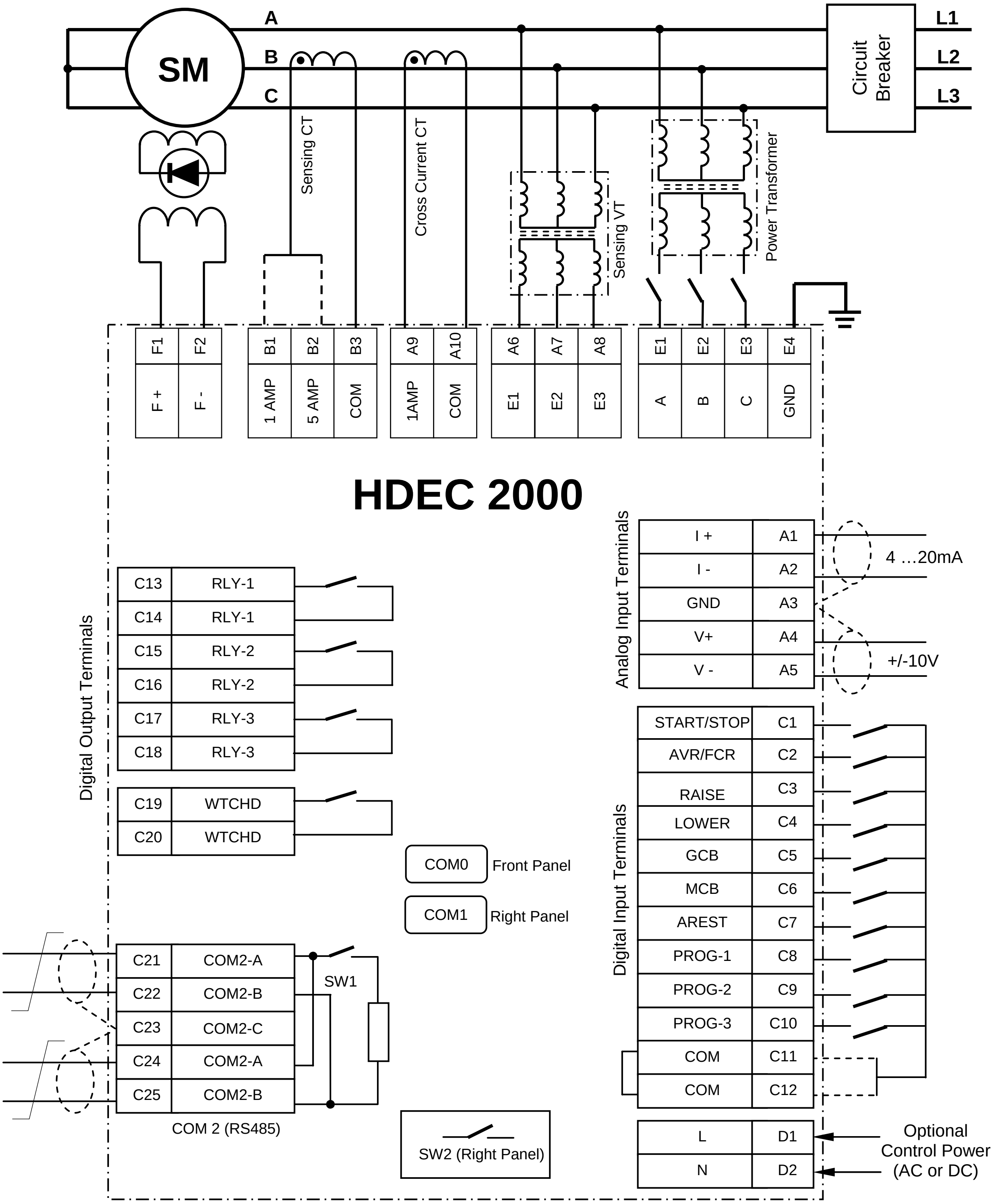
Be sure, Figure 2-7 is only for typical wiring diagram. This diagram may be applicable if properly modified depending on configuration of excitation system and application.



Notes:

1: The earlier version is marked with 60-120Vac for control power. However, the 230Vac source can be used without any problems.

Figure 2-6 Left Side View of HDEC2000



Notes:

1: For single phase sensing, use B1 and B3 terminals (omit B2 terminal).

2: For DC or single phase excitation power, use any two out of three terminals (G1, G2, G3).

3: One terminal either C11 or C12 may be used for digital input common.

4. The usable range of control power is 60 …125Vdc or 60 …230Vac, 120Vac is preferred incase of ac source.

5: Normally opened contact (logic) must be connected for GCB and MCB input, if used.

6: SW2 must be closed in case of shunt application without external control power (for other cases, must be opened)

Figure 2-7 Typical Wiring Diagram of HDEC2000

HARDWARE CONFIGURATION (Toggle switch Settings)

The HDEC2000 unit provides two kinds of toggle switches installed on the bottom side of right panel.
The first one selects the connection of termination resistor for RS485 communication.
The second one selects the availability of hardware voltage buildup function.

Toggle Switch 1 (Labeled SW1)

This switch may be turned on, if The HDEC2000 unit installed on the end point of RS485 connections. Push up the toggle switch lever to turn on this switch. For more information, see RS485 communication part of this section. If RS485 communication is not used, the configuration of this switch is not necessary.

Toggle Switch 2 (Labeled SW2)

This switch must be turned on, if no external control power is supplied and the excitation input is powered from the transformer connected with generator terminal (shunt application). Other than shunt application or other than no external control power, this switch must be opened. Push up the toggle switch lever to turn on this switch. For more information, see section 3 (Functional description – Voltage buildup).

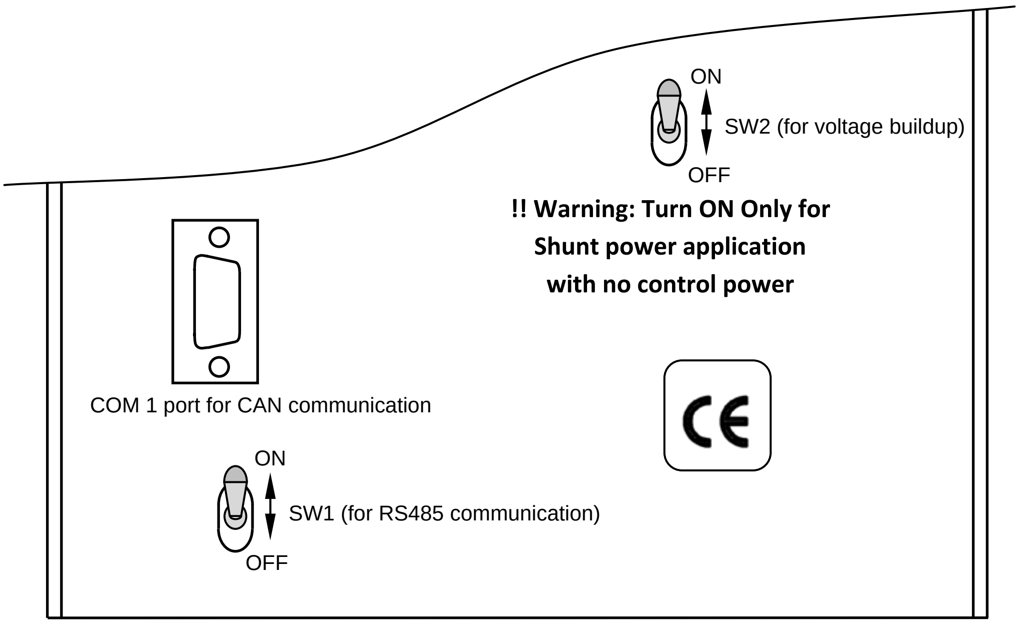


Figure 2-8 Right Panel View of HDEC2000

This page intentionally left blank.

SECTION 3. FUNCTIONAL DESCRIPTION

This section describes the functional description the heart of this manual.

The simplified hardware function block of HDEC2000 unit is shown in Figure 3-1.

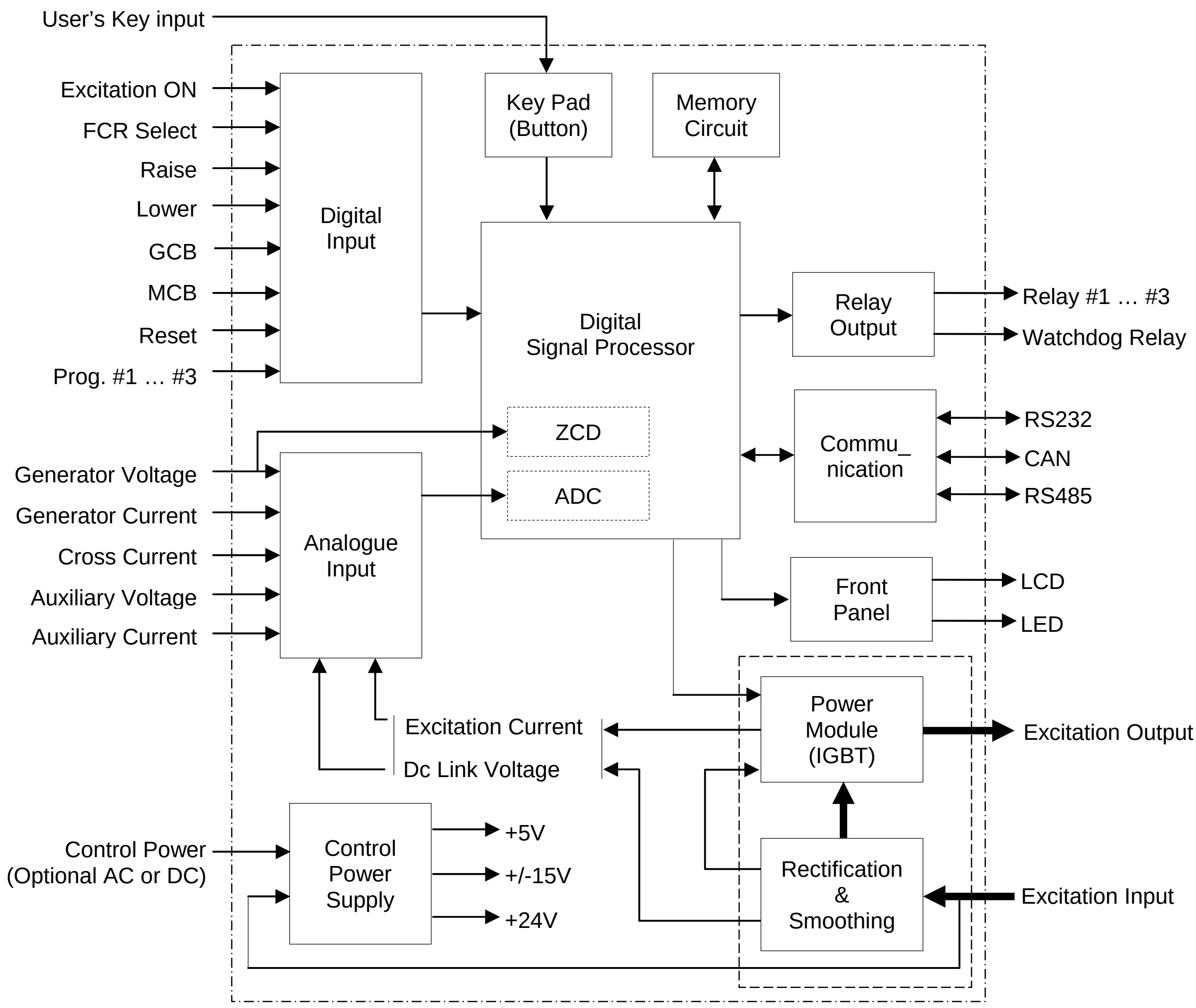


Figure 3-1 Simplified Hardware Function Block Diagram of HDEC 2000

INPUT and OUTPUT

Digital Inputs

HDEC2000 unit provides seven digital inputs for pre-defined functions and three digital inputs for programmable functions. Digital inputs can be controlled by external dry contact or PLC open collector output. In all cases, the digital inputs should be connected with potential free contact (or switch). Each function of digital inputs is described below.

Excitation ON (START/STOP) command

This input determines the condition of excitation on (or off). If this input circuit is closed, HEC2000 unit regulates the excitation power through the power module (IGBT). If this input is opened, the excitation output power is cut off. Continuous contact should be used for this input command.

Normally, This input may be closed while the prime mover speed is higher than specified value (typically 50 …90% of nominal), If the prime mover speed is lower than specified value, or if the generator heavy fault signal is activated, this input should be opened.

However, in case of shunt power application (excitation power is supplied from the transformer connected with generator output terminal) with no external control power and with no excitation input contactor, the excitation on input may be always closed. Alternatively, in this case, we recommend that the excitation input contactor may be installed for the protective purpose, and excitation on input channel may be connected with the auxiliary contact of excitation input contactor instead of external excitation on command. Figure 3-2 shows the typical schematic diagram of excitation on control for the shunt power application with no control power.

In above case (shunt power application with no control power, and input contactor is installed), we strongly recommend that the maximum speed for excitation on is less than approximately 70% of nominal to prevent initial voltage overshoot due to hardware voltage buildup function. See the voltage buildup function for more information.

Table 3-1 Excitation ON Command Control Logic (Fs: excitation on speed)

Control Power	Excitation Power	Recommended Control Logic			Possible Control Logic		
		< 10Hz	10Hz …Fs	> Fs	< 10Hz	10Hz …Fs	> Fs
Supply	PMG	OFF	OFF	ON	OFF	ON, OFF	ON, OFF
	Utility	OFF	OFF	ON	OFF	ON, OFF	ON, OFF
	Shunt	OFF	OFF	ON	OFF	ON, OFF	ON, OFF
Not Supply	PMG	OFF	OFF	ON	ON, OFF	ON, OFF	ON, OFF
	Utility	OFF	OFF	ON	OFF	ON, OFF	ON, OFF
	Shunt	ON (*1)	ON (*1)	ON (*1)	ON, OFF	ON, OFF	ON, OFF

1) This table is based on no excitation input contactor and the loss of power function is disabled. Otherwise, few parts of control logic of this table may be changed.
2) (*1): If excitation input contactor is installed, the control logic is depending on the condition of input contactor.

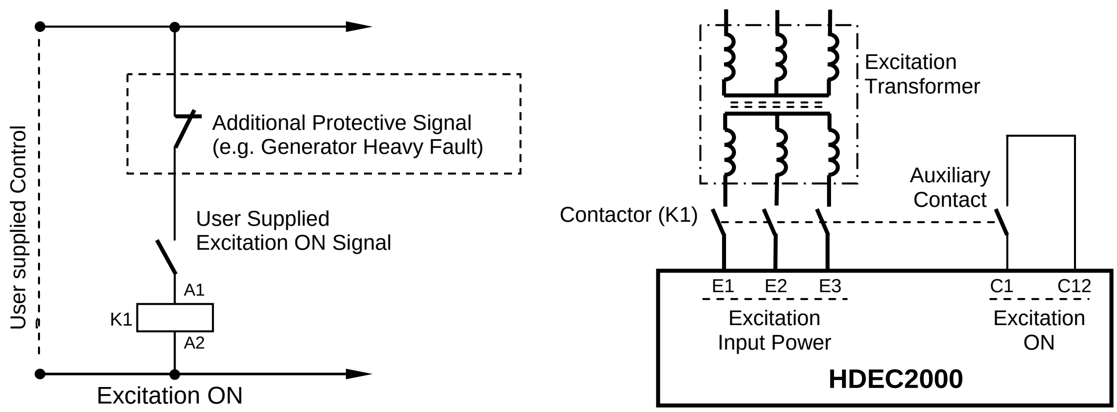


Figure 3-2 Typical Schematic Diagram for Excitation ON Control

(For shunt power application when no control power is supplied)

Table 3-1 shows the recommended excitation on control logic depending on excitation power and external control power. However user can modify the control logic depending on application. For more relative or detailed information, see ready mode function and loss of power function in this section. Or, please contact Electro Electric Systems - Hyundai Heavy Industries Co., LTD.

Especially, in cases that the loss of power is enabled and the loss of power option is configured with [Reset soft Start Time], even though it is not recommended, this input can be always closed for simple application.

Manual select command (non Automatic mode)

This input determines the basic regulation mode of HDEC2000 unit. If this input circuit is closed, HDEC2000 unit operates with FCR mode. Otherwise, the unit operates with AVR mode, VAR mode or PF mode depending on other digital inputs and configuration parameters. Continuous contact should be accepted for this input command.

FCR mode is prior to all operating modes and functions. In the FCR mode, all limitation functions and some protective functions are disabled.

Raiser, Lower command

This input(s) adjusts the setpoint (reference) of active operating mode. The raise command increases the setpoint, and the Lower command decreases the setpoint of active operating mode. These actions are enabled while the corresponding input circuit is closed. If the setpoint of active operating mode reaches to its [max Setpoint] or [min Setpoint], these actions are disabled. Momentary contact should be accepted for these input commands.

The total ramping time which is required to traverse from minimum to maximum setpoint is determined by [Setpoint Traversing Rate] parameter of active operating mode.

MCB (Machine circuit breaker) status

This digital input channel detects on/off status of the machine (generator) circuit breaker which connects the generator to the electrical bus or other generators. If this input channel is used, normal-opened auxiliary contact of generator circuit breaker should be connected.

If this input circuit is closed, HDEC2000 selects either reactive droop compensation or cross current compensation depending on [CCC Enabled] parameter when the operating mode is not FCR Mode.
If this input circuit is opened, HDEC2000 unit disables both the Droop (droop compensation) and CCC (cross current compensation) modes.

The MCB status is not essential part of excitation system. Sometimes it can be omitted. If the excitation system is designed for the generator to be always operated with AVR mode without droop compensation and without CCC, MCB status input circuit can be always opened.
Otherwise, if the excitation system is designed for the generator to be always operated with AVR mode with droop compensation, this input circuit can be always closed.

Alternative, if no auxiliary contact of generator circuit breaker is available or user wants to simple hardwire configuration, the [Virtual MCB] parameter having three options (None, Close, Open) can be used instead of auxiliary contact of physical circuit breaker. The functions of three options listed below are described. But, to enable the CCC function, the auxiliary contact of physical circuit breaker is essentially required.

- [None]: MCB status of HDEC 2000 software is determined by the digital input connected with actual generator circuit breaker
- [Close]: MCB status of HDEC 2000 software is always settled with closed condition.
- [Open]: MCB status of HDEC 2000 software is always settled with opened condition.

GCB (Grid circuit breaker) status

This digital input channel normally detects the on/off status of grid circuit breaker (not machine circuit breaker) which connects the generator to the infinite power grid (not island grid) in comparison with generator output rating. If this input channel is used, normal-opened auxiliary contact of grid circuit breaker (or combined logic status of some circuit breakers) must be connected.

The logical combination of GCB status, MCB status and related configuration parameters select either VAR mode or PF mode. Table 3-2 shows that the operating-mode selection logic depending on the digital inputs and configuration parameters.

If MCB and GCB status are closed, and [VAR/PF Mode] is configured with [VAR] or [PF], HDEC2000 unit operates either VAR mode or PF mode while the FCR mode is not selected. The VAR mode or PF mode is selected by the setting of [VAR/PF Mode] parameter. Otherwise, HDEC2000 unit operates with AVR mode.

Table 3-2 Regulation mode selection Logic

Operating mode	FCR mode	AVR mode			VAR mode	PF mode
		No Droop NO CCC	Droop	CCC(*1)	Droop	Droop
Front panel Display	FCR mode	AVR mode	Droop mode	CCC mode	VAR mode	PF mode
Digital input (Command and Status)						
FCR select	Close	Open	Open	Open	Open	Open
GCB status	-	Open	Open	Open	Close	Close
MCB status	-	Open	Close	Close	Close	Close
Configuration Parameter Setting						
CCC Enabled	-	-	False	True	-	-
VAR/PF mode	-	-	-	-	VAR(*1)	PF(*1)

Note:
(*1): If VAR or PF operating mode is selected, CCC function is disabled. CCC function is only enabled while AVR mode is selected.

Due to the safety reason, we recommend that this digital input channel may be connected with the logically combined status of some user's circuit breakers which determine VAR or PF mode depending on the power grid configuration.

Programmable #1, #2, #3 input (Command or Status)

HDEC2000 unit provides three programmable input channels for flexible configuration. Any function pre-defined by HDEC2000 software can be assigned for the programmable digital input channel.

If the input circuit is closed, the assigned function corresponding to its digital input channel is enabled (activated).The useable functions are listed and described below.

- [None]:

No function is assigned and no action is executed.

- [Preposition]:

If a corresponding input circuit is closed, HDEC2000 unit changes the setpoint of all operating modes (AVR, FCR, VAR and PF) to the pre-settled [Preposition Setpoint] of each operating mode. This function is useful for initialization of setpoint adjusted by user or for the application which required the fixed setpoint permanently. Momentary or continuous contact may be accepted for this function depending on application.

In some cases, this function is used to prevent excessive over voltage when circuit breaker is opened from the condition that the generator operates with FCR mode, and heavy load.

- [Secondary Unit]:

This function determines that HDEC2000 unit operates with primary (master) or secondary (backup) unit for redundant application configured with two HDEC2000 units. If a corresponding input circuit is closed, HDEC2000 unit operates with the secondary unit. The secondary unit always tracks the primary unit via CAN communication. This function is not supported now, and the revision for this function is planned later. Continuous contact may be accepted for this function.

- [Local Request]:

HDEC2000 unit can be commanded from three directions via three devices of digital input commands of left panel (local command), COM0 port (RS232) and COM2 port (RS485, read only now). This function determines that the local command (physical digital input command) is priority.

If a corresponding input circuit is closed while the HDEC2000 unit is controlled remotely, then the commands from remote device are disregarded. Momentary contact may be accepted for this function. For more information about remote access, see separated MODBUS communication manual.

- [Secondary Soft Start]:

This function is used for the special application (e.g. the different two kind's loads are powered from one generator at different time). If corresponding input circuit is closed, The HDEC2000 unit controls the voltage setpoint by using the second soft start parameter set. Even though the status of digital input is changed during soft starting processing, the changed event is not applied, but it may be applied with next excitation on event. For more information, see soft start function.

Alarm Reset command

When the input circuit is closed, this input clears the latching status of all fault events of the output relay assigned for fault event, internal software fault flag, front panel fault messages and fault LED. Momentary contact may be accepted for this command.

Analog Input and Output

HDEC2000 unit measures nine analogue signals. The seven signals are external inputs and two other signals are internally measured. The processing procedure of analogue signals is described below.

First, all analogue signals are converted to suitable low level by means of resistive divider, shunt resistor, current transformer or current sensor. Next, the analogue signals are transmitted to ADC (analogue to digital converter) through operational amplifiers, analogue filter circuits and MUX (multiplex). Finally, DSP (digital signal processor) performs quantization, digital filtering and signal conversion for the analogue signals. HDEC2000 unit performs control and other functions by using of these signals.

The analogue signals measured by HDEC2000 unit are listed below:

- Three phase-to-phase generator voltages (A-B phase, B-C phase, C-A phase, C-A phase).
- Generator B phase current
- Cross current loop input
- Auxiliary voltage input and Auxiliary current input
- Dc link voltage (excitation voltage)
- Excitation current

Generator voltage sensing

This signal is normally measured from sensing voltage transformer installed on generator inside or generator circuit breaker cubicle.

HDEC2000 unit provides three voltage sensing range (110Vac, 220Vac and 460Vac). HDEC2000 unit automatically selects voltage measuring range by using the turn ratio of sensing voltage transformer and the generator nominal voltage.

The unit supports both single phase and three phase sensing system. In case of three phase sensing system, the average of three phase-phase voltage is obtained for the purpose of regulating. In case of single phase sensing system, the A-C phase voltage is obtained. We recommend that user designs three phase sensing system for the more stable (smaller feedback ripple) voltage feedback and the fast regulation response.

The combination of true rms technique and optimum digital filtering technique achieves very stable and fast control of the generator voltage even though the sensing voltage has very high harmonic component. This voltage sensing signal is used for most of function as well.

Generator B-phase current sensing

This signal is measured from current transformer having 1A or 5A secondary current. And the current transformer must be installed on generator B-phase. This signal is used for reactive droop compensation, VAR/PF control and other functions.

When very big induction motor is started by using only one generator, if the starting current is higher than approximately 1.5 times of rated generator current and the starting current should be limited lower than proper level, the current transformer and the current input range of HDEC2000 unit must be considered to prevent the saturation (or over range) problem of both component.

Cross current loop input

The current signal called cross current loop input for reactive differential compensation (for reactive load sharing between generators) is measured from the loop circuit consist of some current transformers having 1A secondary current. And the all current transformers must be installed on generator B-phase.

To obtain equal reactive load sharing by cross current compensation, the turn ratio of cross current CTs of all paralleled generators should be same based on percent output rating of each generator.

The 2Ω burden resistor is installed internally in the HDEC2000 unit for compensating the unequal reactive power sharing caused by different resistance of interconnection cables. By this reason, no external burden resistor is required.
Also, the internal auxiliary relay controlled automatically by MCB status is installed in HDEC2000 unit. By this reason, additional auxiliary contact of generator circuit breaker is not required for the cross current compensation.

Auxiliary voltage input, Auxiliary current input

Normally, HDEC2000 unit controls the generator voltage (or other controllable parameter depending on operating mode) by using the setpoint determined by raiser (or lower) input channel. Sometimes, the auxiliary analogue signal called Auxiliary Input (auxiliary voltage or auxiliary current) adjusts the generator voltage together with raise and lower commands depending on application.

Two kinds of analog signal can be connected with HDEC2000 unit at the same time. Even though HDEC2000 unit measures both signals simultaneously, HDEC2000 unit controls the generator voltage by using the converting signal called analog reference, and the analog reference is converted from either auxiliary voltage or auxiliary current depending on [Aux Input Type] parameter.

After the analog reference is calculated from auxiliary input, the analog reference is multiplied with [AUX Gain] of each operating mode. And then, the multiplied value (analog reference * Gain) is summed up with the setpoint of each operating mode depending on [Aux Input Summing Type] parameter. Summed-up values (analog reference * Gain) are defined as a percentage of rated quantities for all operating modes.

Table 3-3 Auxiliary Analog Input Type

Type	Input Range	Polarity(*1)	Conversion (*2)	Type	Input Range	Polarity(*1)	Conversion (*2)
0	+/-10V	bipolar	-10 …+10	5	0 …10V	Unipolar	0 …+10
1	4 …20mA			6	1 …5V		
2	0 …10V			7	4 …20mA		
3	1 …5V			8	0 …20mA		
4	0 …20mA			9	-		

(*1) means the polarity of final converted analog reference.

(*2) means the final boundary of analog reference (converted signal from auxiliary voltage or current) when the input signal is varied from predefined minimum level to maximum level.

The relationship of auxiliary input and configuration parameter are summarized in Table 3-3 and Table 3-4, and the sample configuration is described below. With below configuration, if the analog input is varied from -10 to +10V, the generator voltage may be varied in the range of 90 …110% of nominal.

- Operating mode: AVR mode
- AVR mode setpoint: 100% (nominal voltage)
- AVR mode min Setpoint, AVR mode max Setpoint: 90%, 110%
- Aux Input Type = 0: +/-10V (converted with bipolar value)
- Aux Input Summing Type: 0 (inner loop)
- Aux input AVR Gain: 1.0

Table 3-4 Auxiliary Analog Input (Summing Type)

Parameter	Setting Value	Description
Aux Input Summing Type	0: inner Loop	**SP_{SUMMED}** is added only with FCR, AVR mode's setpoint
	1: Outer Loop	**SP_{SUMMED}** is added only with VAR, PF mode's setpoint
	2: Both	**SP_{SUMMED}** is added with all four operating mode's setpoint

SP_{SUMMED} = Analog Reference * Aux Gain

Where: **SP_{SUMMED}:** The summed value with setpoint of each operating mode in [%]
Defined as percentage of rated quantities for all operating mode.

Analog Reference: The converted signal from the auxiliary input (voltage or current) in Volts

Aux Gain: [Aux Gain] setting of each operating mode (configured by HDCM software), four configuration parameters are provides for each regulation mode called with [Aux input FCR Gain], [Aux input AVR Gain], [Aux input VAR Gain], [Aux input PF Gain]

We recommend that the analog signal may be used for auxiliary control only (ex: very narrow band adjustment for precision control or auxiliary control for synchronization). And it is also recommended that the analog signal is only used for adjusting the setpoint of one main operating mode (e.g. AVR mode or VAR/PF mode) to prevent the discordance between the summed setpoint of inactive operating mode and the actual value of inactive operating mode (e.g. the summed setpoint of FCR mode cannot track the actual excitation current during AVR mode even though the bump-less mode transfer function is enabled).

If auxiliary signal is supplied from the device such as the similar kind of PLC analogue output card (having multiple channels), we recommend that isolation signal converter may be used to prevent any influence caused by other device connected with same PLC card.

Dc link voltage (Excitation voltage)

The DC Link Voltage is internally measured from rectified voltage of excitation input power. This signal is used for protective function and monitoring purpose. The monitored excitation voltage of the HDCM software is not value directly measured from excitation output terminal but calculated from dc link voltage by using PWM duty and voltage drop of power module (IGBT).

Excitation current

This signal is internally measured from output current of power module (IGBT) by using of current sensor installed in HDEC2000 unit. This signal is used for the excitation current control, over excitation limitation, protective functions and monitoring purpose.

Excitation power

Three kinds of Excitation input power source (Shunt power, PMG power and External utility) are available. Three phase ac. source, single phase ac. source, or dc power source is usable and the permissible maximum voltage is 260Vac or 360Vdc. The input power is rectified and smoothed by capacitor, and then supplied to excitation winding through the power module (IGBT).

The current ratings of excitation input power source and all other components carrying excitation current are not calculated from the power rating of HDEC2000 unit, but should be determined from design data of the generator.

If the excitation input voltage is much higher than the excitation requirement, the dynamic response is improved but control accuracy or stability may be reduced.
On the other hand if the margin of excitation input voltage is a little bit higher than excitation requirement, the control accuracy or stability may be improved, but the dynamic response may be very poor. The balance between dynamic response and control accuracy is the first consideration in the designation of excitation system (input power). See Appendix C (Specification) for more information.

Control power

HDEC2000 unit does not require the external control power for the most of application. In case of external control power is supplied depending on application, some consideration may be made. For more information, see Voltage Buildup function of this section, section 2 (Installation and Hardware) and Appendix C (Specification).

CAUTION

If excitation system is designed with permanent external control power, external control power must be supplied to the unit before any generator operation or excitation input power contactor (or switch ...) is closed.

Digital (Relay) Output

HDEC2000 unit provides three programmable output relays and one watchdog relay. The output relays are controlled by DSP (digital signal processor) and the power rating is 250Vac, 10A.
Even though the current rating of relays is 10A, we strongly recommend that the output relay be used with the control purpose only for the robustness of overall excitation system.

If the output relay is connected with reactive load (ex: relay coil) in dc circuit, the load should have freewheeling diode across the load terminals, or the freewheeling diode should be installed externally to protect the circuit against switching arc.

Programmable Output relay #1 to #3

The output relay#1 to #3 can be assigned for any functions (or events) listed below. When the assigned function or event is activated, the output relay is also energized and latched (if assigned for fault event). The logic of each relay contact can be configured with normally opened (NO) or normally closed (NC).

More than one function can be assigned simultaneously for one relay. In this case, the logical combination (combined with OR logic) determines whether the output relay is energized or not. Assignable fault events (or functions) are listed below:

- generator over voltage
- generator under voltage
- generator over current
- excitation over current
- loss of field
- loss of sensing
- loss of power
- DFM(diode fault monitor) open diode alarm
- DFM(diode fault monitor) short diode fault
- short circuit excitation output
- excitation on status
- FCR status
- secondary unit status (not supported now)
- local Mode
- mode mismatch
- upper setpoint limitation status
- lower setpoint limitation status
- OEL status
- UEL status
- SCL status
- UFL (V/F limiter) status

Watchdog relay

Watchdog process detects the abnormal software execution. The watchdog process energizes the watchdog

relay when the abnormal software execution is detected, and then its output contact will be closed. The logic of watchdog relay is normally open. Also, if the abnormal software execution is detected, the excitation power output is shut downed by HDEC2000 unit to prevent the damages of the generator, system and the HDEC2000 unit.
In case of critical application, we recommend that the excitation power input be disconnected for overall system protection if watchdog relay contact is closed

Peripheral Device

Communication and User interface

The communication ports consist of RS232 (COM0), CAN (COM1) and RS485 (COM2) ports. For more information about communication, see section 4 (Configuration) and separated MODBUS communication manual.
For Information about User interface, see section 5 (User Interface).

Memory usage and configuration

Three types of memories (Flash memory, RAM and EEPROM) are internally used for HDEC2000 unit operation. EEPROM stores configuration parameters, and user can access (readable and writable) to this information via HDCM software. Executable control software code (firmware) is stored in the nonvolatile Flash memory integrated in the DSP. RAM is used for temporary data storage, and it is also integrated in the DSP.

OPERATIONAL FUNCTION

This section describes control modes, limitation functions and protective functions of HDEC2000 unit. The helpful technical information is also described for understanding the internal architecture of the unit.

Regulation Mode and More

Controller (Function block) and Control gain

HDEC2000 unit has four regulation (operating) modes called FCR, AVR, VAR and PF mode. One regulation mode is selected depending on the combination of digital input(s) and configuration parameters.

Each regulation functions are performed by its controller (sometimes called software function block) containing adjustable control gains, and each controller controls the target parameter such as voltage, excitation current, reactive power or power factor by using control gains. Thus, the control gain is one of the major parameters which determine the dynamic (or static) response or steady state stability of generator and excitation system.

Four major control gains are used for each controller. Some controller has all four control gains or more and other controller has only two control gains. The simplified description of each control gains are listed below

- Loop Gain K_G: scaling gain, determines the overall response

- Proportional Gain K_P: Improve transient response
- Integral Gain K_I: improve steady state error and recovery speed
- Derivative Gain K_D: Improve the steady state stability and initial response

For more detailed information about control gains tuning and controller structure, see section 4 (Configuration) and Appendix B (Mathematical Models).

FCR mode

FCR regulation mode controls the excitation current by setpoint. HDEC2000 unit measures the excitation current and compares it with commanded setpoint. And the unit controls the excitation current so that the excitation current be equal to [FCR Setpoint]. FCR controller is PI (proportional, integral) controller which has K_G, K_P, and K_I. In the FCR mode, over excitation limiter, stator current limiter, under-excitation limiter and the under frequency limiter are not enabled.

FCR mode is normally used for commissioning or selected for the application which requires manual control like test bench system.

AVR mode

AVR regulation mode controls the generator voltage by setpoint. HDEC2000 unit measures the generator voltage and compares it with commanded setpoint. And the unit controls the excitation current so that the generator voltage be equal to [AVR Setpoint]. AVR controller is PID (proportional, integral, derivative) controller which has K_G, K_P, K_I and K_D.

In case of the medium or small size generator which is connected with related big power grid (not island grid) or in case of synchronous motor application, the AVR mode cannot be selected. In which case, the VAR mode or the PF mode is preferred.

VAR mode

VAR regulation mode controls the reactive power by setpoint. The HDEC2000 unit measures the reactive power and compares it with commanded setpoint. And the unit controls the excitation current so that the reactive power be equal to [VAR Setpoint]. VAR controller is PI (proportional, integral) controller which has K_G, K_I.

VAR control mode is only prepared in case of small or medium generator which is connected with related big power grid (not island grid) or in case of synchronous motor application.

PF mode

PF regulation mode controls the power factor by setpoint. The HDEC2000 unit measures the power factor and compares it with commanded setpoint. And the unit controls the excitation current so that the power factor be equal to [PF Setpoint]. PF controller is PI (proportional, integral) controller which has K_G, K_I

PF control mode is only prepared in case of small or medium generator which is connected with related big power grid (not island grid) or in case of synchronous motor application.

Droop compensation (reactive current compensation)

Droop compensation provides the reactive load sharing if generator operates in parallel with other generator(s) or power grid. HDEC2000 unit adjusts (compensates) the measured generator sensing voltage depending on the calculated reactive current. Compensated voltage feedback (internally applicable sensing voltage for AVR function block) is calculated with simplified below formula.

$$U_C = U_G + (i_{G\ IMAGE} * 0.01 * \text{Reactive Droop Compensation})$$

Where: U_C is the compensated sensing voltage applied to AVR function block (controller)

U_G is the measured (sensed) generator voltage

$i_{G\ IMAGE}$ is the calculated reactive current from measured value:

- positive sign: over excitation, negative sign: under excitation

Reactive Droop Compensation: configuration parameter in percent

According to above formula, the compensated feedback (sensing) voltage is increased if reactive power increases. HDEC2000 unit reduces generator voltage as a result of feedback voltage increasing. This means that higher reactive power causes more generator voltage drop and lower reactive power causes the less generator voltage drop. So, the reactive load sharing is possible by droop compensation, because the reactive power is proportional to the generator voltage.

CCC (Cross current compensation or Reactive differential compensation)

Cross current compensation provides the reactive load sharing when the generator operates in parallel with other generator or power grid (not huge grid but island grid consist of some or few generators).

CCC function detects (senses) the residual unbalanced current in the CCC loop. And HDEC2000 unit internally adjusts (compensates) the measured generator sensing voltage depending on CCC loop current by mean of same manner described above (in the droop compensation part)

Compared with droop compensation, this function has a few features such as no (or fewer) voltage drop and automatic correction of unequal reactive power caused by unequal droop or unequal droop characteristic. But in case that the system requires high grade reliability and independence between each generator's excitation system and it is important issue, the cross current compensation is not recommended because of complexity of system configuration.

CAUTION

If CCC function is enabled, the disconnected CCC input cable must be isolated with each other when HDEC2000 unit is repaired (or replaced). Or, install the optional CCC disable switch. If not so, the unequal reactive load sharing may be caused. … See Figure 2-5

Other manufacturer supports the reactive load sharing through communication link.
However, in this case, if one generator (or regulator) is in fault, disconnection of communication cable can cause the breakdown of reactive load sharing. So HDEC2000 unit does not support reactive load sharing via communication link. In case of hardwire cross current compensation, the compensation mode is automatically transferred to droop compensation mode even though cross current loop is broken because the faulted

regulator is removed (CCC loop cable is disconnected). But in this case, [Reactive Droop] parameter is applied instead of [CCC Droop] parameter.

Voltage buildup

Most functions of HDEC2000 unit are digitally controlled. But few functions are realized by hardware device (by analogue circuit only). Voltage buildup function is one of these functions realized by hardware device.

In case of shunt power application, the residual generator voltage is very low (typically 4 …15% depending on the exciter machine's design). If no control power is supplied to the internal control circuits of voltage regulator, the power module (switching semiconductor, IGBT) of voltage regulator cannot be turned on. This leads that the generator voltage never increases to its desired value in normal case.

HDEC2000 unit provides the voltage buildup function without external control power for shunt power application.

Even though the excitation input power is very low (typically single phase 6Vac), the hardware buildup circuit of HDEC2000 unit can turn on the power module (IGBT), this leads that the generator voltage increases from very low residual voltage to its nominal voltage. This function is automatically disabled by DSP (digital signal processor) when the DSP booting process is completed. The hardware voltage buildup function has very useful advantages in case of shunt application without external control power. For enabling the hardware voltage buildup function, toggle switch 2 (Labeled SW2) installed on the right panel of the unit must be closed (turned ON). For other cases (with external control power or non shunt excitation power), the toggle switch SW2 must be opened.

IMPORTANT	**Hardware voltage buildup function is not always guaranteed. In case of shunt application, if the residual voltage is too low (e.g. approximately lower than 6Vac when measured at excitation input terminals), the external control power should be supplied for voltage buildup, or the pre-excitation circuit must be applied during startup.**

Ready mode function

In case of shunt power application with no external control power, if the excitation on command circuit is opened while prime mover operated with nominal speed, large generator voltage fluctuation (approximately 15 to 50% depending on the turn-ratio of excitation transformer) may be occurred by hardware voltage buildup function (due to the continuous repetition process of voltage coast-down, DSP power-down, hardware voltage buildup and DSP power-up).

To prevent this voltage fluctuation and to maintain power up condition of HDEC2000 unit, HDEC2000 unit controls the generator voltage with very low level (approximately 15 …20%) of nominal value depending on the turn ration of excitation transformer. This function is called with ready mode function.

If user wants minimum (residual) induced voltage at nominal speed operation with excitation off status, the excitation power input contactor (switch) should be installed and it should be turned off. It is the best solution in case of shunt power application (with no control power) for safety.

Soft start function

The soft start function leads the generator voltage buildup to the nominal setpoint voltage with minimal overshoot for the desired (configured) time from excitation on event. When excitation on command is detected, after the time delay corresponding [Soft Start Delay] time, The HDEC2000 unit linearly adjusts [AVR Setpoint] from [Soft Start Level] to [AVR Mode Setpoint] through [Soft Start Time].

Typical setpoint change by soft start function is shown in Figure3-3. In case that the generator speed does not reach to nominal value within [Soft Start Time], the generator setpoint is limited by under frequency limiting function. The typical setpoint change is shown in Figure in Figure 3-4. Soft start function is enabled in FCR mode also. In this case, HDEC2000 unit adjusts [FCR Setpoint].

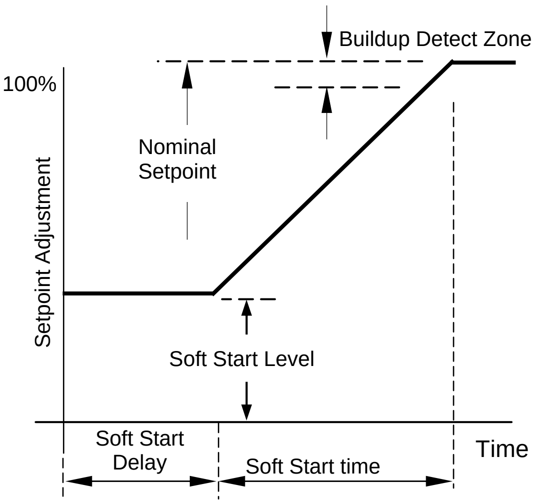


Figure 3-3 Soft Start Function

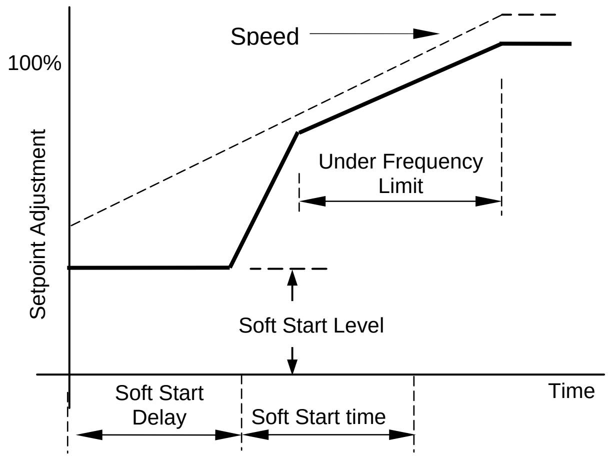


Figure 3-4 Soft Start Function with Long startup time

Some cases, non-standard configuration is required for special application (if one generator is designed to service for two loads having different property. However, only one load is connected at one time).

- Case 1: The generator operates with the conventional load. The maximum load is less than the generator nominal rating and the instantaneous over load (current) is not required.
- Case 2: Only one generator operates with one induction motor. The nominal load is less than generator nominal rating, but the starting capacity of induction motor is almost 4 … 5 times of generator rating.

In this case, only one fixed soft start function (configuration) is enough for any one load, but not sufficient to satisfy for both applications.

HDEC2000 unit provides the second soft start parameter set called [Soft Start Level 2] and [Soft Start Time 2] for second case load. These two parameters are used instead of [Soft Start Level] and [Soft Start Time] when the programmable digital input is assigned with [Secondary Soft Start] and corresponding digital input circuit is closed.

The sample configuration is listed below if the second soft start function is assigned for the load corresponding to case-2 described above.

- [Soft Start Level 2]: = $U_{LR} + U_C + U_D + U_{CM}$

- [Soft Start Delay]: T_{ST} + T_{SD}
- [Soft Start Time 2]: typically 1 … 5sec, depending on the [Soft Start Level 2]
- [Buildup Detect Zone]: typically 0% or 3 … 5%
  - If the generator voltage is reached to this zone during motor starting, the voltage setpoint is jumped up to the nominal value even though the soft start processing is not completed. This function is used to prevent big voltage swing after the motor starting is completed. If this parameter is zero, this function is disabled.
- [SCL Hi Level]: target starting (limiting) current of induction motor … stator current limiter function
- [SCL Hi Time]: T_{ST} + T_{SM} … See stator current limiter function

Where

U_{LR}: locked rotor voltage corresponding to target starting current in percent

U_C: voltage drop of power cable during starting, typically 2 …4%

U_D: 0.95 * [Reactive Droop compensation] * target starting current in percent … see droop compensation

U_{CM}: control margin, typically 5%

T_{ST}: expected starting time in seconds

T_{SD}: starting delay (margin) time, typically 3 …5s

T_{SM}: safety margin for generator protection, typically 1 … 2s but depending on generator temperature rise margin and starting current, typically T_{SM} <= T_{SD}

Bump-less mode transfer (Internal tracking) function

Bump-less mode transfer (sometimes called internal tracking) function minimizes the impact or fluctuation of system parameter (e.g. voltage) when switching from one operating mode to another operating mode.

When the operating mode transferred from AVR mode to FCR mode:

The FCR setpoint is continually updated by actual value (excitation current) during AVR mode and the control output (PWM duty) of FCR mode is determined from the value of AVR control output when the operating mode is transferred from AVR mode to FCR mode.

However, after the operating mode is changed, the setpoint of active operating (FCR) mode is gradually changed to the memorized (and smoothed) excitation current before [Internal Tracking Delay Time] from mode transfer event through [Internal Tracking Traversing Rate].

If too shorter [Internal Tracking Delay Time] is configured, and the operating condition is unstable when operating mode is transferred, the excitation current shall be not backed to desired steady level.
If too longer [Internal Tracking Delay Time] is configured, the excitation current is returned to the much older level. In second case, the new control parameter is not related with recent value.

When the operating mode transferred from FCR mode to AVR mode:

Oppositely, the setpoint of AVR mode is continually updated by actual value (generator voltage) during FCR mode and the control output of AVR mode is determined from the value of FCR control output when the operating mode is changed. And the return procedure of AVR mode setpoint is same as above explanation.

By the similar way, HDEC2000 unit provides bump-less mode transfer function between any operating modes as well.

Below four options are used for bump-less mode transfer function.

- Disabled: internal tracking function is not used.
- Auto Manual Only: internal tracking function is available between Auto operating mode (AVR, VAR or PF mode) and FCR operating mode. However the internal tracking function between each Auto operating mode is not available.
- From VAR/PF to AVR: this option basically supports [Auto Manual Only] option. Additionally, the internal tracking function is available when the operating mode is transferred to AVR mode from VAR/PF mode. However the opposite case is not available.
- All Mode: internal tracking function is available between any operating mode without regard to the direction of mode transfer.

Limitation Functions

Different types of limitation functions of HDEC 2000 unit are provided for generator protection from abnormal operation condition. This section described the limitation functions.

Generator capability curve

The generator capability curve graphically illustrates the safe operation region without any damage caused from abnormal operation conditions in the P-Q (active and reactive power) plane. HDEC2000 unit provides all limitation functions for synchronous machine. A typical synchronous machine capability curve is shown in the Figure 3-5.

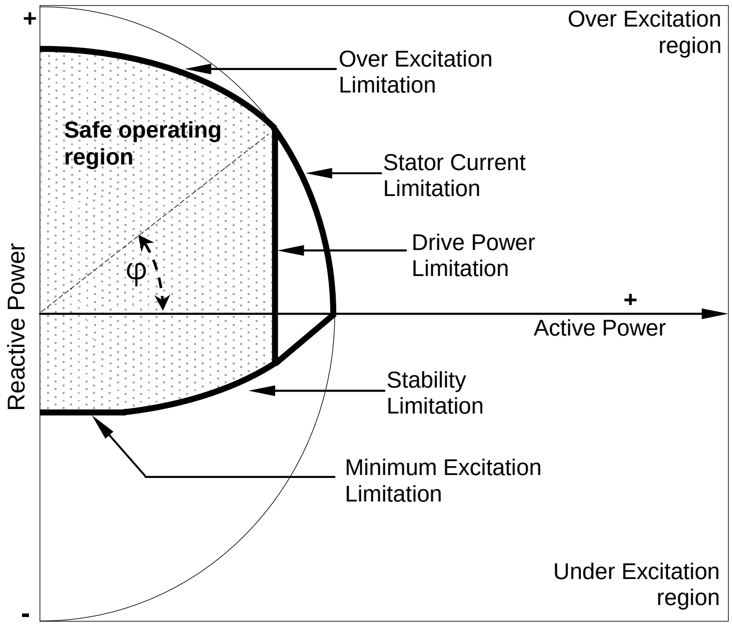


Figure 3-5 Typical Generator Capability Curve in the P-Q Plane

Under frequency limiter (V/F or UFL)

Under frequency limiting function provides for preventing the overheating caused by excessive magnetic flux (over excitation current) in the low frequency range, and provides for reducing the mechanical impact when large resistive load is suddenly applied. Under frequency limiting function is disabled in the FCR mode and also disabled if generator frequency is below than 10Hz.

HDCE2000 unit provides standard mode under frequency liming [Std UFL] and maximum flux mode under frequency limiting [Max Flux UFL] function. [Std UFL] is widely applicable for general application and provides two purpose of above. [Max Flux UFL] is very useful in case that wide generator voltage adjustable range is required (e.g. test bench application).

- Standard mode Under Frequency Limiter (Std UFL)

The [Std UFL] automatically reduces the voltage setpoint proportional to the dropped frequency when the generator frequency drops down lower than the [Under Frequency Corner Frequency]. The [Under Frequency Corner Frequency] is configured with typically 95% of nominal. The setpoint reduction rate is determined by [Under Frequency Slope (or V/Hz ratio)]. Generator voltage is more rapidly decreased if this parameter is increased. Typical standard mode under frequency limiting function is shown in Figure 3-6.

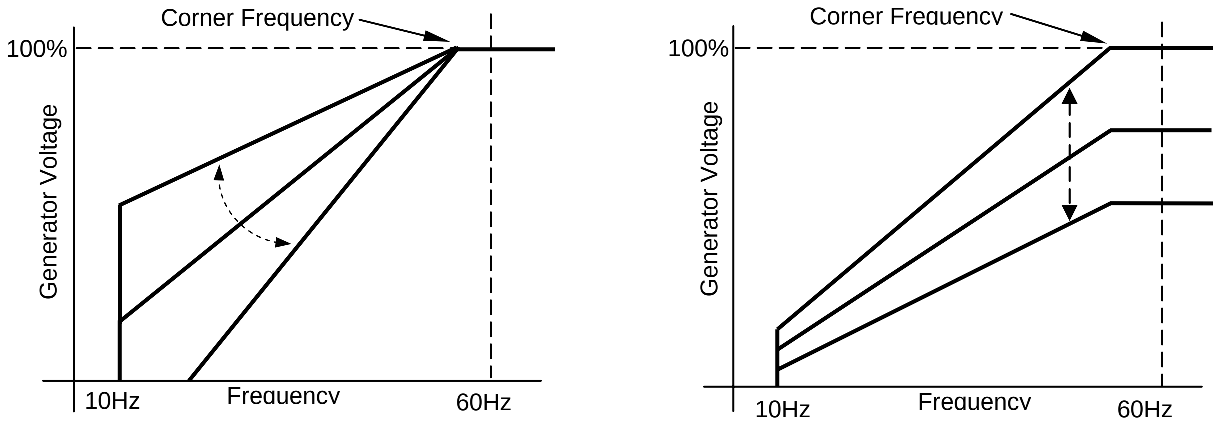


Figure 3-6 Standard mode V/F Limiting (Left: V/Hz slope varied, Right: Setpoint varied)

- Maximum Flux mode Under Frequency Limiter (Max Flux UFL)

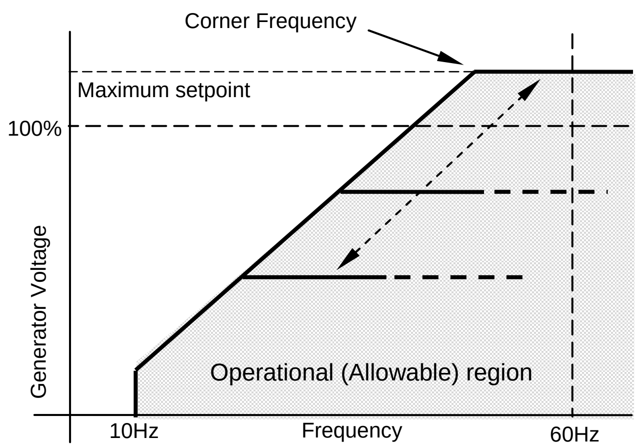


Figure 3-7 Maximum Flux Mode V/Hz Limiting
(Setpoint varied)

The [Max Flux UFL] reduces the voltage setpoint by similar manner as [Std UFL]. In this case, the voltage setpoint is not reduced automatically when the generator frequency drops down than the [Under Frequency Corner Frequency], but limited when the voltage setpoint is higher than the pre-calculated limiting level determined by [AVR mode max Setpoint]. The [Under Frequency Corner Frequency] and the [Under Frequency Slope] are used commonly with [Std UFL]. Typical maximum flux mode under frequency limiting function is shown in Figure 3-7

Over Excitation Limiter (OEL)

Over-excitation limiting (OEL) function operates in order to prevent the overheating when the excitation current exceeds the safe level. Or, OEL operates in order to prevent the over voltage with no load operating condition. OEL function can be always enabled in any operating mode except the FCR operating mode. If the excitation current exceeds the limiting level by any reason, the excitation current is limited below than the configured level.

Three kinds of OELs, Off-Line OEL, On-Line OEL and Default-OEL are defined. One kind of OEL is selected by logical combination of digital inputs and configuration parameters. Table 3-5 shows the relationship between OEL mode and others (digital inputs, configuration parameters setting, stator current).

Table 3-5 OEL mode selection Logic

Selected OEL mode	OEL Enabled	OEL Option	GCB status	MCB status	Generator Current
Off Line	True	GCB or MCB	Open	Open	-
	True	GCB	Open	-	-
	True	Dynamic	-	-	Up to 5% of nominal
On Line	True	GCB or MCB	-	Close	-
	True	GCB or MCB	Close	-	-
	True	GCB	Close	-	-
	True	Dynamic	-	-	Higher than 5% of nominal
	True	On-Line	-	-	-
Default	False	-	-	-	-

Note: OEL function is enabled when operating mode is not FCR mode.

- On-Line OEL

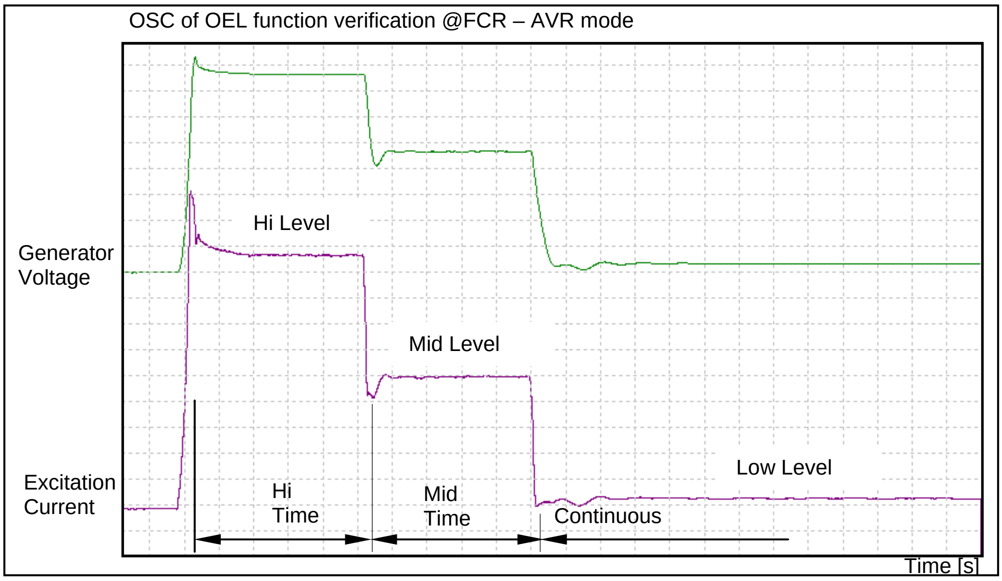


Figure 3-8 On-Line Over Excitation Limiting

Three kinds of current level, [Hi level], [Mid level] and [Low level] are used for limiting the excitation current. The excitation current level corresponding to the [Hi level] and [Mid level] is only allowable during the time configured as [Hi Time] and [Mid time] parameters. The [Low level] excitation current can be accepted continuously.

Generally, [Hi level] is used for limiting the short circuit supporting excitation current or initial high excitation current on special application (e.g. the system consisted of one generator and one induction motor only). [Mid level] is used for limiting the current when the instantaneous over load may be allowed. [Low level] is used for continuous thermal protection of excitation winding. The OEL level should be configured by considering both the generator thermal capability and application requirement. Figure 3-8 shows typical On-Line OEL function through test result.

- Off-Line OEL

Two kinds of current levels, [Hi level] and [Low level] are used for limiting the excitation current under no load condition. [Hi level] current is only allowable during the time configured as [Hi time] parameter. [Low level] current can be accepted continuously. Generally, [Hi level] is used to prevent the instantaneous over excitation at no load and [Low level] can be configured by considering the continuous over voltage capability of generator. Figure 3-9 shows typical characteristics of Off-Line OEL function.

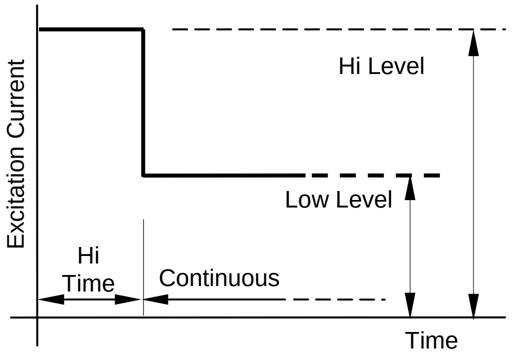


Figure 3-9 Off-Line Over Excitation Limiting

- Default-OEL

Default-OEL is used for protecting the HDEC2000 unit but not for generator protection when the OEL function is disabled. Default-OEL is controlled by three levels of current and two levels of limiting time similar with On-Line OEL. The internally predefined values are [Hi Level = 30A], [Hi time = 10s], [Mid Level = 20A], [Mid time = 5s] and [Low Level = 15A].

Under Excitation Limiter (UEL)

Under-excitation limiting (UEL) function is used for preventing the loss of synchronization and excessive end-core heating when the generator connected with power grid and operated with under excitation region (reactive power is absorbed from grid).

HDEC200 unit measures the generator reactive power. If measured reactive power is less than the configured or calculated reactive power, the excitation current is increased by HDEC200 unit in order to be out of the unstable operating status. UEL function can be always enabled on any operating mode except the FCR mode. Two kinds of UEL are defined and the one is selected by [UEL Curve Type] parameter.

- Circular UEL

When the circle type UEL is selected, HDEC2000 unit automatically calculates the limiting level based on the [UEL Circular Reactive Power] parameter and the present measured active power. The calculated value is used as UEL reference power. [UEL Circular Reactive Power] parameter is defined based on the safe maximum (permissible) reactive power absorbed from network when no active power (power factor = 0) is present. Figure 3-10 shows typical circle type UEL curve.

- Segment UEL

When the segment UEL is selected, HDEC2000 unit interpolates the limiting level based on the five points of active and reactive power level configured by user. The interpolated level is used as UEL reference power. The five coordinate values are configured as the [UEL Segment Real power 1 … 5] and [UEL Segment

Reactive power 1 … 5] parameters. With this method, the more precise setting is possible rather than circle UEL. Typical segment UEL curve is shown in Figure 3-11

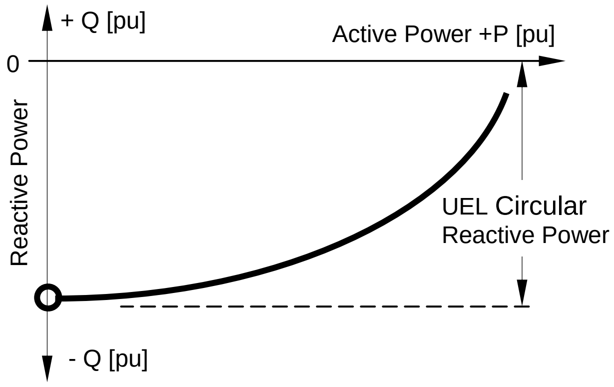


Figure 3-10 Circular UEL Curve

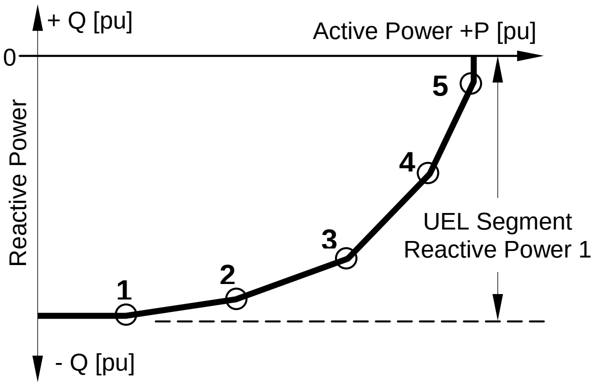


Figure 3-11 Segment UEL Curve

Stator current Limiter (SCL)

Generally, stator current limiting (SCL) function provides for preventing the overheating of stator winding caused from the higher current than safe level. Sometimes, this function can be used for limiting the starting current of special application (e.g. the system consisted with one generator and one induction machine only).

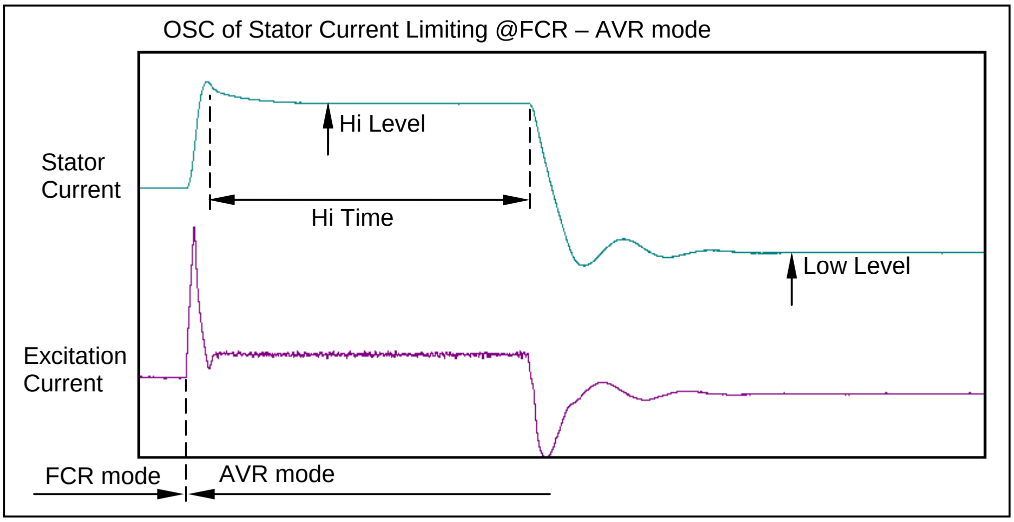


Figure 3-12 Typical Chart Record of SCL function

If the reactive power is less than the minimum configured level calculated from [SCL Accept PF] parameter or the generator is operated with under excitation condition, the SCL controller disregards the excessive current even though the stator current exceeds the limitation level. In case of permanent single operation (not paralleled), if the generator is operated with passive load such as lighting load and the setting level of [SCL Accept PF] parameter is higher than 0.97, the SCL controller disregards the under excitation condition (or the less reactive power condition).

Two kinds of current levels, [Hi level] and [Low level] are used for the control of SCL. [Hi level] current is only allowable during the time configured as [Hi time] parameter, and [Low level] current can be accepted continuously. Normally, [High Level] is used for limiting the initial inrush current of induction motor and momentary over-load, [Low Level] is used for continuous thermal protection.

Figure 3-12 is the typical chart record of SCL function:
The operating mode is transferred to AVR mode from FCR mode with generator voltage lower than [AVR setpoint], at the moment of mode transferred, because of lower generator voltage, the excitation current (PWM duty) goes to full range. But the excitation current is reduced immediately by SCL function. So, the stator current can be limited up to the configured limiting level.

Protective Functions

HDEC2000 unit provides ten protective functions listed below.

- Generator over voltage
- Generator under voltage
- Generator over current
- Exciter over current
- Loss of filed (under excitation)
- Loss of sensing
- Loss of power
- Diode Fault Monitor for open and short rotating diode status (DFM)
- Excitation output short circuit protection (hardware support)
- Mode mismatch

The protective functions of HDEC 2000 unit are designed to provide a high degree of reliability and accuracy, but few protective functions are not successful for critical primary protective function (e.g. generator over current) due to measuring range (or saturation problem) of measuring hardware. The reason is described below.

Internal measuring devices (ex: current sensor) are designed for optimum operation of generator voltage (or excitation current, reactive power …) regulation because the core function of HDEC2000 unit is regulation. By this reason, we recommend that few protective functions corresponding to this kind are used for secondary protection in conjunction with a primary protective system.

Normally, a fault event is activated when the generator operating condition exceeds the setting level of each protective function and the operating condition is not returned to normal operating condition within the delay (configured or calculated) time. Each fault event can be indicated on the front panel display and remotely through Com0 or Com2 communication ports.

When any fault event is activated, internal software fault flag, front panel fault message and output relay (if fault event is assigned for that relay) are latched until the fault event is inactivated and reset command is activated. Additionally, all fault events can be assigned for any output relays (#1 relay to #3 relay).

Detailed information is described below for each protective function.

Generator Over-voltage (GEN. OV)

When generator voltage rises above the predefined setting level and is maintained for duration of predefined over voltage delay time, the generator over voltage fault is activated.

Generator Under-voltage (GEN. UV)

When generator voltage falls below the predefined setting level and is maintained for duration of predefined under voltage delay time, the generator under voltage fault is activated. The generator under voltage fault function is disabled during [Soft Start time].

Generator Over-Current (GEN. OC)

HDEC2000 unit provides three types of generator over current (GEN. OC) protective function which called [Constant Time], [Standard Inverse Time] and [Preload Inverse Time]. The last two types of over current protective functions are very similar together, but [Constant Time] over current protective function is some different.

- Constant Time GEN. OC

This type of GEN. OC operates as fully same manner of GEN. OV protective function. When generator current rises above the predefined setting level [Gen. Constant OC Level] and is maintained for duration of predefined delay time [Gen. Over Current Delay], the generator over current fault is activated.

! CAUTION	**Do not use HDEC 2000 unit for primary over current protective device of overall system.** **Due to the measuring range of the hardware of HDEC2000 unit and generator sensing current transformer, it can be only used for thermal protective purpose with low fault current range (ex: up to 170% of nominal).**

- Standard Inverse Time GEN. OC and Preload Inverse Time GEN. OC

These two types of GEN. OC functions are designed based on generator thermal model as per IEC255-8 standard. When generator current rises above the predefined safe operation level and is maintained for duration of calculated delay time which has inverse characteristic (function) for square of generator current, the generator over current fault is activated.

The tripping time is not pre-determined value but the calculated value from present (varied) generator current, predefined over-current delay and predefined preload current based on equivalent temperature rise. This tripping time is always varied depending on the generator current variation. This means that the relative higher generator current leads shorter tripping time when compared with relative lower generator current.

Three configuration parameters [Gen. Inverse OC Level], [Gen. Inverse OC Preload] and [Gen. Over Current Delay] determine the tripping time with measured generator current. Each configuration parameter is described below.

- Gen. Inverse OC Level: means the safe operation current without thermal damage in percent base of generator rated current, but not means the dangerous tripping current level.

- Gen. Inverse OC Preload: means the equivalent preload current level corresponding to winding temperature before operation in percent base of [Gen. Inverse OC Level].
- Gen. Over Current Delay: means the tripping time based on 150% fault current, 90% preload current. But actual tripping time (fault event activating time) is depending on measured generator current and preload current

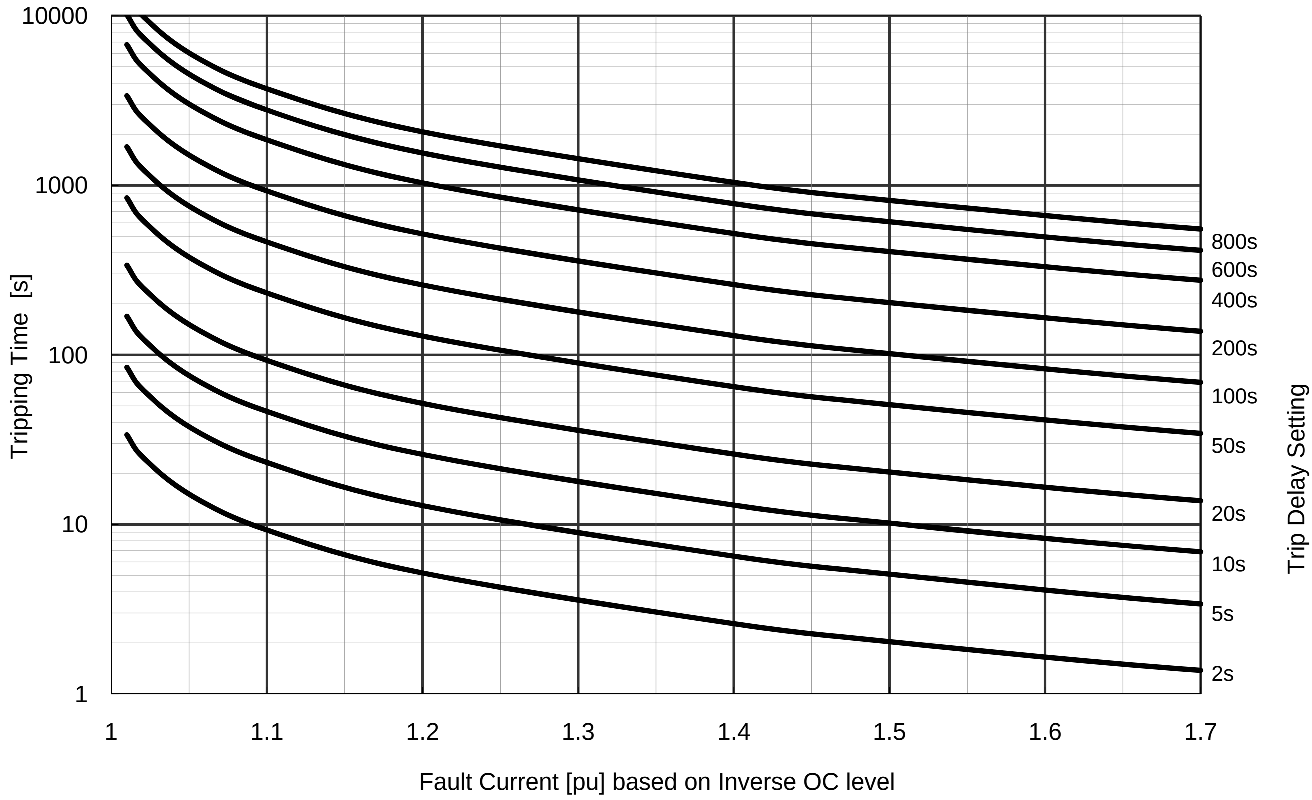


Figure 3-13 Over-Current Tripping Time VS Fault Current with preload 90%

Generator over current tripping time **Ttrip** can be calculated by using below formula.

$$\mathbf{Ttrip = Tc * Ln \{ (I_G^2 - I_P^2) / (I_G^2 - 1) \}} \text{ in seconds}$$

Where: T_C is the calculated time constant from [Gen. Over Current Delay] parameter

= 7.2 * [Gen. Over Current Delay] in seconds

$\mathbf{I_G}$ is the measured generator current in per-unit based on [Gen. Inverse OC Level]

$\mathbf{I_P}$ is the configured preload current [GEN. Inverse Preload] in per-unit based on [Gen. Inverse OC Level]

The unique difference between [Standard Inverse Time GEN. OC] and [Preload Inverse Time GEN. OC] is the processing method of minimum generator current considering the difference time between heating time constant and cooling time constant.

In case of [Preload Inverse Time GEN. OC], even though the generator current is below the preload current, Software of HDEC2000 unit perceives that the generator current is still preload current (minimum generator current). However, the [Standard Inverse Time GEN. OC] always perceives the actual generator current.

If user wants to configure conservative over current protective function, [Preload Inverse Time GEN. OC] may be selected. Figure 3-13 and Figure 3-14 shows the relationship between tripping time and fault current with the fixed preload 90% and the fixed 20s tripping delay time respectively.

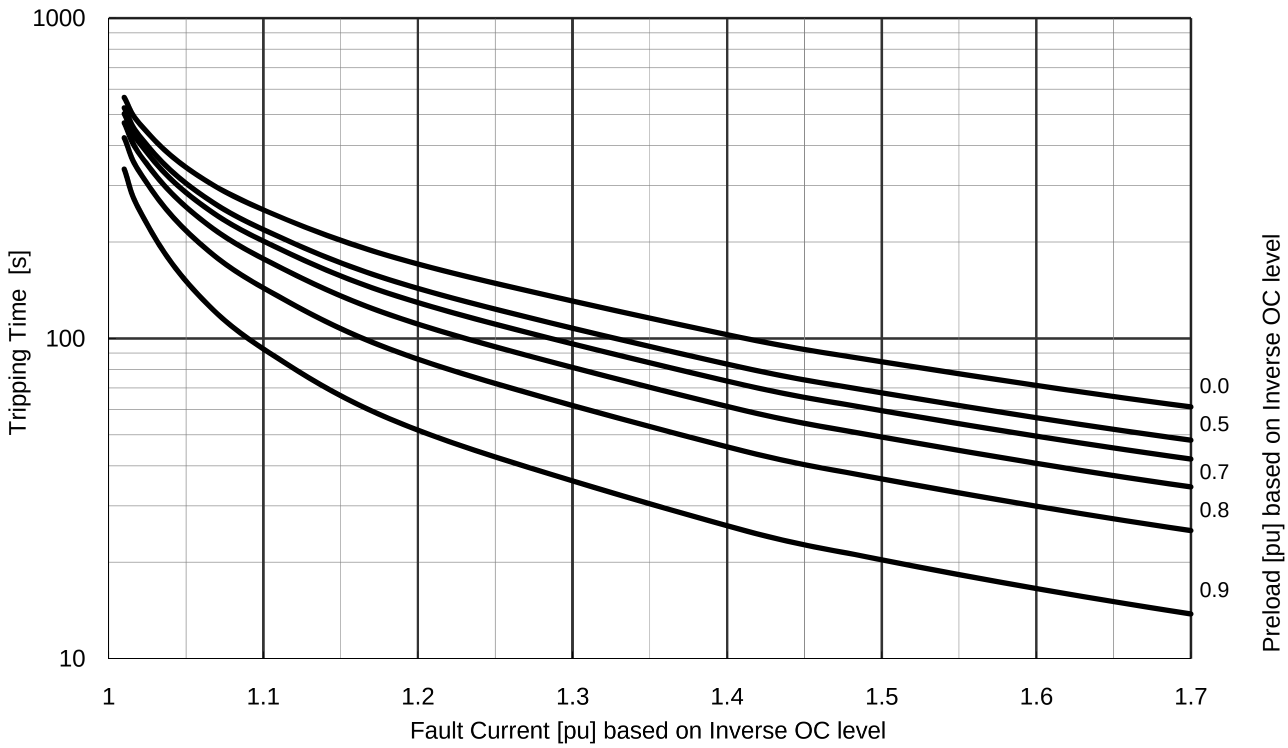


Figure 3-14 Over-Current Tripping Time VS Fault Current with trip delay 20s

Exciter over current (EXC. OC)

HDEC2000 unit provides three types of exciter over current (EXC. OC) protective functions which called [Constant Time], [Standard Inverse Time] and [Preload Inverse Time]. All three types of exciter over current functions are operates by the entirely same manner as GEN. OC protective function.

However, preload (corresponding to [Gen. Inverse OC Preload] of Gen. OC function) parameter is fixed with 70% level and the exciter over current fault event is activated when excitation current rises above predefined safe level instead of generator current. Others are the same as GEN. OC. Figure 3-13, Figure 3-14 and calculation formula for tripping time are also used for EXC. OC configuration.

Loss of field current (under excitation)

If reactive power falls (this means that the sign of reactive is minus, absorbed reactive power rises) below the predefined setting level and is maintained for duration of predefined delay time, the generator loss of field fault is activated.

Loss of sensing

The loss of sensing detection is very critical algorithm. Also it is some complex to realize. So, only one or two operating information never simply determine the loss of sensing fault. Below operating conditions are used for determining the loss of sensing fault.

(a) Excitation current is higher than 105 % of predefined no load excitation current.

(b) Any phase-phase voltage difference is more than [Loss of Sensing Unbalanced Level].
- This condition is applicable for three phase sensing system only.

(c) The averaged (in case of three phase sensing) generator voltage falls below the [Loss of Sensing Balanced Level].

(d) Dc link voltage is higher than 30% of predefined [Dc Link Voltage].

(e) Generator current is lower than 3% or MCB status is open (this means no load condition).
- If [Virtual MCB] option is [Close] or [Open], The MCB status logic is disregard.

(f) Generator current is lower than 145% of nominal value.

(g) Generator voltage rises above 95% of nominal value.

If generator operating condition meets any one (logic 1 to logic 5) of logical combinations of Table 3-6 and the condition is maintained for duration of pre-settled delay time, a loss of sensing fault is activated.

Table 3-6 Loss of sensing Logic

Status	Logic 1	Logic 2	Logic 3	Logic 4	Logic 5 (*1)
excitation power	Shunt	Shunt	PMG	PMG	PMG
(a)	True	True	True	True	True
(b)	True	-	True	-	-
(c)	-	True	-	True	True
(d)	-	True	-	-	-
(e)	-	-	-	True	-
(f)	-	-	-	-	True

Notes
- (*1): Logic 5 only can be activated after the item (g) is trigged.
- In the FCR mode or during soft start time, Loss of sensing fault is not enabled

If loss of sensing fault is occurred, four optional protective actions called [None], [Transfer to FCR], [Fixed PWM] and [Shutdown] are available. The protective option is configured by [Loss of Sensing Option] parameter and each protective action is described below:

- None: no protective option is assigned.
- Transfer to FCR: when a loss of sensing fault is detected, the operating mode is automatically transferred to FCR mode.
- Fixed PWM: when a loss of sensing fault is detected, the operating mode is automatically transferred to FCR mode. And the excitation current setpoint is adjusted to 80% of no load excitation current. This protective action serves with no load operating condition only. If loss of sensing option is specified with [Fixed PWM] and [MCB status] is closed, then HDEC2000 unit serves [Transfer to FCR] protective action.
- Shutdown: normally, when a loss of sensing fault is detected, the control output (PWM duty of IGBT) is immediately downed to zero and the excitation on command is disregarded (this means that the HDEC2000 unit is stopped). However, in case of shunt application with no control power, the control output is downed to approximately 30% of no load excitation current to prevent the repeated fluctuation of generator voltage due to the hardware voltage buildup function.

To clear this fault, close the alarm reset digital input channel after the sensing circuit failure is corrected while internal control power is activated (in case of shunt application without external control power, close the alarm reset digital input while the generator voltage is approximately 30% …50% of rated after the prime mover is started).

Loss of power

When generator operating status meets all of below conditions and the condition is maintained for duration of pre-settled [Loss of Power Delay Time], loss of power fault is activated. During [Soft start time], loss of power fault is not enabled. loss of power fault is not latched.

(a) [Control Power Source] = [External]
(b) [Excitation Source] = [Shunt] or [PMG]
(c) Generator frequency is lower than 10Hz
(d) Dc link voltage is lower than [Loss of Power Level]
(e) Generator voltage and generator current are lower than 4% of nominal
(f) Excitation current is lower than 15 % of predefined no load excitation current

When loss of power fault is occurred, two optional protective actions called [None] and [Reset Soft Start Time] are available, and described below.

- None: No protective action is executed.
- Reset Soft Start Time: this option is very useful, if no external excitation on command contact (switch) is prepared by user, or user do not want control the excitation on command by reason of simple system configuration.

  If generator is started up from long time standstill condition, and the excitation on command is always closed, the soft start timer is may be passed its whole setting value (this phenomenon is same as that the [Soft Start Time] setting is zero). In this case, very high voltage overshoot may be obtained due to the big difference (error) between nominal voltage setpoint and very low feedback voltage (generator residual voltage). As a result of voltage overshoot, the system may be shut-downed.

  However, if [Reset Soft Start Time] option is specified, HDEC2000 software automatically resets the soft start timer at the moment of releasing the loss of power fault. This means that no very high voltage overshoot is obtained even though excitation on command is always closed. This option is disabled when [Excitation Source] = [Utility]

Diode fault monitor (DFM)

HDEC2000 unit provides Diode Fault Monitor (DFM) functions. The DFM function detects opened or shorted status of diode(s) of the rotating rectifier by following means.

During normal steady operating condition, the ripple frequency of exciter field current is calculated by using below formula in case of six-pulse rotating rectifier (three phase full bridge rectifier).

$$\mathbf{F_R = 6 * F_G} * \text{(exciter machine poles / main machine poles) in [Hz]}$$

Where: $\mathbf{F_R}$ is the ripple frequency of exciter field current in [Hz].

F_G is the frequency of main synchronous machine in [Hz].

One or more shorted diode(s) produce very high ac (ripple) component current in the exciter field circuit and the frequency of ac component is 1/6 of the ripple frequency of nominal operating condition. Also, one or more opened diode(s) produces high ac (ripple) component current in the exciter field circuit, and the frequency of ac component is 1/3 of the ripple frequency of nominal operating condition.

HDEC2000 unit separates the ripple frequency component corresponding to open and short diode condition from overall excitation current by mean of digital filter techniques.

When the processed (calculated) ripple current exceeds the pre-settled fault level and the ripple current is not decreased below the fault level within the predefined delay time, the open (or short) diode fault event is activated.

The DFM function is disabled if the excitation current is less than 1A or 80% of no load excitation current. And the DFM function is also disabled if the generator frequency is not presented between 45 …70Hz.

Output short circuit

HDEC2000 unit provides the protective function of output short circuit by mean of hardware device. Due to the relative slower processing interval of software code than physical phenomenon, software protection of excitation output short circuit is very difficult (sometimes, it is impossible). The internal measuring device detects short circuit current very fast and cuts off the excitation output power.

This function provides for preventing damage from incorrect wiring or inappropriate behavior during factory setup and commissioning. But not provides for protective function while normal operating. Be careful, short circuit of excitation output may cause unit damage since this function is not guaranteed always.

CAUTION

Short circuit protective function is tested with HDEC2000 regulator successfully. Be careful, Short circuit excitation output may cause unit damage since this function is not always guaranteed.

Mode mismatch

This function compares the digital input command (FCR mode or none-FCR mode) and actual operating mode when HDEC2000 unit is controlled remotely. If a local input command (operating mode via digital input circuit) is different with actual operation mode, then mode mismatch fault event is activated. However, this fault is not latched

For example:

When The HDEC2000 unit controlled via communication port with AVR mode, but the FCR select input circuit (digital input channel) is closed, if control mode is transferred to local mode from remote mode by [Local Request] command (or remote command), HDEC2000's operating mode is transferred to FCR mode from AVR mode. At that moment, the system may be shut downed if the difference is very high between [FCR Setpoint] and the actual-excitation-current.

So, user should match that the input command (digital input status) is same as actual operating mode before operating mode is transferred to local mode from remote control status.

SECTION 4. CONFIGURATION

INTRODUCTION

This section provides the configuration procedure of HDEC2000 unit in the factory by using the HDCM software and the description of overall configuration parameters. However some simple directions of HDCM software may be omitted to avoid complication of this section, however the operating rule of HDCM software follows the general windows software. Even though this section describes the initial configuration procedure, the most procedure of this section may be applicable for site commissioning.

The various configuration parameters required to optimize user application. However all configuration parameters may not be used essentially for practical application. Please read this section carefully for successful configuration of user's application since some incorrect configuration may result in damage to the unit or the system. For more technical information for HDEC2000 configuration, see section 3 (Functional Description).

CAUTION

Configuration of HDEC2000 unit is performed by only qualified personnel who has fully understanding about HDEC2000 unit and has intermediate or higher level knowledge about synchronous machine and excitation system.

The HDCM is configuration and monitoring software for HDEC2000 unit. This software may be used for factory setup, site commissioning. The major functions of this software are listed below.

- Configuration capability of setup parameter
- Control gains estimation from generator reactance and time constant
- Remote control and real time monitoring (provides for commissioning purpose only)

CONFIGURATION PROCEDURE

A rough configuration sequence (step) is explained below.

- Install the configuration software (HDCM) to setup computer.
- Supply external control power to the HDEC2000 unit with the generator is at standstill condition.
- Connect RS232 communication cable between HDEC2000 unit and setup computer.
- Start HDCM software.
- Establish communication between HDEC2000 unit and setup computer.
- Configure each parameter of each group by using HDCM software (Standstill Configuration).
- Write configuration parameter to EEPROM of HDEC2000 unit and store to the setup computer.
- Disconnect control power (if HDEC2000 system is designed with no external control power).
- Connect all cables between HDEC2000 and generator system.
- Operate the generator with no load.
- Tune the PID (or PI) gains of each regulation and limitation mode by using HDCM software (Running Configuration).
- Check all functions of applicable regulation mode and limitation mode, and check all applicable protective functions (e.g. AVR, OEL and DIO function …).

- Record operating condition (voltage, excitation current …).
- Apply possible load to the generator.
- If necessary, tune the PID (or PI) gains again by using HDCM software if necessary.
- Record operating condition (voltage, current, excitation current …).
- Write configuration parameter to the EEPROM of HDEC2000 unit and store to setup computer.
- Remove the load.
- Stop the generator.

The detailed procedure of each configuration step is described in below sections. For the more procedure not described in this section, see section 6 (Commissioning).

SOFTWARE INSTALLATION and COMMUNICATION

Installation and Start

To install the HDCM software in the setup computer, please carry out the following steps.

- Insert the HDCM CD in CD-ROM drive of setup computer.
- Open the windows explorer and display the CD root directory.
- Double-click [Setup.exe] from the directory [HDCM \ Installer].
- Follow the instructions that appear on the screen.

Then the [Setup.exe] file installs the HDCM software into your hard disk. The configuration software is now installed.

To start the HDCM software, Double click the HDCM shortcut via following menu path.

- [Start] – [Programs] – [Hyundai – Elec.] – [HDCM for HDEC2000]

Then HDCM screen will be appeared.

Connection (Communication) with HDEC2000 unit

To establish communication between the HDEC2000 unit and setup computer by using HDCM software, carry out the following steps.

- Supply specified external control power (not excitation power) according to drawing. If control power is not supplied permanently, supply temporarily control power (40 … 120V, ac or dc) to D1, D2 terminals.

CAUTION

First Configuration must be performed while the machine is at a standstill.

During standstill configuration, the excitation power output cable between HDEC2000 unit and the generator must be disconnected.

If temporarily control power is used (HDEC2000 system is designed with no external control power) for configuration at standstill condition, the external control power must be disconnected after standstill configuration.

- Connect RS232 cable between COM0 port of HDEC2000 front panel and serial port of setup computer.

- Start the HDCM software.
- Click [Port Configuration] sub menu via [Communication] menu bar, then Port Configuration Screen is appeared (see Figure 4-1).
- Select proper communication port (other communication parameters cannot be configured by user but pre-fixed by HDCM software and HDEC2000 unit)
- Click [Connect] command button on the Port Configuration Screen. Then communication port number is confirmed, and the Password Input Screen (see Figure 4-2) may be appeared if connection between HDEC2000 unit and HDCM software is successfully established.

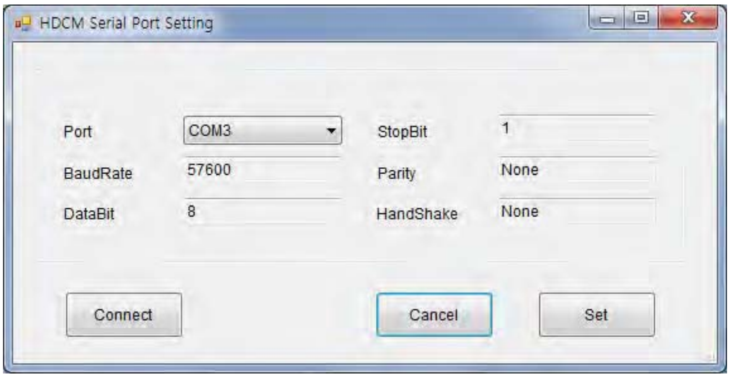


Figure 4-1 Port Configuration Screen

Figure 4-2 Password Input Screen

- Input password (The default password is **"hd2000"** or **"HD2000"**.) and click the [OK] button on the Password Input Screen.

> **Note!:**
> The lower case characters (password) and the upper case characters (password) are identified with same characters by HDEC2000 unit for password.

- The HDCM software may receive all parameters from HDEC2000 unit if password is corrected. The progress bar may be appeared during communication (data receiving).
  After few seconds, the displayed parameters on the HDCM screen are replaced (updated) with transmitted data from HDEC2000 unit.
  Now, user can access (read and write) any configuration parameters.
- Click [Close Comport] menu to disconnect communication between HDEC2000 unit and HDCM software
- If user clicks the [Set] command button on the Port Configuration Screen, the port configuration parameters are confirmed only, and the Port Configuration screen is disappeared.

After the communication connection between HDEC2000 unit and HDCM software is successfully established onetime, the next connection is archived by clicking of [Open Comport] sub menu via [Communication] menu bar.

SETUP

This section provides simple description of all configuration parameter, and provides description for PID gain tuning not described in other sections.

The configuration parameter is organized with several groups called Tab, and each group is listed below. To access parameters of each group, click the corresponding tab button placed on the top screen of HDCM software.

- Configuration
- Generator
- AVR/FCR
- VAR/PF
- Startup & Aux
- Gain Control
- Digital IO
- Protection
- Limiter
- Monitoring (This Tab is separately described in the Monitoring and Control section)

After each group's parameters are configured successfully at each active Tab screen, Click [Send to HDEC] or [EEPROM] sub menu via [Communication] menu-bar, if not so, the parameters of HDEC2000 unit are not updated with new configured parameters.

Note!:

If the [Send to HDEC] menu is clicked, the parameters of active Tab (not all parameters) are transmitted to HDEC2000 unit, but not stored into EEPROM. In this case, if the internal control power is interrupted, the all configuration parameters are lost.

If the [EEPROM] menu is clicked, the parameters of active Tab (not all parameters) are transmitted to HDEC2000 unit, and stored into EEPROM permanently. In this case, even though the internal control power is interrupted, the configuration parameters are not lost (maintained).

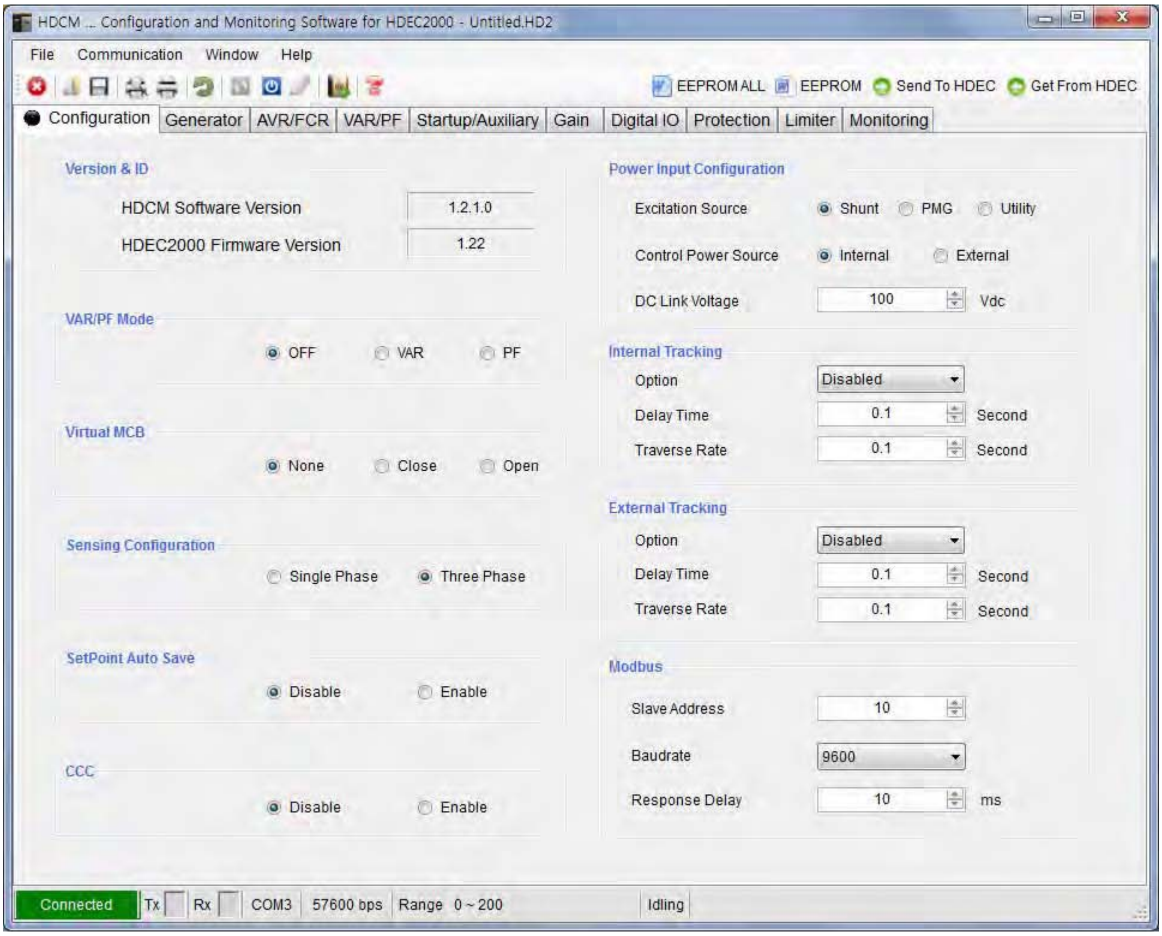
After all parameters of all groups are configured successfully, the parameters must be stored into EEPROM of the HDEC2000 unit. To save all configuration parameters onetime, click [EEPROM All] sub menu via [Communication] menu bar, then all configuration parameters of all groups are stored into EEPROM.

IMPORTANT	**Do not forget to store the parameter into EEPROM after configuration. If configuration parameters are not stored into EEPROM of HDEC2000 unit, the all configuration parameters are lost when the excitation power is interrupted.**

Configuration Tab

- Software Version: Read only parameter. Means that the HDCM version number.
- Hardware Version: Read only parameter. Means that the HDEC2000 unit's firmware version number.
- AVR ID: Reserved communication address of HDEC2000 regulator. Not used now.
- VAR/PF mode: Selects VAR mode or PF mode when FCR mode is deactivated and the both of GCB, MCB input are closed. If Off is selected then HDEC2000 unit operates with AVR mode.

- Sensing Configuration: Configures the generator voltage sensing method either single-phase or three-phase. If single phase selected then generator A, C phase must be connected to A6, A8 (Labeled E1 and E3) terminals.
- Excitation Source: Selects the kind of excitation input power (PMG, Shunt or Utility).
- Control Power Source: If optional external control power is supplied (system is designed with control power), the [External] field must be selected. Otherwise [Internal] filed is selected.
- CCC Enable Disable: Determines that the reactive differential compensation (cross current compensation) enabled or disabled. If enabled, CCC function compensates the generator voltage while the MCB digital input is closed.



- Virtual MCB: Determines the internal MCB status of HDEC2000 Software. Three options are available called None, Close, Open. Each option is described below
  - None: The MCB status of HDEC 2000 software is determined by actual hard-wire digital input.
  - Close: The MCB status of HDEC 2000 software is always close (True)
  - Open: The MCB status of HDEC 2000 software is always open (False)

  If Close, or Open option is selected, the physical input status is disregarded
- Setpoint Auto Save: If this function enabled, changed setpoint of AVR mode is automatically stored into the EEPROM while operating mode is AVR Mode. The setpoint of FCR, VAR and PF mode is not saved automatically.
- DC Link Voltage: rectified voltage level of HDEC2000 unit from excitation power input. Roughly, below formulas are applied for dc link voltage calculation.
  - DC Link Voltage = 1.41 * input ac voltage for three phase excitation power

- DC Link Voltage = 1.25 * input ac voltage for single phase excitation power
- DC Link Voltage = 0.98 * input dc voltage for dc power supplied

- Internal Tracking Option: Configures that which inactive operating mode(s) is tracked.
  - Disabled: internal tracking function is not used.
  - Auto Manual Only: internal tracking function is accepted between Auto mode and FCR mode only.
  - From VAR/PF to AVR: AVR mode is tracked while active operating mode is VAR (or PF) mode.
  - All Mode: internal tracking function is accepted between all four operating modes.
- Internal Tracking Delay Time: Target past (delay) time for internal tracking function.
- Internal Tracking Traversing Rate: The time required for internal tracking process from moment of internal tracking start time.

Below three (3) parameters are reserved for future improvement. Not used now.

- External Tracking Option: Configures enabled or disabled of external tracking function.
- External Tracking Delay Time: Target past (delay) time for external internal tracking function.
- External Tracking Traversing Rate: The time required for external tracking process from moment of internal tracking start time.

- MODBUS Device Address: Sets the MODBUS communication address. This parameter is used when Host controller accesses to the HDEC2000 unit over RS485 (COM2) ports. The usable range of communication address is 1 through 247.
- MODBUS Baud Rate: Sets the MODBUS communication baud rate. The selectable values are 2400, 4800, 9600 and 19200 [bps]
- MODBUS Response Delay: MODBUS communication response time delay of slave device. The usable range of delay time is 0 …200ms.

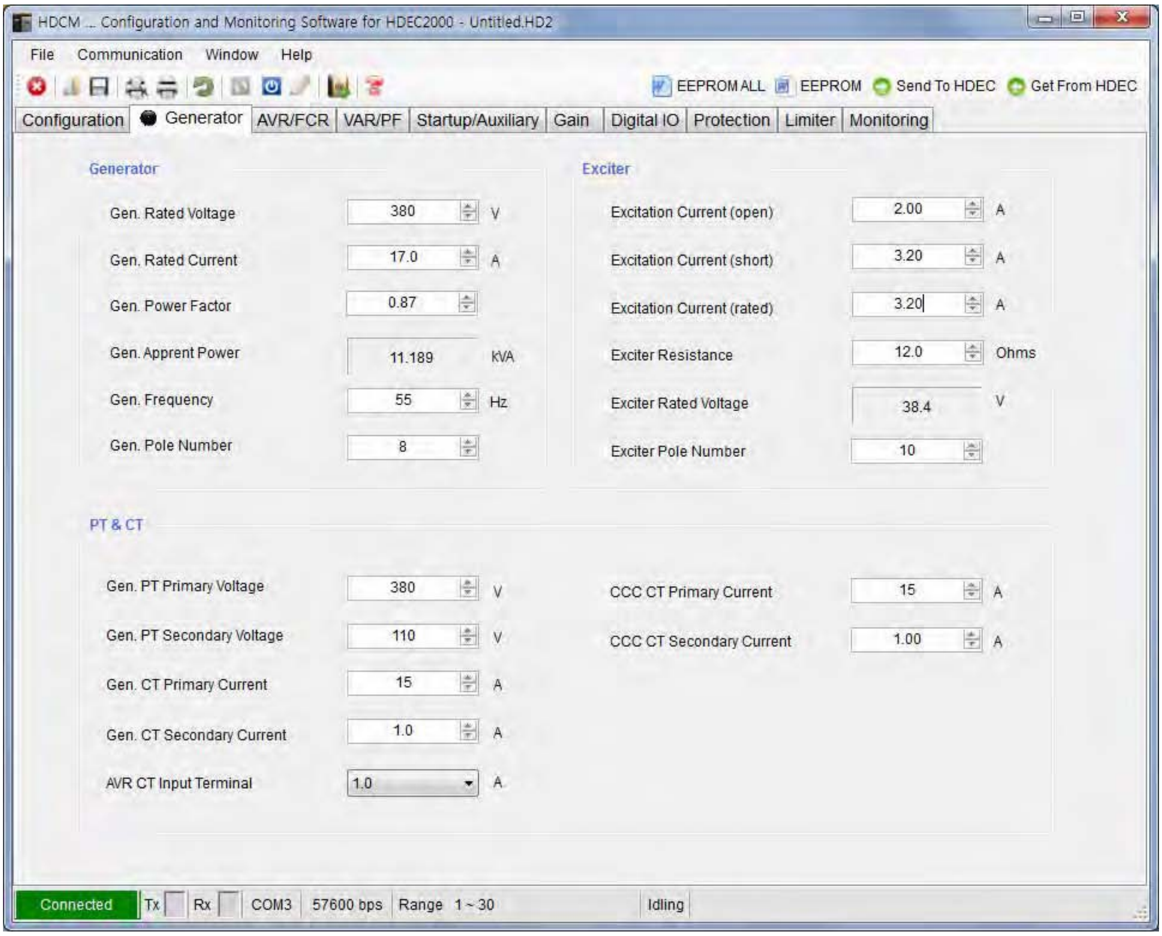
For more information of MODBUS communication, see separated MODBUS communication manual.

Generator Tab

- Gen. Rated Voltage: Amount of phase to phase generator rated voltage.
- Gen. Rated Current: Amount of generator rated phase current.
- Gen. Power Factor: Generator rated power factor.
- Gen. Apparent Power: Read only parameter. Calculated from Gen. Rated Voltage and Gen. Rated Current parameter.
- Gen. Frequency: Power Factor: Generator rated power factor.
- Gen. Pole Number: Number of poles of main machine.

- Excitation Current (open): Excitation current corresponding to the generator rated voltage with no load condition.
- Excitation Current (short): Excitation current corresponding to the generator rated current with three phase sustained short circuit condition.
- Excitation Current (rated): Amount of rated excitation current of exciter machine.

- Exciter Resistance: Resistance of excitation winding of exciter machine. Roughly, 1.15 times of exciter field resistance with cold condition may be used.
- Excitation Rated Voltage: Read only parameter. Calculated from rated excitation current and resistance of excitation winding of exciter machine.
- Exciter Pole Number: Number of poles of exciter machine.



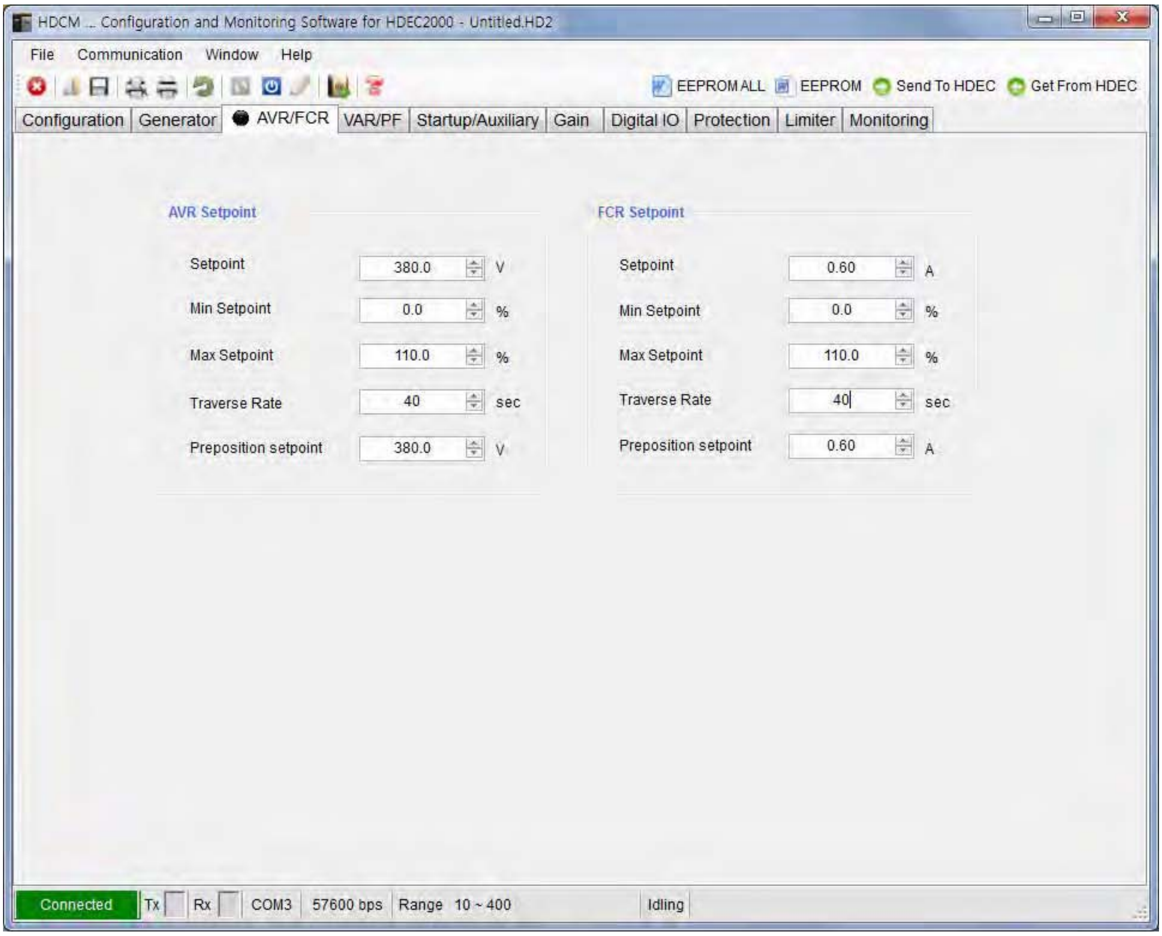
IMPORTANT	**The three components of excitation current (open, short, rated) are only approximately value. The critical comparing with the values of official specification is not needed.**

- Gen. PT Primary Voltage: Primary voltage of sensing voltage transformer. If sensing voltage transformer is not used, this value is same as Gen. Rated Voltage parameter.
- Gen. PT Secondary: Secondary voltage of sensing voltage transformer. If sensing voltage transformer is not used, this value is same as Gen. Rated Voltage parameter.
- Gen. CT Primary Current: Primary current of sensing current transformer. If sensing current transformer is not installed, this value must be settled with zero.
- Gen. CT Secondary Current: Secondary current of sensing current transformer.
- AVR CT input Terminal: Determines which current sensing input terminal is used. Only 1A or 5A is accepted for this parameter. If 1A is selected, sensing CT input must be connected on B1 terminal otherwise B2 terminal must be used.
- CCC. CT Primary Current: Primary current of cross current CT. If current transformer for CCC function is not installed, this value must be settled with zero.

- CCC. CT Secondary Current: Secondary current of cross current CT. Maximum 1A is accepted.

AVR/ FCR Tab

- AVR mode Setpoint: Setpoint of AVR operating mode. Typically nominal voltage.
- AVR mode Min. Setpoint: minimum adjustable setpoint of AVR mode based on rated generator voltage. Typically 70 … 90%.
- AVR mode Max. Setpoint: maximum adjustable setpoint of AVR mode based on rated generator voltage. Typically 110%.
- AVR mode Traverse Rate: Determines the time required to adjust the AVR setpoint from the minimum setpoint to maximum setpoint. Typically 40 … 60s.
- AVR Preposition Setpoint: Defines the pre-position setpoint of AVR mode. If programmable digital input is assigned with Preposition and corresponding input circuit is closed, AVR mode Setpoint returns to the pre-defined value (AVR Preposition Setpoint). Typically nominal voltage

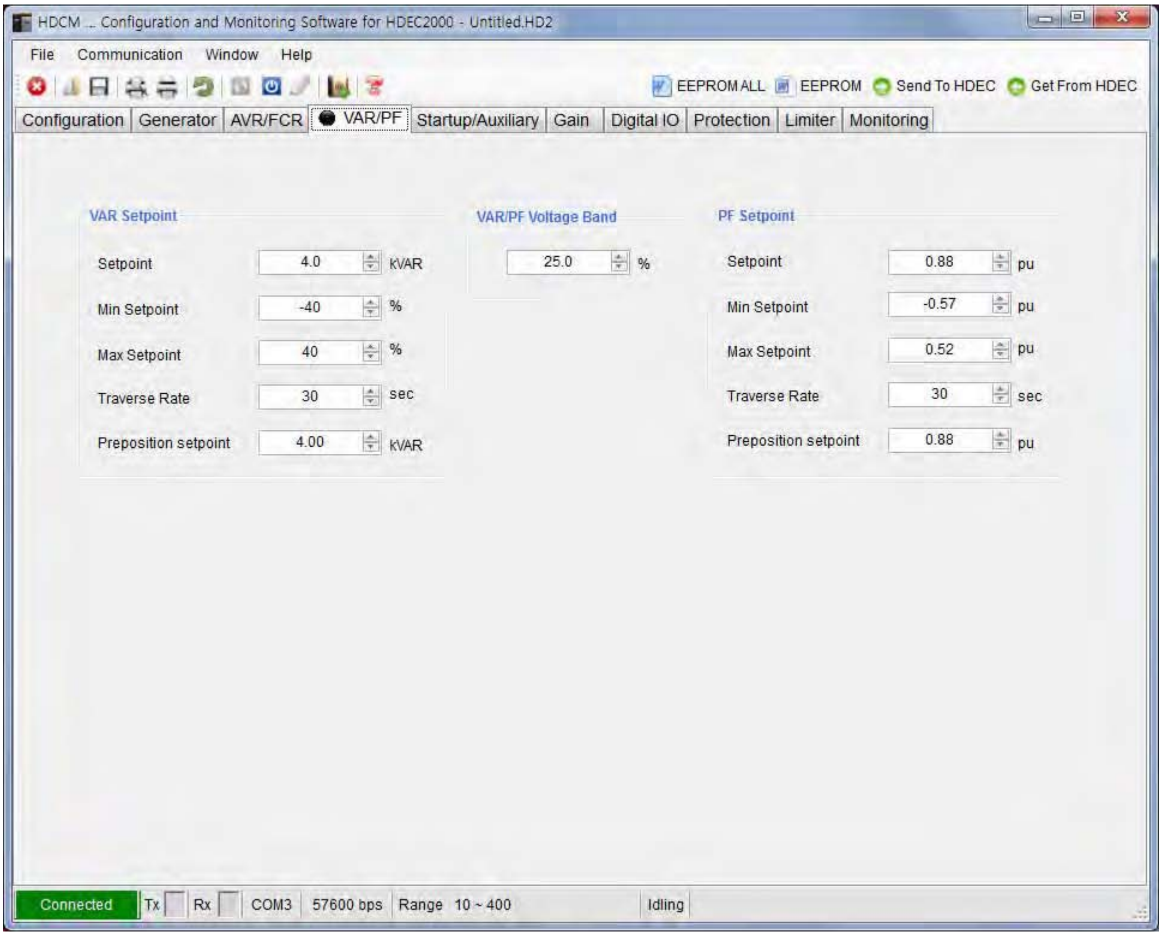


- FCR mode Setpoint: Setpoint of FCR operating mode. Typically no load excitation current or zero.
- FCR mode Min. Setpoint: minimum adjustable setpoint of FCR mode based on rated generator excitation current. Typically 0%.
- FCR mode Max. Setpoint: maximum adjustable setpoint of FCR mode based on rated generator excitation current. Typically 120%.
- FCR mode Traverse Rate: Determines the time required to adjust the FCR setpoint from the minimum setpoint to maximum setpoint. Typically 40 … 60s.

- FCR Preposition Setpoint: Defines the pre-position setpoint for FCR mode. If programmable digital input is assigned with Preposition and corresponding input circuit is closed, FCR mode Setpoint returns to the pre-defined value (FCR Preposition Setpoint). Typically no load excitation current or zero.

VAR/ PF Tab

- VAR mode Setpoint: Setpoint of VAR operating mode.
- VAR mode Min. Setpoint: minimum adjustable setpoint of AVR mode based on rated generator apparent power.
- VAR mode Max. Setpoint: maximum adjustable setpoint of VAR mode based on rated generator apparent power. Typically rated reactive power in %.
- VAR mode Traverse Rate: Determines the time required to adjust the VAR setpoint from the minimum setpoint to maximum setpoint. Typically 40 … 60s.
- VAR Preposition Setpoint: Defines the pre-position setpoint for VAR mode. If programmable digital input is assigned with Preposition and corresponding input circuit is closed, VAR mode Setpoint returns to the pre-defined value (VAR Preposition Setpoint). Typically nominal reactive power or zero.
- VAR/PF Voltage Band: Determines the boundary of voltage correction to maintained desired VAR or PF when operating mode is VAR or PF mode. If grid (power network) voltage fluctuation boundary is wide or to obtain more control margin, increase this parameter. typically 10 … 20%

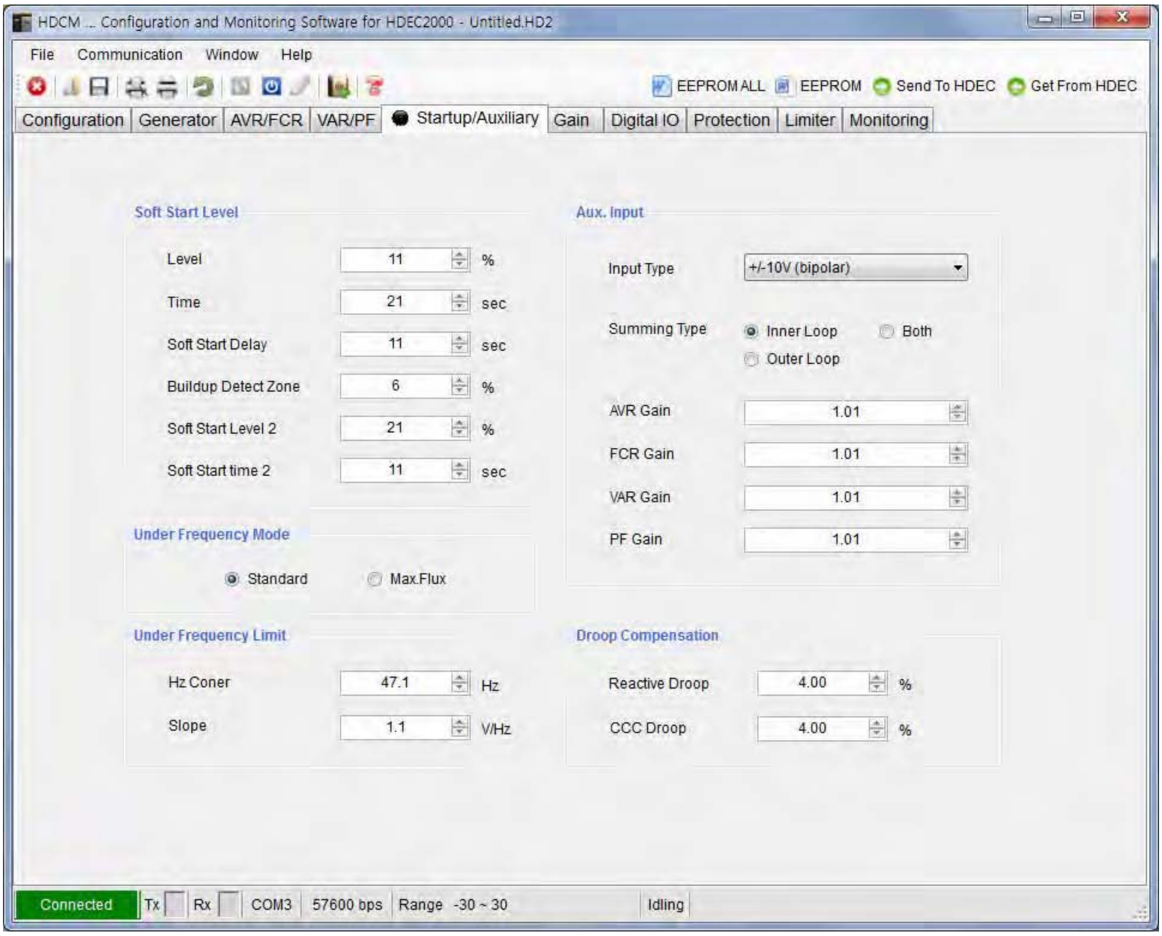


- PF mode Setpoint: Setpoint of PF operating mode. Typically 0.95 or rated power factor.
- PF mode Min. Setpoint: minimum adjustable setpoint of PF mode.
- PF mode Max. Setpoint: maximum adjustable setpoint of PF mode

- PF mode Traverse Rate: Determines the time required to adjust the PF setpoint from the minimum setpoint to maximum setpoint. Typically 40 … 60s.
- PF Preposition Setpoint: Defines the pre-position setpoint for PF mode. If programmable digital input is assigned with Preposition and corresponding input circuit is closed, PF mode Setpoint returns to the pre-defined value (PF Preposition Setpoint). Typically nominal power factor.

IMPORTANT	**Positive sign of PF setpoint means over excitation region (lagging power factor for generator, leading power factor for motor). Negative sign of PF setpoint means under excitation region (leading power factor for generator, lagging power factor for motor). This rule is applied for entirely with HDEC2000 application (setpoint setting, power factor display of front panel …)**

Startup/ Auxiliary Tab



- Soft Start Level: Determines the initial setpoint of AVR mode (and FCR mode) for soft start function when excitation on command is detected. Typically 10 …30%.
- Soft Start Time: Determines the required time for process the soft start function when excitation on command is detected. Typically 5 …15s.
- Soft Start Delay: Determines the initial delay time of Soft Start Function Typically. 0s.
- Buildup Detect Zone: Determines the automatic voltage buildup detect level. While soft start processing, if generator voltage is reached in this zone, the voltage setpoint is automatically settled with nominal

value even though the soft start processing is not completed. If this parameter is zero, this function is disabled. Typical value is 0% or 1 … 5%.

- Soft Start Level 2: Determines the initial setpoint of AVR mode for secondary soft start function when excitation on command is detected and [Soft Start 2] function is enabled by assigned digital input. Soft Start Time 2: Determines the required time for process the secondary soft start function when excitation on command is detected and [Soft Start 2] function is enabled by assigned digital input.

- Droop Compensation: Sets the amount of reactive droop compensation for parallel operation.
- CCC Droop: Sets the amount of reactive differential compensation (cross current) for parallel operation.

- Under Frequency Mode: Configures under frequency limiting mode either Std Mode or Max Flux Mode when generator frequency falls below than Under Frequency Corner Frequency. Typically Std Mode is selected.
- Under Frequency Corner Frequency (Hz Corner): Determines the frequency that under frequency limitation function is activated when generator frequency decreases. Typically 95% of nominal frequency.
- Under Frequency Slope: Determines the generator voltage reduction slope when under frequency limitation function is activated. If this slope is increased, generator voltage is more rapidly decreased depending on the generator frequency. Typically 0.8 … 1.5 V/Hz

- Aux Input Type: Selects that the kinds of auxiliary input, and defines the boundary of analog reference used with remote setpoint
- Aux input Summing Type: Selects that which operating mode uses the auxiliary input as remote setpoint. Three selectable parameters called [Inner loop], [Outer loop] and [Both] are available. If inner loop is selected, auxiliary input is summed with AVR and FCR mode setpoint (this means that auxiliary input controls generator voltage and excitation current). If outer loop is selected, auxiliary input is summed with VAR and PF mode setpoint (this means that auxiliary input controls generator VAR or PF). Otherwise auxiliary input is summed with all four operating mode setpoint.
- Aux input AVR Gain: The selected auxiliary signal (voltage or current) input is multiplied by this gain setting, and the result is summed with AVR setpoint.
- Aux input FCR Gain: same as Aux input AVR Gain. But summed with FCR setpoint instead of AVR setpoint.
- Aux input VAR Gain: same as Aux input AVR Gain. But summed with VAR setpoint instead of AVR setpoint.
- Aux input PF Gain: same as Aux input AVR Gain. But summed with PF setpoint instead of AVR setpoint.

Gain (Control Gain) Tab

This section contains the descriptions about most important configuration parameter (control gains) for optimum generator performance, and contains the directions for tuning.

General Description and Directions

Each control mode and limitation functions have its own software control (function) block, and each function block regulates the control parameter (e.g. generator voltage in case of AVR mode) corresponding to its regulation mode.

The function block(s) of HDEC2000 software operates like as below description:

First, the error (difference) between feedback signal (e.g. sensed generator voltage in case of AVR mode) and setpoint (or limitation reference) of each operating mode is calculated. Next, the error, the integral of error and the derivation of error is multiplied with each operating mode's control gains by PID algorithm. Finally, the sum of three multiplied results (control output) determines the PWM duty of power module.

This means that the error and the control gains determine (control) the excitation current. This also means that the control gains of each function blocks determine the transient response or (and) steady state stability.

Generally, three control gains called proportional gain. Integral gain and derivative gain are used for the purpose of controlling the generator voltage (or excitation current) for brushless synchronous machine. But in case of static exciter or some function blocks having shorter delayed feedback consist of only two components (proportional gain, Integral gain) of gains.

Table 4-1: Typical Range of Control Gain

Function Block	Parameter	Unit	Coarse Range	Typical Range
AVR	K_G	%	5 …30	8 …25
	K_P	-	50 …400	80 …200
	K_I	-	10 …300	50 …200
	K_D	-	2 …50	3 …20
	T_H	ms	1 …50	2 …30
	T_F	ms	0 …50	0 …30
FCR	K_G	%	20 …60	30 …40
	K_P	-	50 …200	80 …200
	K_I	-	10 …200	50 …200
VAR	K_G	%	30 …300	60 …150
	K_I	-	0.5 …20	0.5 …5
PF	K_G	-	30 …300	60 …150
	K_I	-	0.5 …20	0.5 …5
OEL	K_G	%	100 …500	100 …300
	K_I	-	0.5 …20	2 …10
SCL	K_G	%	100 …500	100 …200
	K_I	-	0.5 …10	0.5 …5
	T_D	ms	5…500	20 … 200
UEL	K_G	%	30 …300	60 …150
	K_I	-	0.5 …10	0.5…5

Note: The typical ranges (OEL, UEL and SCL) are changed from firmware V1.22

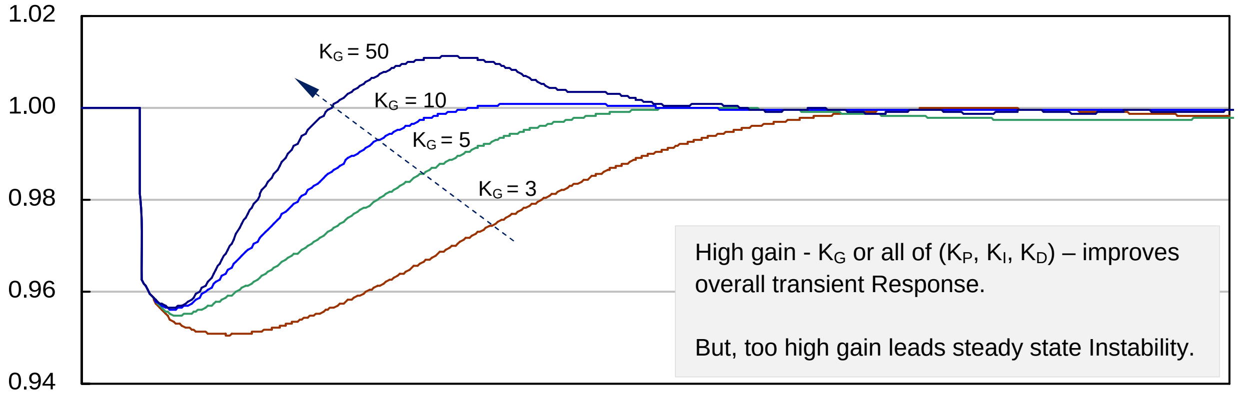


Figure 4-3 Voltage Response with Sudden Load Application *(variable K_G and Fixed K_P, K_I, K_D)*

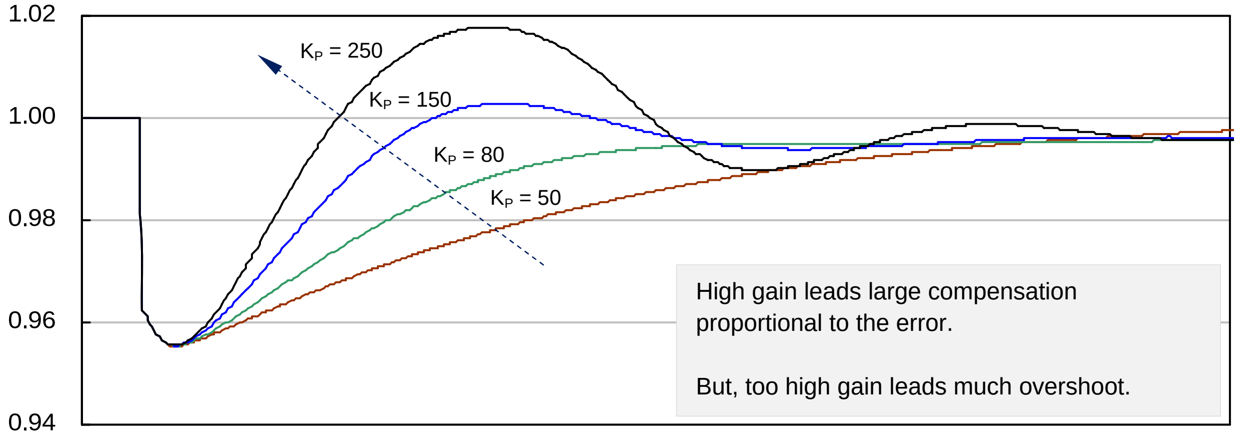


Figure 4-4 Voltage Response with Sudden Load Application *(variable K_P and Fixed K_G, K_I, K_D)*

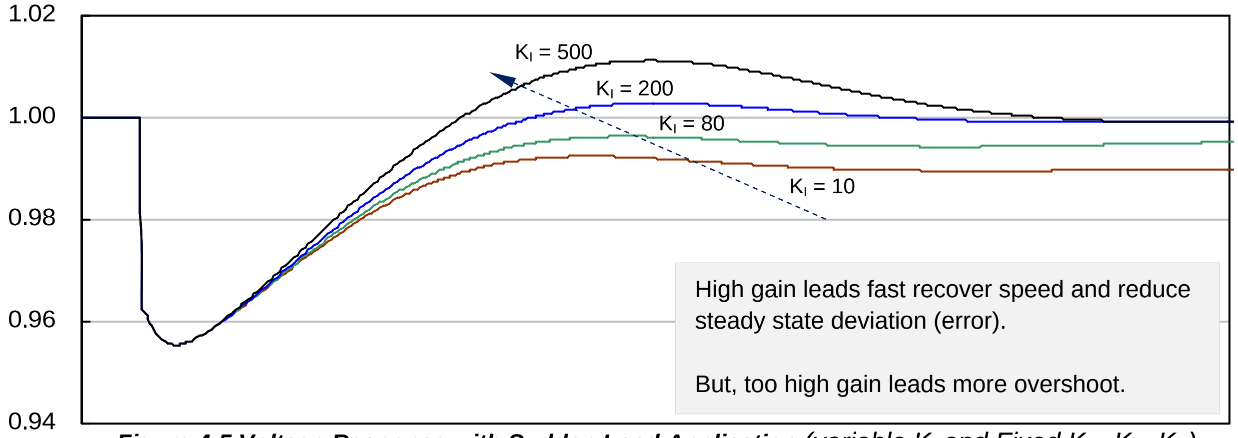


Figure 4-5 Voltage Response with Sudden Load Application *(variable K_I and Fixed K_G, K_P, K_D)*

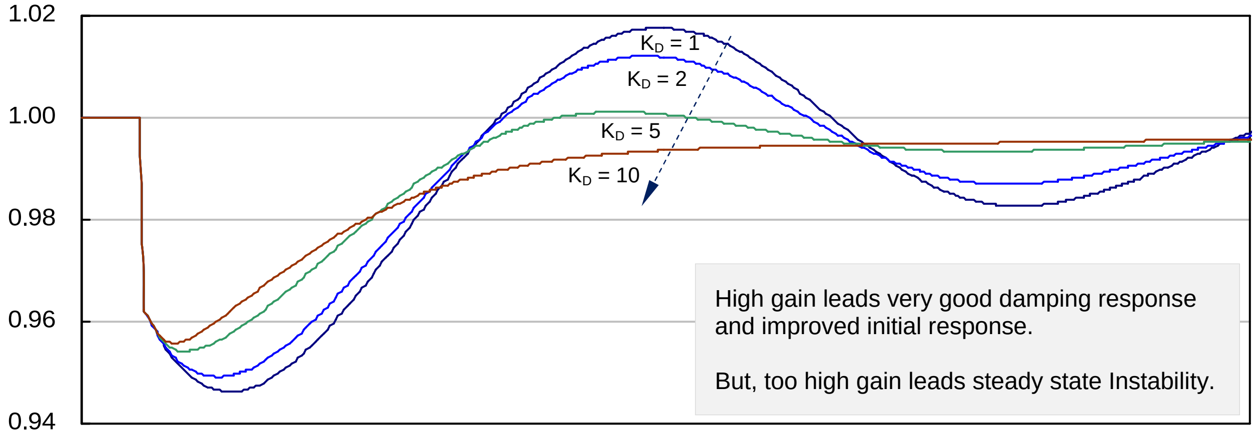


Figure 4-6 Voltage Response with Sudden Load Application *(variable K_D and Fixed K_G, K_P, K_I)*

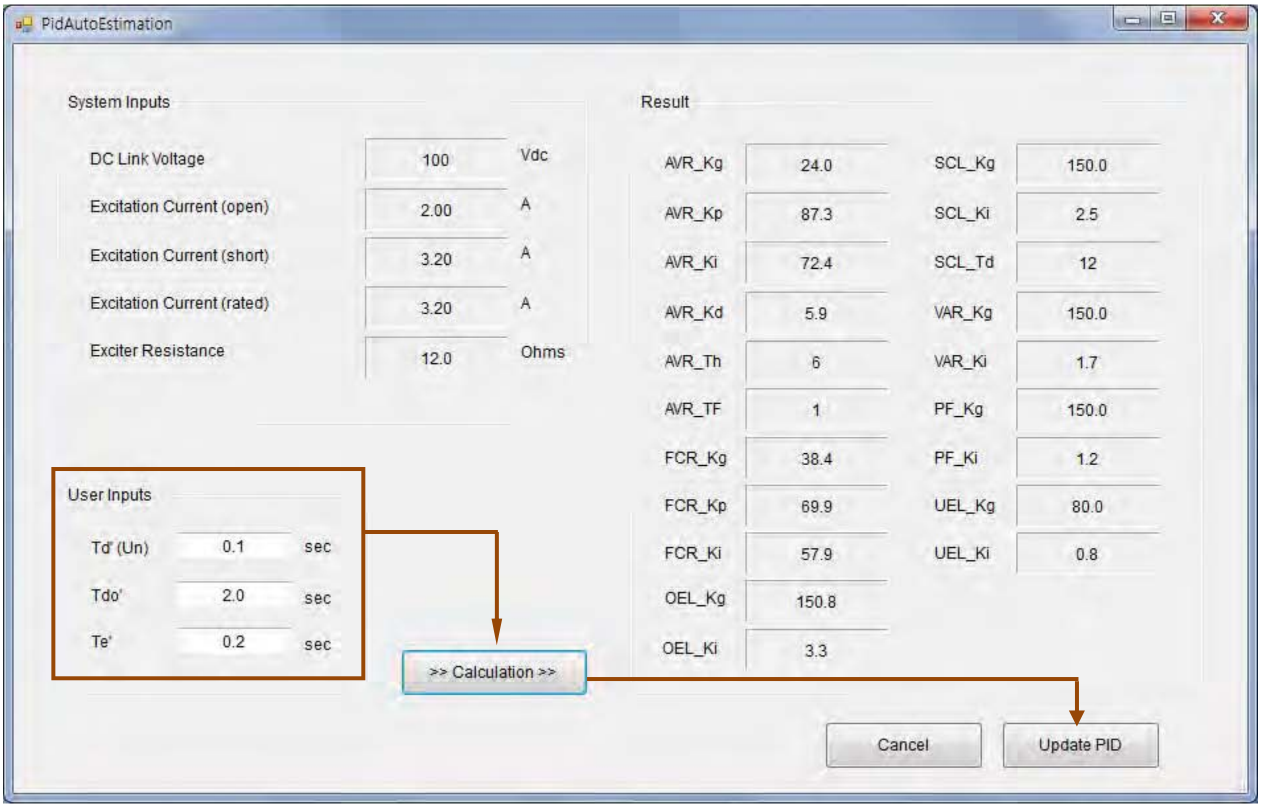
Table 4-1 illustrates the typical range of control gains of each function block from our experience, be sure, the values shown in Table 4-1 are only typical value. Optimum control gain is depending on the excitation system design, machine time constant, reactance and application. Some cases, even though the machine is same, but the optimum control gain may be different when optimum (ex: transient response or stability) criterion or the kinds of load are different. For more information about the structure of control block and control gains, see Appendix B (Mathematical Models).

Typical simulation results (voltage recovery characteristics when very big load is sudden applied) by simulation software developed by Hyundai Heavy Industrial Co., LTD with variable control gains in AVR operating mode are shown in Figure 4-3 to 4-6.
From these figures, the effects of each control gains and the generic tuning guides for PID gains can be realized.

To obtain optimum PID gains, please perform step change response by below instruction:

Change voltage setpoint (5 …10% for no load, 2 …5% for load condition) suddenly by using [Lower] or [Raise] setpoint button of Monitor Tab screen and monitor the generator voltage response by using proper instrument (e.g. chart recorder) or by manually (indicating instrument). If proper response is not obtained, tune the PID gains until satisfactory result is obtained. Normally, this procedure may be performed with no load condition first (repeat step change response with load condition if necessary). For more information about step change response, see **MONITORING and CONTROL** part of this section

Auto. Estimation Button:



The HDCM software provides estimation function for PID gains. PID Auto Estimation screen is appeared when [Auto Estimation] button located on right top screen is pressed. Few generator parameters listed below are used for calculation control gains.

- DC Link Voltage: direct current voltage level of HDEC2000 unit, rectified from excitation power input.
- Excitation Current (open): no load excitation current.
- Excitation Current (short): excitation current corresponding to rated generator current with three phase sustained short circuit condition.
- Excitation Current (Rated): excitation current corresponding to nominal generator load.
- Exciter Resistance: excitation winding resistance.
- Td'(Un): direct axis transient short circuit time constant (saturated value).
- Tdo': direct axis transient open circuit time constant.
- Te: exciter time constant.

Five parameters (DC Link Voltage, three components of excitation current and exciter resistance) are already entered in the Configuration Tab and Generator Tab. three additional parameters (Td', Tdo', Te) are required for calculation, and user must be input those parameters from design data of machine.

At this screen, HDCM software calculates PID gains of all regulation and limitation mode if [Calculation] button is pressed. Next, [Update PID] button is used to replace the PID gains of Gain-Tab's screen with newly calculated PID gains. Be sure, the calculated PID gains are only roughly estimated value. The optimum PID gain may be obtained from tuning with actual operating condition.

CAUTION

Do not use the function (PID auto estimation) while the generator is in normal service (loaded condition), It causes impact (or damage) to the generator or system due to sudden change of many control gains at same time.

Control Gain Description

- AVR Mode K_G: Determines scaling (or loop) gain of software function block for AVR mode. Generally, this gain determines the overall response of feedback loop. Below formula is applied for AVR mode loop gain calculation. However to obtain more fast (or stable) response, the AVR loop gain may be adjusted in a range of between 50 and 300% of calculated value.

$$\textbf{AVR Mode } K_G = 100 * U_{EO} \textbf{ / DC Link Voltage [\%]}$$

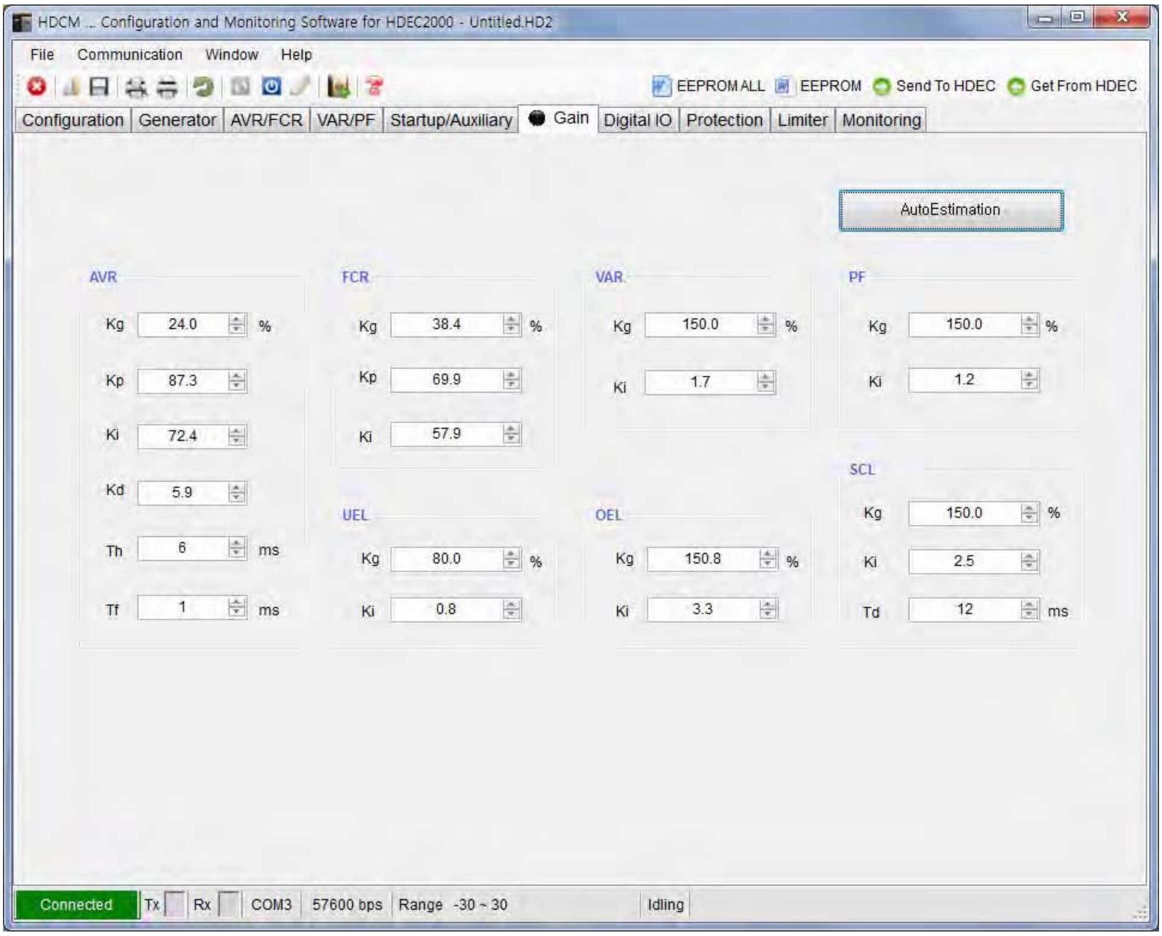
Where: U_{EO} is excitation voltage corresponding to rated generator voltage with no load condition in Volts.

DC Link Voltage is internally rectified voltage from excitation power input in Volts.

- AVR Mode K_P: Determines proportional gain of software function block for AVR mode. Generally, this gain improves transient response, but too high, the transient response has much overshoot. In normal case, this gain may be increased if machine size (time constant) is increase.
- AVR Mode K_I: Determines the Integral gain of software function block for AVR mode. Generally, this gain improves recovery speed of transient response and control accuracy of steady state. But too high, the transient response has overshoot. In normal case, the typically range is 50 … 200 and this gain may be gradually decreased if machine size (time constant) is increased. Other gains may be determined

from generator parameter. However, AVR Mode K_I may be determined from generator parameter and other control gain(s).

- AVR Mode K_D: Determines derivative gain of software function block for AVR mode. Generally, this gain improves steady state stability and initial response. But too high, unstable fluctuation may be occurred with steady state and the recovery speed may be very poor. If main machine and exciter machine time constants are increased, this gain may be increased also.
- AVR Mode T_H: Determines sampling interval of derivation error (the variation slope of generator voltage) calculation. Shorter T_H improves the dynamic response of system. But too short, the system may be unstable in case of system has much sensing noise. If main machine time constant is increased, increase this parameter (time interval).
- AVR Mode T_F: Determines the filtering time constant of derivation error. T_F reduce (improves) the influence of much sensing noise of system and increases stability. But too high, the dynamic response is decreased and system stability is also decreased due to the time delay of derivative action. Typically, 0 …100% of AVR mode T_H is applicable depending of sensing noise.



- FCR Mode K_G: scaling (or loop) gain of software function block for FCR mode. Generally, this gain determines the overall response of feedback loop. Below formula is applied for FCR mode loop gain calculation.

FCR Mode $K_G = 100 * U_{EN}$ / DC Link Voltage [%]

Where: U_{EN} is rated excitation voltage calculated from rated excitation current and exciter field resistance in Volts.

DC Link Voltage is internally rectified voltage from excitation power input in Volts.

- FCR Mode K_P, K_I: Determines proportional gain and Integral gain of software function block for FCR mode. These gains serve same manner as AVR mode control gain.

- VAR Mode K_G, K_I: Determines loop gain and integral gain of software function block for VAR mode. These gains serve same manner as AVR mode control gain.

- PF Mode K_G, K_I: Determines loop gain and integral gain of software function block for PF mode. These gains serve same manner as AVR mode control gain.

- OEL Mode K_G, K_I: Determines loop gain and integral gain of software function block for OEL mode. These gains serve same manner as AVR mode control gain.

- SCL Mode K_G, K_I: Determines loop gain and integral gain of software function block for SCL mode. These gains serve same manner as AVR mode control gain.
- SCL Mode T_D: Determines time constant for determining (predicting) future stator current error. T_D Improves dynamic response. But too high, the system may be fluctuated unstably. If main machine time constant is high, then increase this parameter (time constant) also.

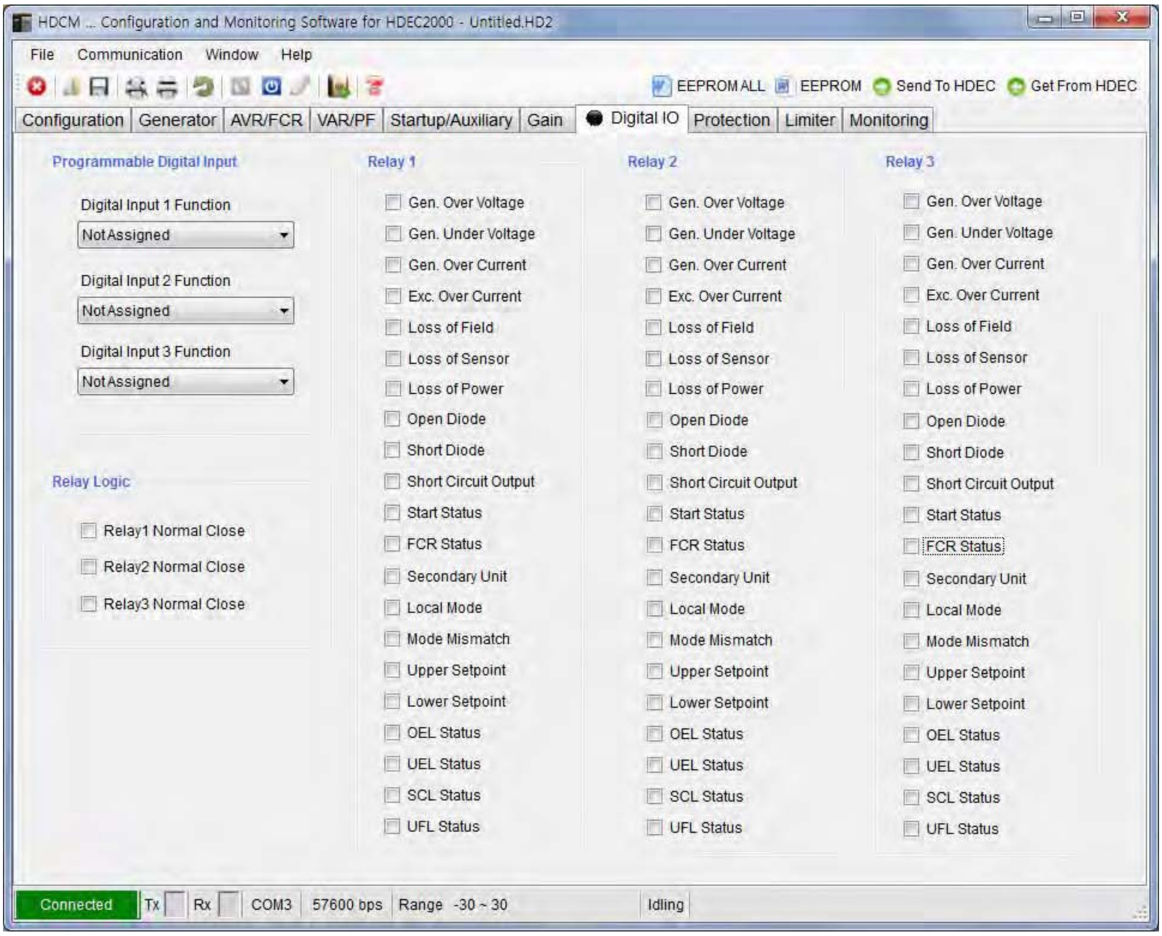
- UEL Mode K_G, K_I: Determines loop gain and integral gain of software function block for UEL mode. These gains serve same manner as AVR mode control gain.

Digital IO (Input and Output) Tab

- Programmable Digital Input (#1, #2 and #3) Function: These fields determine that which function is activated (or performed) when corresponding programmable digital input circuit is closed. Five Assignable functions are available called None, Preposition, secondary unit, local request and secondary soft start. Each option is described below
  - None: No function is assigned.
  - Preposition: If corresponding digital input circuit is closed, setpoint of four operating modes returns to pre-defined value called preposition setpoint.
  - Secondary Unit: This function is reserved, and not available now
  - Local Request: This function determines that the local command (excitation on or FCR select command only) is priority. But remote two commands via RS232 and RS485 port are not accepted.
  - Secondary Soft Start: Enabled or disabled the secondary soft start functions. If corresponding digital input circuit is closed, the parameters (soft start level 2 and soft start time 2) are used instead of (soft start level and soft start time) parameters.

- Relay Logic (#1, #2 and #3): Configures the output relay logic (either normally open or normally closed) when assigned event is activated and the relay is energized. Relay outputs cannot remain closed status when internal control power is interrupted.

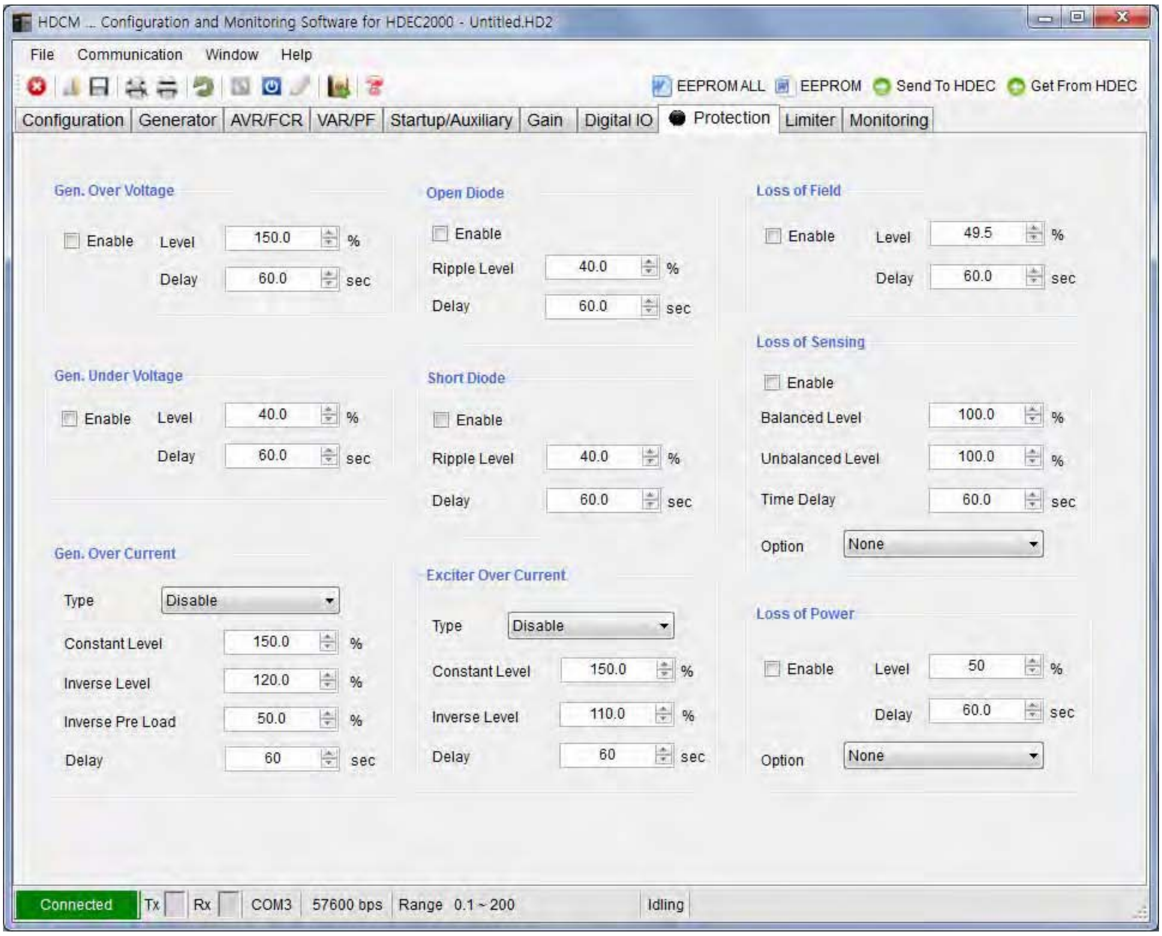
- Relay (Digital Output) Function (#1, #2, #3): Assigns the function (event or status) of output relay. Most of operating status, events can be assigned. Assignable status and event are shown on Digital Input and Output Tab screen.



Protection Tab

- Gen. Over Voltage Enabled: Determines that the generator over voltage protective function enabled or disabled. If disabled, even though the generator voltage rises over than trip level and maintained longer than delay time, the generator over voltage fault event is not occurred (activated).
- Gen. Over Voltage Level: Sets the trip (trigger) level of generator over voltage protective function based on rated generator voltage. If generator voltage rises over than this setting, the generator over voltage fault is triggered, but fault event is not occurred (activated) until generator over voltage delay time is passed.
- Gen. Over Voltage Delay: Sets the amount of delay time for generator over voltage protective function.

- Gen. Under Voltage Enabled: Determines that the generator under voltage protective function enabled or disabled.
- Gen. Under Voltage Level: Sets the trip (trigger) level of generator under voltage protective function based on rated generator voltage.
- Gen. Under Voltage Delay: Sets the amount of delay time for generator under voltage protection function.



- Gen. Over Current Type: Determines the generator over current protective function type. Four selectable options called [Disable], [Constant Time], [Standard Inverse Time] and [Preload Inverse Time] are available.
- Gen. Over Current Level: Sets the trip (trigger) level of generator over current protective function for constant time protective function.
- Gen. Inverse OC Level: Sets the safe operation level of inverse and preload inverse over current protective function based on generator rated current.
- Gen. Inverse OC Preload: Sets the preload current level based on the Gen. Inverse OC Level.
- Gen. Over Current Delay: Sets the amount of delay time for generator over current protective function.

- Exc. Over Current Type: Determines the exciter over current protective function type. Four selectable options called [Disable], [Constant Time], [Standard Inverse Time] and [Preload Inverse Time] available.
- Exc. Over Current Level: Sets the trip (trigger) level of exciter over current of constant time protective function.
- Exc. Inverse OC Level: Sets the safe operation level of standard inverse and preload inverse exciter over current protective function based on rated excitation current.
- Exc. Over Current Delay: Sets the amount of delay time for exciter over current protective function

- Loss of Field Enabled: Determines that the loss of field protective function enabled or disabled.
- Loss of Field Level: Sets the trip (trigger) level of loss of field protective function.
- Loss of Field Delay: Sets the amount of delay time for loss of field protective function.

IMPORTANT	**Even though the actual sign of reactive power is negative for triggering the loss of field fault, the parameter (Loss of Field Level) must be configured with absolute value (positive sign).**

- Loss of Sensing Enabled: Determines that the loss of sensing protective function enabled or disabled.
- Loss of Sensing Balanced Level: Sets the trip level that compared with averaged (in case of 3-phase sensing) sensing generator voltage, based on generator rated voltage. Typically 80%.
- Loss of Sensing Unbalanced Level: Sets the trip level which compared with any phase-phase sensed voltage difference, based on generator rated voltage. Typically 20%.
- Loss of Sensing Delay: Sets the amount of delay time for loss of sensing protective function. Typically 0.2 … 1s
- Loss of Sensing Option: Determines that which option serves protective action when loss of sensing fault is occurred. For more information, see section 3 (Functional Description).

- Loss of Power Enabled: Determines that the loss of power protective function enabled or disabled.
- Loss of Power Level: Sets the trip (detecting) level which compared with internally rectified excitation input power (dc link voltage), based on nominal dc link voltage configured by dc link voltage parameter. Typically 15%
- Loss of Power Delay: Sets the amount of delay time for loss of power protective function.
- Loss of Power Option: Determines that which option serves protective action when loss of power fault is occurred. For more information, see section 3 (Functional Description).

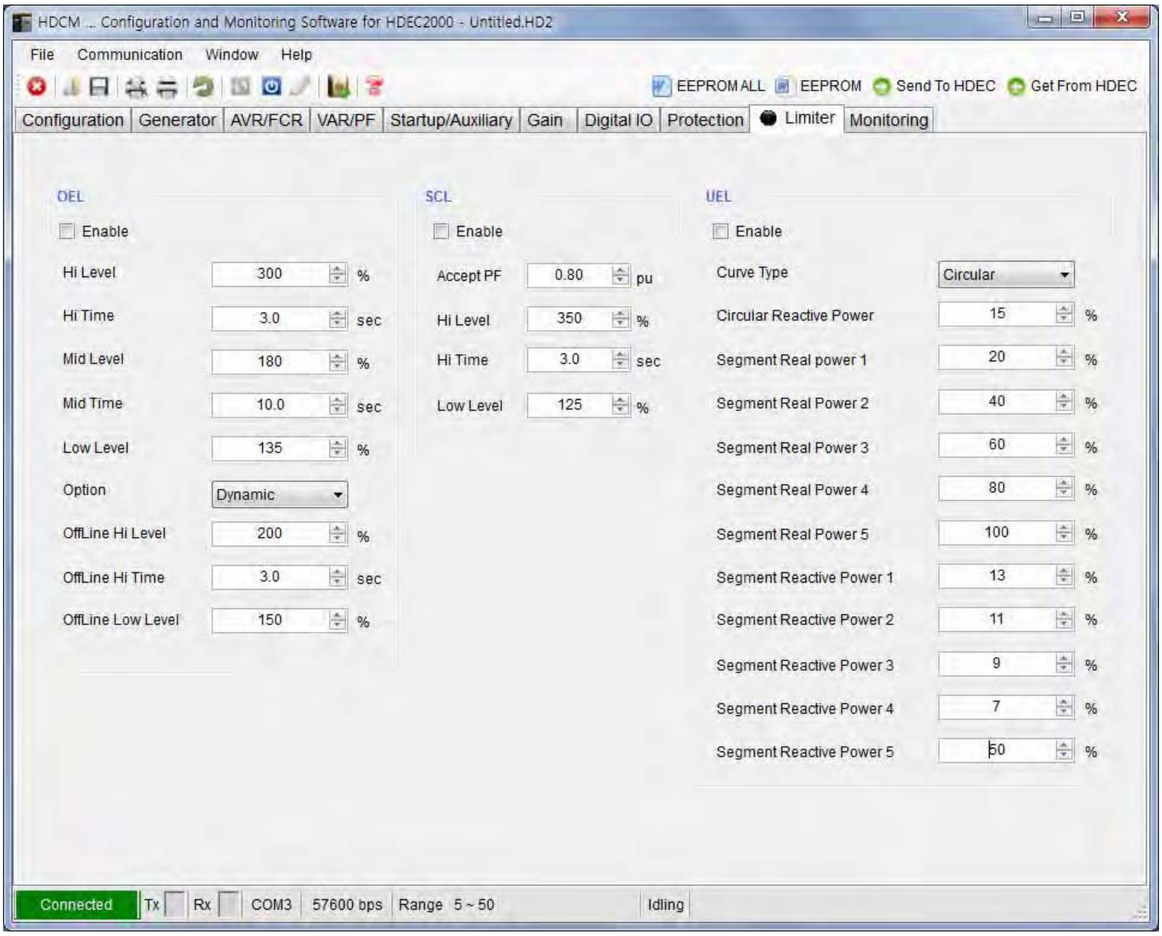
- Open Diode Enabled: Determines that the DFM (open diode) monitor function enabled or disabled.
- Open Diode Ripple: Sets the fault detecting ripple level of DFM (open diode) function.
- Open Diode Delay: Sets the amount of delay time for DFM (open diode) function.

- Short Diode Enabled: Determines that the DFM (diode fault monitor – short diode status) monitor function enabled or disabled.
- Short Diode Ripple: Sets the fault detecting ripple level of DFM (short diode) function.
- Short Diode Delay: Sets the amount of delay time for DFM (short diode) function.

Limiter Tab

- OEL Enabled: Determines that the OEL function enabled or disabled.
- OEL Hi Level: Sets the on line OEL Hi current level based on rated excitation current
- OEL Hi Time: Sets the on line OEL Hi Time duration
- OEL Mid Level: Sets the on line OEL Mid current level based on rated excitation current
- OEL Mid Time: Sets the on line OEL Mid Time duration
- OEL Low Level: Sets the on line OEL Low current level based on rated excitation current
- On line OEL Option: Sets the On-Line OEL enabling logic.
- Off-Line OEL Hi Level: Sets the off line OEL Hi current level based on no load excitation current
- Off-Line OEL Hi Time: Sets the off line OEL Hi Time duration
- Off-Line OEL Low Level: Sets the off line OEL Low current level based on no load excitation current

IMPORTANT	**The base current of On-line OEL and Off-line OEL are different with each other. The On-Line OEL current level must be determined based on rated field current. The Off-Line OEL current level must be determined based on no load excitation current.**



- SCL Enabled: Determines that the SCL function enabled or disabled.
- SCL Accept PF: Sets the accepted power factor level for SCL function, if the generator power factor is over then this parameter with positive band, the SCL function is disregarded. If this parameter is configured higher than 0.97, this parameter is neglected.
- SCL Hi Level: Sets the SCL Hi current level based on rated generator current
- SCL Hi Time: Sets the SCL Hi Time duration.
- SCL Low Level: Sets the SCL Low current level based on rated generator current.
- SCL Td: Sets the SCL error prediction time.

- UEL Enabled: Determines that the UEL function enabled or disabled.
- UEL Curve Type: Determines which curve is used for UEL function.
- Circular Reactive power: base reactive power for Circular UEL.
- Segment Real Power #1 … #5: active power point #1 to #5 for Multi Segment UEL.
- Segment Reactive Power #1 … #5: reactive power point #1 to #5 for Multi Segment UEL.

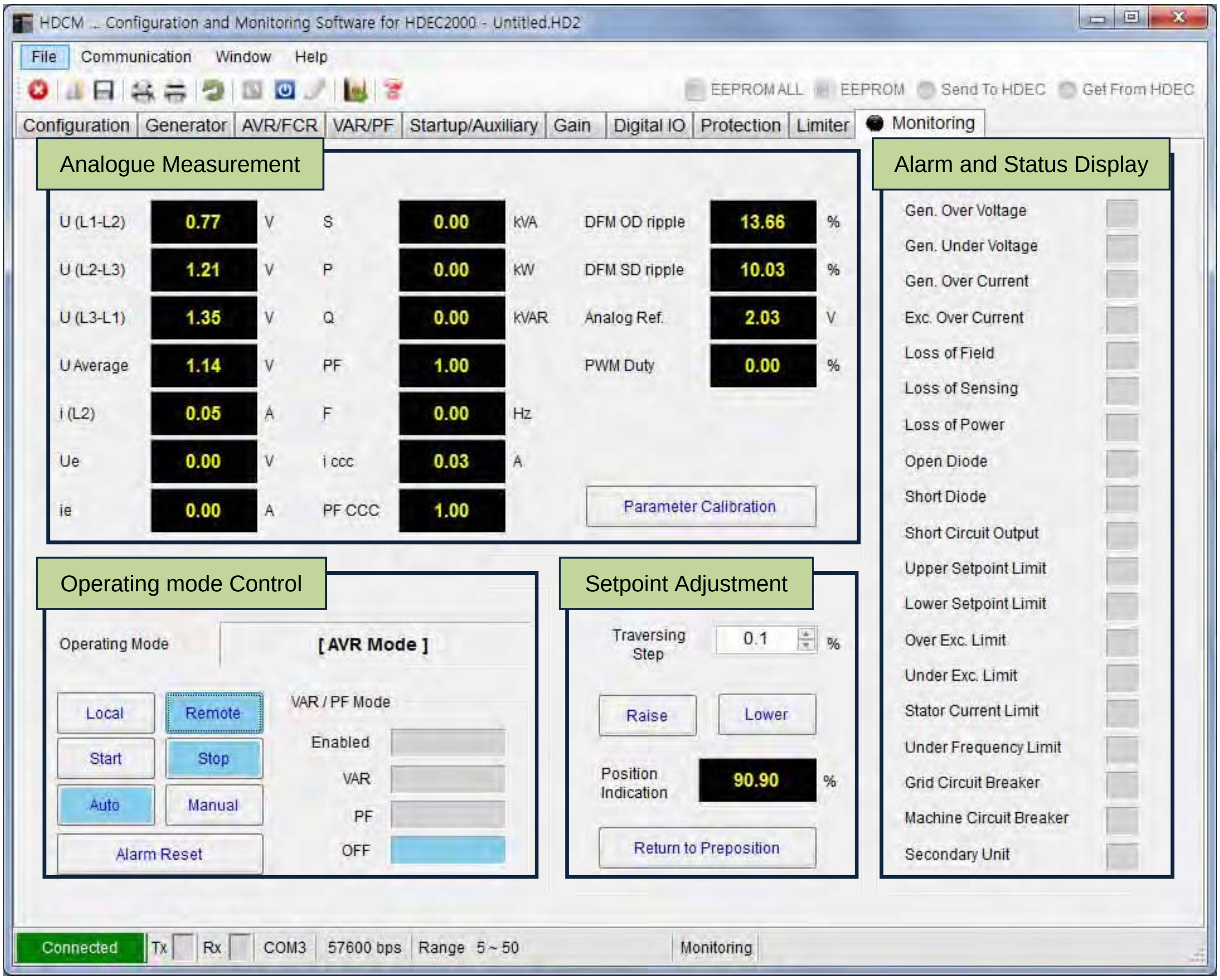
MONITORING and CONTROL

Monitor Tab

The Monitor Tab is not used for parameter configuration but used for monitoring and remote control during factory setup or site commissioning.

All monitoring (measurement of analogue parameters and the statuses of digital IOs) and remote control for commissioning (for factory or site) can be performed by using HDCM software at Monitor Tab screen and the control capability is listed below.

- Remote and Local mode transfer
- Start and Stop control
- Auto an manual mode transfer
- Alarm Reset
- Setpoint Adjustment (including preposition setpoint and step change) for all operating mode
- Parameter Calibration function (DC Link Voltage and no load excitation current)



Monitoring Tab screen is divided with four areas (Analogue Measurement, Alarm and Status Display, Operating Mode Control and Setpoint Adjustment). Table 4-2 to Table 4-4 illustrates the function of each component (button, lamp or box ...) and the description of displayed parameter.

Table 4-2 Analogue Measurement Area Description

Display Label	Unit	Description (displayed parameter)
U (L1-L2)	V	Generator A-B phase-phase voltage
U (L2-L3)	V	Generator B-C phase-phase voltage
U (L3-L1)	V	Generator C-A phase-phase voltage
U Average	V	Generator 3 phase averaged voltage In case of single phase same as U(L3-L1)
i (L2)	A	Generator B phase current
Ue	V	Calculated excitation voltage from dc link voltage
Ie	A	Excitation current
S	kVA	Generator Apparent power
P	kW	Generator active power Positive: generator, Negative: motor
Q	kVAR	Generator reactive power Positive: over excitation, Negative: under excitation
PF	pu	Generator power factor Positive: over excitation, Negative: under excitation
F	Hz	Generator frequency
I ccc	A	CCC loop current
PF ccc	pu	CCC loop power factor
DFM OD ripple	%	Diode fault monitor open diode band ripple (rms ripple)
DFM SD ripple	%	Diode fault monitor short diode band ripple (rms ripple)
Analog Ref.	V	Converted Auxiliary input signal
PWM duty	%	PWM duty

Parameter Calibration Button:

If this button is pressed, two parameters (DC Link Voltage and no load excitation current) are replaced with actual measured value by HDEC2000 unit instead of user’s setting. But this function is accepted when the generator is operated with no load and rated voltage. If this button is pressed while the generator is operated with load, the HDCM software disregards this command.

Table 4-3 Description for Operating mode Control Area

Name (Display Label)	Description (Function)
Operating Mode Label	● Displays active operating mode
Local / Remote Button	● Selects Local / Remote mode ● Indicates Local / Remote status
Start/ Stop Button	● Determines that the Start/Stop status ● Indicates Start/Stop status ● Enabled when Remote mode
Auto/ Manual Button	● Determines the Auto/ Manual mode ● Indicates the Auto/ Manual mode status ● Enabled when Remote mode
VAR/PF mode Lamps	● Enabled Lamp: Indicates VAR/PF Enabled parameter setting ● VAR Lamp: ON if VAR mode is selected ● PF Lamp: ON if PF mode is selected ● OFF Lamp: ON if VAR/PF mode is not selected

Name (Display Label)	Description (Function)
Operating Mode Label	● Displays active operating mode
Alarm Reset Button	● Resets all latched alarm (fault)

Table 4-4 Description for Setpoint Adjustment Area

Name (Display Label)	Description (Function)
Traversing Step Box (*1)	Sets the amount of setpoint change when Rise (or Lower) setpoint button is clicked onetime
Raise Setpoint Button (*1)	Increases the setpoint of active mode
Lower Setpoint Button (*1)	Decreases the setpoint of active mode
Position indication Box	Display the related position of active mode's setpoint
Return to Preposition Button	Changes setpoint of all four operating mode to Preposition setpoint

Notes

1. To perform step change response, input 5% to10% in the [Traversing Step Box] and click the [Lower Setpoint Button] or [Raise Setpoint Button] with no load condition, but the setpoint change step for load condition may be limited (less than 2 …5%).
2. For normal adjustment (control) of setpoint, input 0.1% to 0.5% in the [Traversing Step Box] and click the [Lower Setpoint Button] or [Raise Setpoint Button].

Monitoring Tab screen is divided with four areas (Analogue Measurement, Alarm and Status Display, Operating Mode Control and Setpoint Adjustment). Table 4-2 to Table 4-4 illustrates the function of each component (button, lamp or box ...) and the description of displayed parameter.

MENU NAVIGATION

This section provides the simple description of menu tree of HDCM software and the function of each menu. Figure 4-7 shows the menu tree of HDCM software. User can access each menu by using of tool bar placed on top screen instead of menu bar.

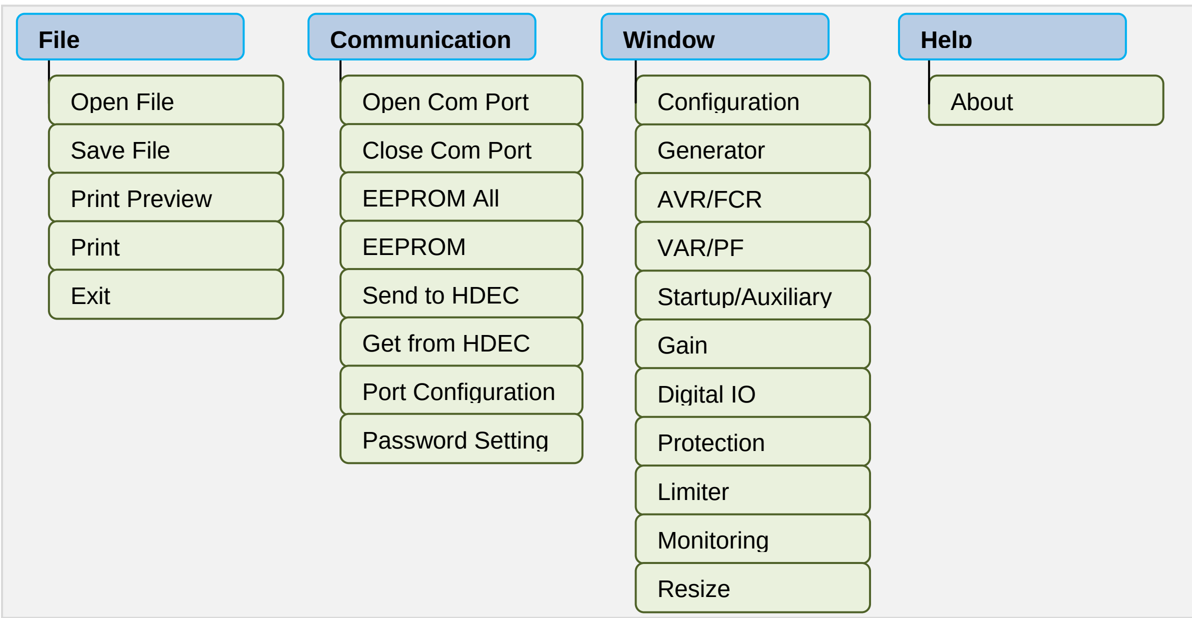


Figure 4-7 Menu Tree of HDCM Software

File Menu

- Open File: Click this menu to open configuration file which is early saved at computer storage (hard disk). If file open dialogue box is appeared, select file you want to open and click [OK] button.
    (a) If communication is established between HDEC2000 unit and HDCM software, overwrite warning message box will be appeared. If you select [Yes] button, all configuration parameters stored into the computer hard disk are transmitted to HDEC2000 unit. And displayed parameters on the selected Tab screen are updated from parameter file. If you select [No] button, file is not opened.
    (b) If communication is not established between HDEC2000 unit and HDCM software, only displayed parameters on the selected Tab screen are updated from parameter file.

IMPORTANT	**Do not open configuration file while generator is in service condition (no load or load). If communication is established between HDEC2000 unit and HDCM software, It (open file while the generator serviced) may cause damage to the HDEC2000 unit and also generator.**

- Save File: Click this menu for saving configuration parameters into the computer storage.
- Print Preview: Click this menu to review the contents (configuration parameter list) to print.
- Print: Click this menu for print configuration parameter.
- Exit: Click this menu to exit the HDCM software.

Communication Menu

- Open Com Port: Click this menu for communication connecting between HDEC2000 unit and HDCM software.
- Close Com Port: Click this menu for communication disconnecting between HDEC2000 unit and HDCM software.
- EEPROM All: Click this menu to store all configured parameters (not active Tab only) into EEPROM of HDEC2000 unit. If this action is not performed, the configuration parameter is lost when the excitation input power (and control power) is (are) interrupted.
  If possible, do not use (click) this menu while the generator is at a service condition (load condition), it can leads momentary generator voltage fluctuation due to the influence caused from large configuration parameters transmission via communication port.
  To store few parameters corresponding to certain Tab while generator is at a service operation, use [EEPROM] menu instead of [EEPROM All] menu, then the parameters corresponding to active Tab are only stored.
- EEPROM: Click this menu to store the configured parameters corresponding to active Tab (not all parameters) into EEPROM of HDEC2000 unit

IMPORTANT	**Be careful, when [EEPROM] menu clicked, configuration parameters corresponding to inactive Tabs are not stored. But, parameters corresponding to active Tab only are stored into EEPROM.** **However, in below three cases, all configuration parameters of all Tabs are saved.** ● **If user clicks [EEPROM All] menu.** ● **If user selects [Yes] button on the save dialog screen when [Close Com Port] menu bar clicked.** ● **If user selects [Yes] button on the save dialog screen when [Exit] menu bar clicked while communication is established**

- Send to HDEC: Click this menu for sending configuration parameters to the HDEC2000 unit. Only displayed parameters on the selected (active) Tab screen are transmitted.
- Get from HDEC: Click this menu to receive parameter corresponding to selected Tab screen from HDEC2000 unit
- Port Configuration: Click this menu for editing communication parameter.
- Password Change: Click this menu to change the password of HDEC2000 uni**t.** If communication between HDEC2000 unit and setup computer is not established, this sub-menu is not enabled.

Window Menu

- Each sub menu of window menu except [Resize] menu activates tab screen corresponding to each sub menu. Instead of window sub menu, user can use tab button placed on the top screen.
- Resize: Click this menu to recovery window size of HDCM software if the window size is adjusted

Help Menu

- Information: information message about the HDCM software will be appeared if this menu is clicked.

SECTION 5. USER INTERFACE

INTRODUCTION

This section describes the functions, display parameters and operation procedure of user interface of HDEC2000 unit. Much upgrade of firmware for user interface is accomplished from old version, so, instructions of user interface in this manual (version D) only can be applied for firmware version 1.22 or later. For firmware version older than V1.22, see user manual version C

The HDEC2000 unit has very simple user interface consists of LCD display, LED lamps and operational buttons. All components of user interface are located on the front panel. Each component is shown in Figure 5-1.

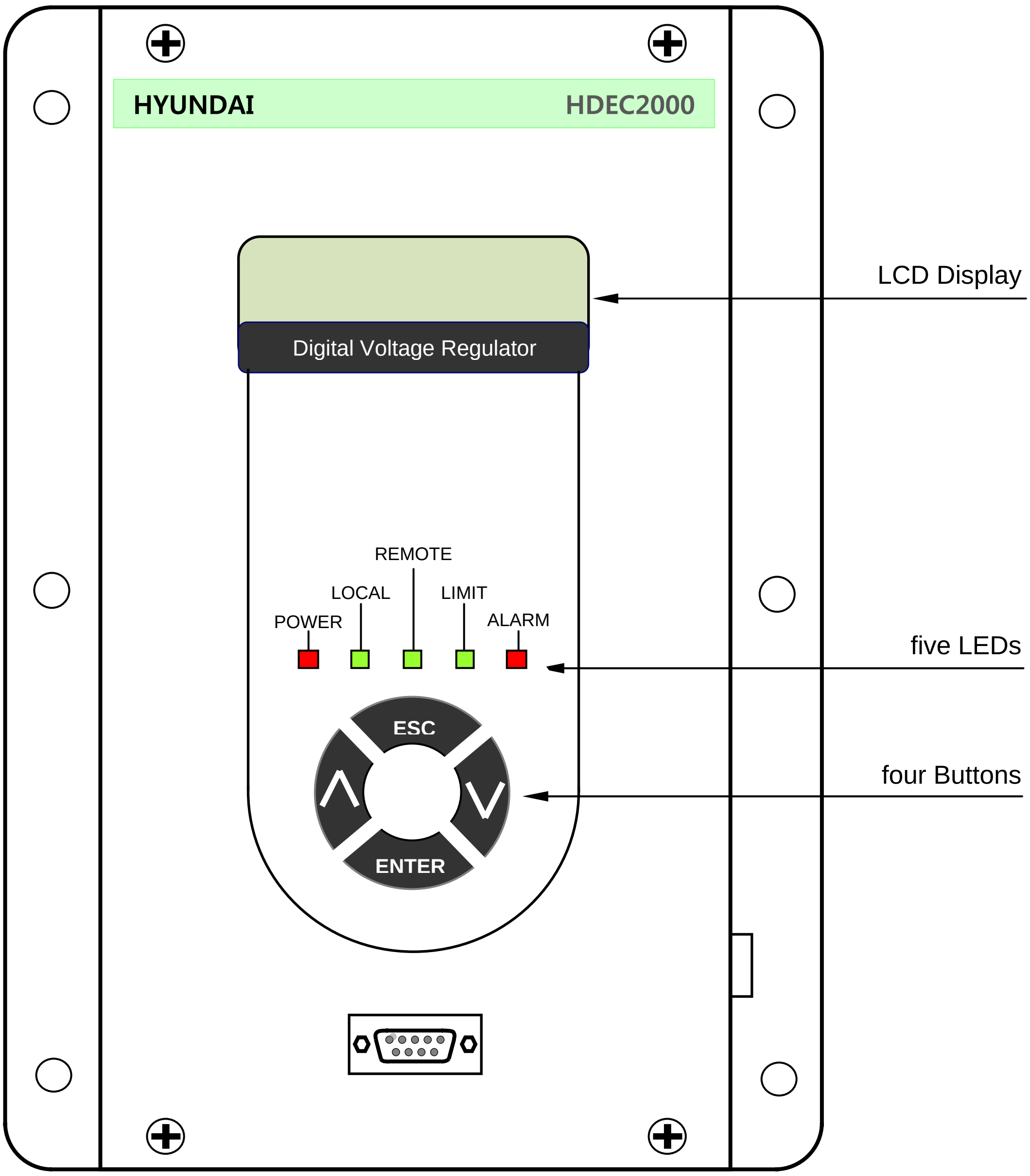


Figure 5-1 Front Panel User Interface

OPERATION

Normally, the most accesses with HDEC2000 unit are achieved via RS232 communication while factory setup or commissioning. However, for service engineer not caries setup computer, or if the HDEC2000 unit is installed on the place to difficult access with setup computer, the HDEC2000 unit provides the capability for configuration of important parameters, some operational functions and enhanced measurement functions (display function).

Figure 5-1 graphically shows operation sequence of front panel button

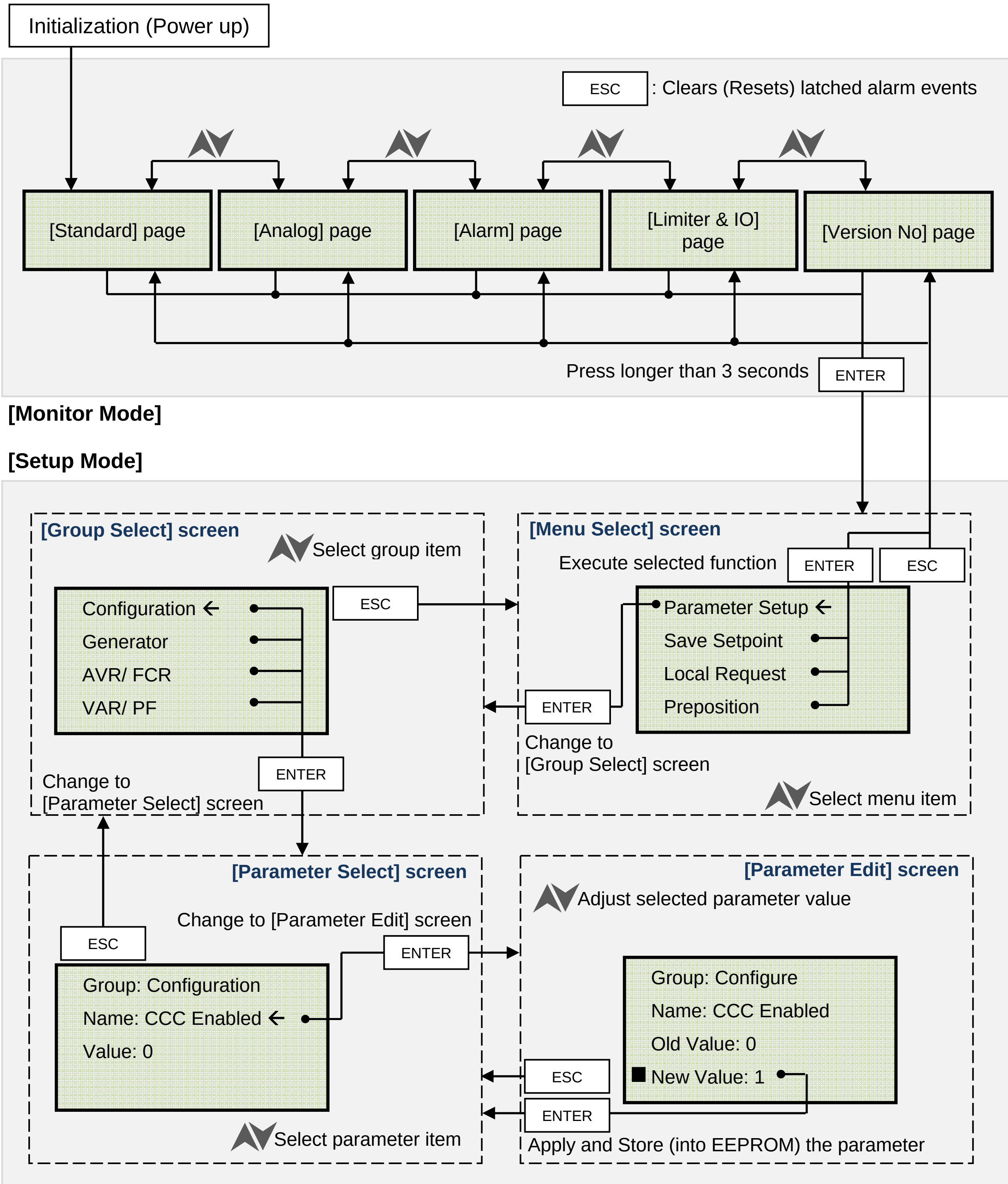


Figure 5-2 Flow Chart of Front Panel Operation

Mode of Operation

The Operation (Display) mode of front panel consists of two modes called Monitor Mode and Setup Mode.

- Monitor Mode: provides five display pages (Standard, Analogue, Alarm, Limiter & IO and Version) for monitoring the operating condition.
- Setup Mode: User can perform few operational functions, and user can configure the important parameter via LCD display and buttons without setup computer in this mode.

Functions of each Component

Table 5-1 illustrates the functions of LCD display, LED lamp, and operation buttons.

Table 5-1 Functional Description for each Component of User Interface

Item	Description (Function)
LCD Display	● Provides two display (operation) mode called Monitor Mode and Setup Mode ● Provides five display pages in the Monitor Mode to monitoring operating condition. - Standard page - Analog page - Alarm page - Limiter & IO page - Version No page ● Provides four setup screens in Setup Mode for configuration. - Menu Select screen: Selects the menu item to perform - Group Select screen: Selects configuration group to edit - Parameter Select screen: Selects the parameter to edit - Parameter Edit screen: Edits the selected parameter and save into EEPROM
Power LED	● Lit after booting process of HDEC2000 unit.
Local LED	● Lit when HDEC2000 unit is controlled by local mode.
Remote LED	● Lit when HDEC2000 unit is controlled by remote mode.
LIMIT LED	● Lit when setpoint of active operating mode goes to maximum or minimum setpoint. ● Lit when any limitation function (UFL, OEL, SCL and UEL) is activated.
ALARM LED	● Lit when any fault event is activated.
ESC Button	● Clears the latched alarm events and alarm messages in the [Monitor Mode] ● Return to previous (high level menu) screen in the [Setup Mode]
Up and Down Button	● Changes the display pages in the Monitor Mode ● Perform below functions in the Setup Mode - Selects menu item to perform in the Menu Select screen - Selects parameter to edit in the Parameter Select screen - Adjusts (increases or decreases) selected parameter in the Parameter Edit screen
Enter Button	● Performs below function in the Monitor Mode - Changes to [Menu Select] screen of Setup Mode if pressed while 3 seconds. ● Performs below functions in the Setup Mode - If low level menu is existed, changes to low level menu screen corresponding to selected item - If low level menu is not existed, executes selected function and return to previous screen ● See Figure 5-2 (Operational Flow Chart of front panel Button)

Note: If no key response is detected while 20 seconds in the Setup Mode, the displayed screen is returned to Monitor Mode.

Display Pages of Monitor Mode

User can change the display page of Monitor Mode by using arrow button, and Figure 5-1 shows the sequence.

Standard Page Display

The Standard page is divided into eleven areas (area A1 … area A11), and this page displays the important operating parameter on the each assigned area. The display area and typical display screen are shown in Figure 5-3, and display assignment is illustrated in Table 5-2.

Table 5-2 Display Assignment of Standard page of Monitor Mode

Area ID	Display parameter	Remark
A1	Generator Voltage (Ug)	
A2	Generator Current (ig)	
A3	Generator Active Power (P)	
A4	Generator Frequency (F)	
A5	Generator Power Factor (PF)	Positive: Over Excitation, Negative: Under Excitation
A6	Excitation Current (ie)	
A7	Start, Stop Status	ON: Start, Off: Stop, Rdy: Ready mode (see ready mode)
A8	Limiter Status	OEL, SCL, UEL, V/F (last occurred only)
A9	Primary, Secondary Status	Pri: Primary (Master) Unit, Sec: Secondary (Backup) Unit
A10	Active Operating mode & Setpoint of active mode	FCR: Manual Field Current Regulation mode AVR : Automatic Voltage Regulation mode, no load only DRP: Automatic Voltage Regulation mode with Droop CCC: Automatic Voltage Regulation mode with CCC VAR: Reactive Power(VAR) Control mode PF: Power Factor Control mode
A11	Activated alarm message (only last occurred fault)	F1: Over Voltage F2: Under Voltage F3: Generator Over Current F4: Exciter Over Current F5: Loss of Field F6: Loss of Power F7: Loss of Sensing F8: DFM Open Diode F9: DFM Short Diode F10: Output Short Circuit F11: Mode Mismatch

(*1): if the mode mismatch alarm is occurred with other fault event simultaneously, the other fault message is displayed first. After the other fault event is cleared, the mode mismatch alarm message may be displayed.

A1	**A4**	**A7**
A2	**A5**	**A8**
A3	**A6**	**A9**
A10		**A11**

13.21kV	**Hz:60.01**	**ON**
468A	**PF:+0.85**	**OEL**
9095kW	**ie:8.69A**	**Pri**
AVR:13.20kV		**F5**

Figure 5-3 Display Area and Typical Display of Standard page

Analogue Page Display

The Analogue page is divided into eight area (area A1 … area A8), and this page displays analogue parameters not displayed Standard page. The display area and typical display screen are shown in Figure 5-4, and display assignment is illustrated in Table 5-3.

Table 5-3 Display Assignment of Analogue page of Monitor Mode

Area ID	Old Label	New Label	Display parameter	Area ID	Old Label	New Label	Display parameter
A1	**Q**	**-**	Reactive power	A5	**igcc**	**icc**	CCC Loop current
A2	**Udc**	**Udc**	Dc Link Voltage	A6	**PFcc**	**PFc**	CCC Loop Input PF (PF CCC)
A3	**Uaux**	**Uax**	Converted Analog Reference	A7	**OD**	**ODR**	Open Diode ripple
A4	**PWM**	**PWM**	PWM duty for IGBT	A8	**SD**	**SDR**	Short Diode ripple

Notes

(1) Positive sign means over excitation and negative sign means under excitation condition for reactive power and CCC loop power factor

(2) New Labels are applied for firmware version 1.24 or later

A1	**A5**
A2	**A6**
A3	**A7**
A4	**A8**

+354.5kVAR	**icc: 123.5A**
Udc: 245.2V	**PFc:+0.99**
Uax: - 5.38V	**ODR:2.56%**
PWM:32.5%	**SDR:1.33%**

Figure 5-4 Display Area and Typical Display of Analogue page

Alarm Page Display

The [Alarm] page is divided into twelve area (area A1 … area A12), and this page displays alarm information. The display area and typical display screen are shown in Figure 5-5, and display assignment is illustrated in Table 5-4.

Table 5-4 Display Assignment of Alarm page of Monitor Mode

Area ID	Label: Description	Area ID	Label: Description
A1	GNOV: Generator Over Voltage	A7	L_SEN: Loss of Sensing
A2	GNOV: Generator Under Voltage	A8	-
A3	GNOC: Generator Over Current	A9	EXSD: Short Diode Fault
A4	EXOC: Exciter Over Current	A10	SHRT: Output Short Circuit
A5	L_FLD: Loss of Field	A11	EXOD: Open Diode Fault
A6	L_PWR: Loss of Power	A12	Mode: Mode mismatch alarm

A1	A5	A9
A2	A6	A10
A3	A7	A11
A4	A8	A12

GNOV	☐	L_FLD	☐	EXOD	☐
GNUV	☐	L_PWR	☐	EXSD	☐
GNOC	☐	L_SEN	☐	SHRT	☐
EXOC	☐			Mode	■

Figure 5-5 Display Area and Typical Display of Alarm page

Limiter & IO Page Display

The Limiter & IO page is divided into twelve parts (area A1 … area A12), and this page displays the status of limitation function and additional digital inputs. The display area and typical display screen is shown in Figure 5-6, and display assignment is illustrated in Table 5-5.

Table 5-5 Display Assignment of Limiter & IO page of Monitor Mode

Area ID	Label: Description	Area ID	Label: Description
A1	V/F: Under Frequency Limitation	A7	-
A2	OEL: Over Excitation Limitation	A8	-
A3	SCL: Stator Current Limitation	A9	GCB: Grid Circuit Breaker
A4	UEL: Under Excitation Limitation	A10	MCB: Machine Circuit Breaker
A5	U_SP_LMT: Upper Setpoint Limitation	A11	Pri: Primary (Master) mode
A6	L_SP_LMT: Lower Setpoint Limitation	A12	Sec: Secondary (Backup) mode

A1	A5	A9
A2	A6	A10
A3	A7	A11
A4	A8	A12

V/F	☐	U_SP_LMT	☐	GCB	☐
OEL	☐	L_SP_LMT	☐	MCB	■
SCL	☐			Pri	■
UEL	☐			Sec	☐

Figure 5-6 Display Area and Typical Display of Limiter & IO page

Version Page Display

The Version page only displays the installed software (firmware) version number of HDEC2000 unit.

Hyundai Digital
Excitation System
HDEC2000
Ver: 1.22

Figure 5-7 Display of Version No page

Setup Mode Functions

The Setup Mode has four selectable menus item called Parameter Setup, Save Setpoint, Local Request and Preposition. Each menu item can be selected by up (or down) arrow button, and each functions may be performed by pressing Enter button. The functions corresponding to each menu are described below.

- Parameter Setup: The Group Select screen may be appeared when Enter button is pressed if this menu is selected by arrow button(s).
- Save Setpoint: The setpoint of active operating mode may be stored into EEPROM when Enter button is pressed if this menu is selected by arrow button(s).
- Local Request: The operating mode is transferred to Local Mode from Remote Mode when Enter button is pressed if this menu is selected by arrow button(s).
- Preposition: The setpoint of all four operating modes are returned to its preposition setpoint when Enter button is pressed if this menu is selected by arrow button(s).

Parameter Configuration (Edit and Store)

Table 5-5 shows the configurable parameter list by using front panel. And user can access (read, edit and store into EEPROM) to each parameter according to button operation sequence shown in Figure 5-2.

Table 5-6 Configurable Parameter List by using front panel Button

Tab Name	Parameter	Unit	Symbol:	Format	Remark
Configuration	CCC Enable	-	CCC Enable	0, 1	0 = Disabled, 1 = Enabled
	Excitation Power Source		EXC Source	0, 1, 2	0 = Shunt 1 = PMG 2 = Utility
	Dc Link Voltage	V	DC LNK	600V	
	Sensing Configuration		Sensing	0, 1	0 = Single 1 = Three
	Setpoint Auto Save	-	SP Auto	0, 1	0 = Disabled, 1 = Enabled
Generator	Gen. Rate Voltage	V	GEN UN	13800V	
	Excitation Current rated (ieN)	A	Ex ieN	15.00A	
	Gen. Sens. PT Pri. Voltage	V	PT Pri	30000V	
	Gen. Sens. PT Sec. Voltage	V	PT Sec	600V	
	Gen. Sens. CT Pri. Current	A	CT Pri	60000A	
	Gen. Sens. CT Sec. Current	A	CT Sec	5.0A	
	AVR CT input Current	A	CT input	1A, 5A	
AVR/ FCR	AVR mode Setpoint	V	AVR Set	99.99 kV 9.999 kV 999.9 V	UN > 10kV UN <= 10 kV UN <=1000V
	AVR mode Traverse Rate	sec	AVR Rate	200s	
	AVR mode Preposition Setpoint	V	AVR Pre	see remark	Same as [AVR Set]
VAR/ PF	VAR/PF Voltage Band	%	PF Band	50.0%	
	PF mode Setpoint	pu	PF Set	+/- 1.00	
	PF mode Traverse Rate	sec	PF Rate	200s	
	PF mode Preposition Setpoint	pu	PF Pre	see remark	Same as [PF Set]
Auxiliary/ Strtup	Soft Start Level	%	Soft Level	10%	
	Soft Start Delay time	sec	Soft Delay	10s	
	Soft Start time	sec	Soft Time	200s	
	Under Frequency mode	-	UFL Mode	0, 1	0 = STD mode 1 = Max. flux mode
	Under Frequency Corner Frequency	Hz	UFL Hz	89.9Hz	
	Under Frequency Slope	V/Hz	UFL Slope	3.0V/Hz	
	Reactive Droop compensation	%	DROOP	+/- 30.0%	
	CCC Droop compensation	%	CCC DRP	+/- 30.0%	

Continue …

Tab Name	Parameter	Unit	Symbol:	Format	Remark
Gain	AVR mode Loop gain K_G	%	AVR KG	500.0	
	AVR mode K_P		AVR KP	1000.0	
	AVR mode K_I		AVR KI	1000.0	
	AVR mode K_D		AVR KD	1000.0	
	AVR mode T_H	ms	AVR TH	100	
	AVR mode T_F	ms	AVR TF	50	
	PF mode Loop gain K_G	%	PF KG	500.0	
	PF mode K_I	-	PF KI	1000.0	
	UEL Loop Gain K_G	%	UEL KG	500.0	
	UEL K_I		UEL KI	100.0	
	SCL Loop Gain K_G	%	SCL KG	500.0	
	SCL K_I		SCL KI	100.0	
	SCL T_D	ms	SCL TD	200	
Limiter	OEL EN/Disabled	-	OEL Enable	0, 1	0 = Disabled, 1 = Enabled
	OEL Option		OEL Option	0 … 3	0 = MCB or GCB 1 = GCB 2 = ON Line 3 = Dynamic
	UEL EN/Disabled	-	UEL Enable	0, 1	0 = Disabled, 1 = Enabled
	UEL Curve Type	-	UEL Curve	0,1	0 = Circular Type 1= Segment Type
	UEL Circular Reactive Power	%	UEL Qmin	50%	
	SCL EN/Disabled	-	SCL Enable	0, 1	0 = Disabled, 1 = Enabled
	SCL Hi Level	%	SCL HiAmp	500%	
	SCL Accept PF	pu	SCL PF	0.98	
	SCL Hi Time	sec	SCL HiSec	60s	
	SCL Low Level	%	SCL LoAmp	150%	

SECTION 6. COMMISSIONING

INTRODUCTION

This section describes the site commissioning procedure of generator and excitation system. However, it is not possible to mention for all possible application. AVR mode generic operation guide may be dealt in this section because HDEC2000 unit operates with AVR mode in most cases.

DANGER

On site commissioning should be performed by qualified personnel who has fully understanding of HDEC2000 unit and has intermediate or higher level knowledge for synchronous machine, excitation system and application.

COMMISSIONING

Note!
The commissioning procedure of this section is not unconditionally obeyed but can be changed.
And some procedure may be omitted or additional procedure may be necessary depending on the site condition, (kind of load, prime-mover …), commissioning engineer or the schedule of application.

Procedure A: Initial Checkout while machine is at a standstill

Note!
If the HDEC2000 unit is supplied as a part of synchronous generator system by Hyundai Heavy Industrial Co., Ltd, parameter configuration while standstill can be omitted.

(1) Verify that all safety measures have been taken.
(2) Inspect physical installation by visually.
(3) Inspect all wiring of HDEC2000 unit and related components (generator, sensing transformer …).
(4) Inspect that the grounding wiring is correctly connected.
(5) Review the generator nameplate, test report of generator or design data.
(6) Supply external control power (not excitation power). If control power is not supplied permanently, then temporarily supply (use D1, D2 terminals).
(7) Make communication connection between HDEC2000 unit and setup computer (note book).
(8) Check (or newly configure) all configuration parameters according to schematic drawing, system design and application requirement.
(9) Write all configuration parameter into the EEPROM of HDEC2000 unit and backup to setup computer storage.
(10) Disconnect control power (if control power is supplied temporarily)
(11) If no problem is found yet, process next procedure.

Procedure B: Checkout before startup to voltage buildup

(1) Open the FCR select command digital input (Select AVR Mode).
(2) Open the excitation on command digital input (Excitation OFF)
(3) Turn off the excitation input circuit breaker if circuit breaker is permanently installed.

(4) Turn off the SW2 for hardware voltage buildup function, installed on the right panel of HDEC2000 unit.

(5) Startup the prime-mover

(6) Measure excitation input voltage before closing the excitation input circuit breaker. After measuring, verify that the measured input is not exceeded permissible value and it meets design data by below criterion.

- PMG application: compare it with PMG test data or PMG design data.
- Shunt application: compare it with expected value measured from other device by using excitation transformer turn ratio.
- Utility supply: compare measured value with design data.

(7) Measure input sensing voltage (generator residual voltage). And compare it with expected value (from other measuring device.

(8) Turn on the excitation input circuit breaker if available.
In case of PMG, Utility excitation power, or external control power is supplied, verify that the nearly same value obtained between displayed generator voltage on the front panel of HDEC2000 unit and the values measured from other instrument.

(9) In case of shunt power application with no external control power, turn on the SW2 for hardware voltage buildup function installed on the right panel of HDEC2000, then the possible lowest voltage (approximately 15 … 20% depending on the turn ratio of excitation transformer) may be controlled by HDEC2000 unit. In this step, some initial voltage overshoot not exceeding nominal value may be occurred depending on generator or excitation transformer

(10) Close the excitation on command input (excitation on)

(11) Monitor the generator voltage buildup condition. If voltage is increased too rapidly, open the excitation on digital input circuit (Excitation OFF) and remove excitation power (or stop the prime-mover).

(12) If smooth voltage buildup is obtained while [Soft Start Time], process next procedure.

Procedure C: Checkout while no load running

(1) Monitor the stability of generator voltage, if the unstable voltage is obtained, check the control gains or others.

(2) Measure and record excitation current with nominal voltage condition. And compare it with design data or test data (if available).

(3) Adjust setpoint from minimum setpoint to maximum setpoint.

(4) Measure and record generator voltage adjustable boundary.

(5) Adjust generator voltage with nominal value.

(6) Wait at least few minutes. If operating condition suddenly changed, then check the reason(s).

> **Note!**
> If the HDEC2000 unit is already configured by generator (and excitation) system supplier, the no load voltage step response procedure (procedure No. 7 …9 described below) can be omitted.

(7) Change Setpoint (-5 … -10% of nominal) suddenly by using HDCM software, and monitor voltage step response.

(8) Change Setpoint to nominal value (100%) suddenly by using HDCM software, and monitor voltage step response.

(9) If voltage step response is too slow (or too fast), then tune the control gain(s) until proper response is obtained. For more detailed procedure about control gain tuning, see section 4 (Configuration).

(10) If no problem is found yet, process next procedure.

Procedure D: Checkout while load condition (Single or parallel operation, connected with island grid)

(1) Close main circuit breaker according to synchronization procedure if necessary. If parallel operation is applied, adjust the generator no load voltage same as the no load voltage of others before circuit breaker closing.

(2) With Light load condition, Record the important measuring parameter displayed on the front panel of HDEC2000. And compare it with other recording obtained from other instrument.

(3) Slowly increase the load to the possible maximum value step by step (if possible).

(4) Record all important measuring parameter with each load step.

(5) If other generator(s) is paralleled, check reactive load sharing of each generator(s).

(6) If unequal load sharing is obtained, check configuration parameter (Setpoint of each generator, Reactive Droop or CCC Droop) or others.

(7) Monitor the stability of generator voltage, if voltage is unstable, check control gain or others.

(8) Wait at least few minutes. If operating condition suddenly changed, check the reason(s).

(9) If no problem is found yet, write your final configuration parameter on the EEPROM of HDEC2000 unit and backup to your computer storage also.

Procedure E: Checkout while load condition (Parallel operation, with VAR/PF operating mode)

> **Note!**
> This Procedure is carried out in case of below case
> - The generator is voltage following machine and is operated with the voltage supporting machine(s) (the generator is connected with large power grid, not the small island grid).

(1) Before synchronization, please check listed below

- Reactive Droop parameter: not less than 4%
- CCC Enabled: disabled
- VAR/PF mode: VAR of PF mode is enabled
- UEL Enabled: Enabled
- OEL Enabled: Enabled
- Related parameter of UEL, OEL: properly configured.
- MCB status input terminal: connected with generator circuit breaker (normal open logic)
- GCB status input terminal: connected with grid circuit breaker or logical combination contact of system breaker contactors (normal open logic)

(2) Close main circuit breaker according to synchronization procedure.

(3) At the moment of breaker closing, monitor the generator current, excitation current, reactive power and operating mode display carefully.

(4) If any of below condition is obtained, open the generator circuit breaker immediately. And check the reason(s)

- Sudden increasing of generator current, Sudden increasing (or decreasing) of excitation current or reactive power
- Operating mode is not change to VAR mode or PF mode from AVR mode

(5) If PF mode is selected, carry out follows:
- Increase the load not higher than about 30% (if possible)
- Monitor the power factor of HDEC2000 and compare it with setpoint and other available value. If comparing result is not nearly same then check the reason(s).
- Increase the setpoint slowly (about 0.05pu lower than original setpoint), then the actual power factor decreasing (increasing of reactive power) is obtained. And next, re-adjust the setpoint to the original value

(6) If VAR mode is selected, carry out follows:
- Monitor the reactive power value. And compare it with setpoint and other available value. If comparing result is not nearly same then check the reason(s).
- Decrease the setpoint slowly (about 0.05… 0.1pu lower than original setpoint) but not less than zero (under excitation region), then the actual reactive power decreasing is obtained. And next, re-adjust the setpoint to original value.

(7) Slowly increase the load to possible maximum value, step by step.
(8) Record all important parameter (voltage, excitation current …) with each load step.
(9) Monitor the generator reactive power or power factor stability, if the result is unstable, check control gain or others.
(10) Wait at least few minutes. If operating condition is suddenly changed, check reason(s).
(11) If no problem(s) is found yet, write your final configuration parameter on the EEPROM of HDEC2000 unit and backup to your computer storage also.

IMPORTANT	**While light load (less than 10% approximately) with the PF mode, the power factor may be unstable due to the active power change, even though the fluctuation of active power is very small. For this reason, control gain must be tuned with the load condition not less than approximately 30% of nominal.**

SECTION 7. TROUBLE SHOOTING

INTRODUCTION

This section describes corrective action procedures for common problem of excitation system. However, it is not possible to mention for all possible troubles. AVR mode symptom may be dealt in this section because HDEC2000 unit operates with AVR mode in most cases.

TROUBLE SHOOTING

IMPORTANT	**The contents of [Check and Correction] column of each table mean corrective status. For example, if the content is expressed as "Check that the FCR select command is opened.", then FCR Select command circuit must be opened.**

No Load Operation

Issue	Possible causes	Check and Correction
No Voltage buildup	Wiring error	● Check excitation input wiring ● Check excitation output wiring ● Check that the circuit breaker is not tripped or fuse is not broken
	Excitation power	● Check PMG output voltage (PMG application) ● Check excitation transformer output (shunt application)
	Digital input	● Check that the excitation on command is closed ● Check that the FCR select command is opened
	Others	● Check That the control power (if optional control supply is used) is in normal range ● Check that the SW2 is turned on in case of shunt application with no control power (and with no pre-excitation) ● Check the residual voltage at the excitation input terminal in case of shunt application with no control power, if this value is too low (<6Vac), apply the pre excitation power ● Check that the first top right display message is [ON] at the standard display page while HDEC2000 power LED is on status. If not, check digital input circuit (excitation on input)
Too high voltage buildup	Incorrect sensing	● Check voltage sensing circuit wiring ● Check that the sensing VT is not burned or fuse is not broken ● Check the ratio of sensing VT (or configured VT ratio) ● Check sensing configuration (1 or 3 phase)
	Digital input	● Check that the both of MCB and GCB status is opened ● Check that the FCR select command is opened ● Check that the raise command is opened
	Setpoint	● Check that the setpoint of AVR mode is in nominal
	Parameter	● Check that the AVR gain(K_I) is not less than 10

Cont. Trouble Shooting (No load operation)…

Issue	Possible causes	Check and Correction
Too low voltage buildup	Digital input	• Check that the MCB and GCB status is opened • Check that the FCR select command is opened • Check that the Lower command is opened
	Incorrect sensing	• Check the ratio of sensing VT (or configured VT ratio) • Check sensing configuration (1 or 3 phase)
	Setpoint	• Check that the setpoint of AVR mode is in nominal
	Excitation power	• Check PMG output (PMG application) • Check excitation transformer output (shunt application)
	Limiter	• Check that the OEL status is not activated
	Parameter	• Check that the AVR gain(K_I) is not less than 10
Voltage is in normal range, but too high overshoot	Parameter	• Check soft start level parameter (typically 10 …30%) • Check soft start time parameter (typically 5 …15s) • Check Under Frequency protection mode, normally Std mode • Check Under Frequency Corner Frequency, normally 95% of nominal • Check Under Frequency Slope (V/Hz) parameter, normally 1 … 1.5
Voltage is in normal range, but unstable	Prime mover	• Check prime-mover speed. Too high fluctuation of prime mover speed cannot be compensated by HDEC2000 unit
	Parameter	• Tune the AVR mode Control gains (K_G, K_P, K_I …)
	Limiter	• Check that the OEL status is not activated
Voltage is stable, but not controlled	Digital input	• Check that the raise and lower command circuit are connected
	Limiter	• Check that the OEL status is not activated
	Setpoint	• Check that the setpoint limitation of AVR mode is not activated

Load Operation (Single operation)

Issue	Possible causes	Check and Correction
Too large voltage change (dropped or raised) while load changed	Wiring	• Check sensing CT wiring (phase, polarity and ratio) • Check sensing VT wiring (phase)
	Excitation power	• Check PMG output (PMG application) • Check excitation transformer output (shunt application)
	Parameter	• Check Reactive Droop parameter (typically 4 …10%)
Voltage is in normal range, but unstable	Prime mover	• Check prime mover speed. Too high fluctuation of prime mover speed cannot be compensated by HDEC2000 unit
	Parameter	• Tune the AVR mode Control gains (K_G, K_P, K_I …)
	Limiter	• Check that any limitation is not activated (OEL, SCL, UEL)
Voltage is not constant (varied) with CCC mode depending on load	Wiring	• Check sensing CT wiring (phase and polarity) • Check sensing VT wiring (phase) • Check CCC wiring between regulator
	Digital input	• Check that the MCB status is closed while serviced • Check that the MCB statuses (normal open auxiliary contactor) of other generator(s) are correctly connected
	Parameter	• Check that CCC Enabled parameter is enabled

Load Operation (Parallel operation with island network)

Issue	Possible causes	Check and Correction
Unequal reactive power OR Unequal power factor	Wiring	● Check sensing CT wiring (phase and polarity) ● Check sensing VT wiring (phase) ● Check proper CCC loop wiring between HDEC2000 units in case of CCC application
	Sensing CT	● Check sensing CT ratio and input current: If CCC mode is selected, all percentage CT ratio must be same
	Setpoint OR Voltage (*1)	● Check that the voltage setpoint of all generators are same. ● Check that the no load voltages of all generators are same.
	Sensing VT ratio error (*2)	● Adjust Setpoint until equal reactive power is obtained: If any other problems are not found
	Digital input	● Check that the MCB input status is closed: ● Check that the front panel operating mode display is Droop mode or CCC mode.
	Parameter	● Check Reactive Droop parameter ● Check CCC Droop parameter ● above two parameters must be nearly same, or exactly same when compared with other generator(s)
	Limiter	● Check that the any limitation status is not activated
Too large voltage change (drop or raise) while load changed	Wiring	● Check sensing CT wiring (phase and polarity) ● Check sensing VT wiring (phase) ● Check CCC wiring between regulator in case of CCC application
	Sensing	● Check sensing CT ratio and input current
	Parameter	● Check Reactive Droop parameter ● Check CCC Droop parameter ● typically range is 4 …10% for above two parameters
	Limiter	● Check that any limitation is not activated (OEL, SCL, UEL)

(*1): Even though the voltage setpoint of all generators are same, the generator no load voltage may be different due to sensing VT error. Primary important thing is same generator voltage than same voltage setpoint.

(*2): If very little (ex: lower than 0.5% of nominal) ratio error is present and very low Reactive Droop or CCC Droop (ex: typically lower than 2.5%) is configured simultaneously, unequal reactive power sharing may be obtained.

In this case, Check other possible causes first and any failure is not found, adjust voltage setpoint until equal reactive power sharing is obtained. If approximately same reactive load sharing is obtained with two different load points after voltage setpoint is adjusted, the unequal reactive load sharing is caused from little sensing VT ratio error.

If the unequal reactive load sharing is caused from sensing VT ratio and it is confirmed, store the corrective voltage setpoint into the EEPROM of HDEC2000 unit to avoid same situation when generator is re-started.

Load Operation (Parallel operation with large power network – VAR/PF operation)

Issue	Possible causes	Check and Correction
VAR/ PF Sudden Change at the moment of synchronization	Wiring	• Check GCB digital input (status) wiring • Check MCB digital input (status) wiring • Check sensing CT wiring (phase and polarity) • Check sensing VT wiring (phase)
	Parameter	• Check that the VAR or PF mode parameter is selected • Check that the CCC Enabled parameter must be disabled • Check that the Reactive Droop is not less than 4%
	Limiter	• Check that the OEL limiting level is not too low. The OEL [Low Level] parameter must be higher than nominal excitation current
VAR/PF is not adjustable OR VAR/PF is not matched with setpoint	Wiring	• Check sensing CT wiring (phase and polarity) • Check sensing VT wiring (phase) • Check GCB digital input (status) wiring • Check MCB digital input (status) wiring • Check that the raise/lower command(s) is connected properly
	Parameter	• Check the VAR/PF band limit is not less than 10% • Check that the VAR/PF gain(K_I) is not less than 0.5
	Limiter	• Check that any limitation is not activated (OEL, SCL, UEL)
	Grid voltage	• Check that the grid voltage is between the VAR/PF band limit. If not, increase band limit parameter
VAR/PF is unstable	parameter	• Check VAR/PF gain (K_G, K_I) • Check AVR gain (K_G, K_P, …) • Check that the VAR/PF band limit is not less than 10%
	Limiter	• Check that any limitation is not activated (OEL, SCL, UEL)
	Grid voltage	• Check that the grid voltage is between the VAR/PF band limit. If not, increase band limit parameter

APPENDIX A. CONFIGURATION PARAMETER LIST

Notes:

(1) Res: Resolution or incremental

(2) DFLT: Default value

(3) Default values printed in boldface will be changed on the next version

Parameter	Unit	Min.	Max.	Res	DFLT	Description
A: Configuration						
Software Version				-	-	Read only (HDCM Setup Software Version)
Hardware Version						Read only (HDEC 2000 Firmware Version)
AVR ID		1	16	1	1	Reserved
Excitation Power Source		0	2		0	0 = Shunt, 1 = PMG, 2 = Utility
DC Link Voltage	V	20	600	1	200	
Control Power Source		0	1		0	0 = Internal, 1 = External
Sensing Configuration		0	1		1	0 = single phase, 1 = three phase
CCC Enable		0	1	-	0	0 = Disable, 1 = Enable
VAR/ PF mode		0	2		0	0 = OFF, 1 = VAR, 2 = PF
Virtual MCB		0	2	1	0	0 = None, 1 = Close, 2 = Open
Internal Tracking Option		0	3	1	0	0 = Disabled 1 = Auto Manual Only (V1.22 or later) 2 = From VAR/PF to AVR (V1.22 or later) 3 = All Mode (V1.22 or later)
Internal Tracking Delay Time	sec	0	10	0.1	0	
Internal Tracking Traverse Rate	sec	0.1	20	0.1	0.1	
External Tracking Option		0	1		0	0 = Disabled, 1 = Enabled
External Tracking Delay Time	sec	0	10	0.1	0	
External Tracking Traverse Rate	sec	0.1	20	0.1	0.1	
Setpoint Auto Save		0	1	1	0	0 = Disabled, 1 = Enabled
MODBUS Device Address		1	247	1	247	
MODBUS baud rate	bps	2400	19200		9600	Selectable value: 2400, 4800, 9600, 19200
MODBUS Response Delay	ms	0	200	1	10	
B: Generator						
Gen. Rated Voltage	V	100	30000	1	110	
Gen. Rated Current	V	10	6000	0.1	200	
Gen. Power Factor	pu	-0.5	1	0.01	0.80	Range (- 0.50 … -1.0, +1.00 … +0.50)
Gen. Apparent power	kVA			0.1	-	Read only
Gen. Frequency	Hz	30	100	1	60	
Exciter Resistance	ohms	3	60	0.1	12	
Excitation Current (open)	A	0.2	30	0.01	1	
Excitation Current (short)	A	0.5	30	0.01	5	
Excitation Current (rated)	A	1	30	0.01	5	
Excitation Rated Voltage	V			0.1	-	Read only
Gen. pole number		2	60	2	10	
Exciter pole number		4	24	2	12	

Parameter	Unit	Min.	Max.	Res	DFLT	Description
Exciter parallel circuit		1	4	1	1	Reserved
Gen. Sens. PT Pri. Voltage	V	10	30000	1	110	
Gen. Sens. PT Sec. Voltage	V	10	600	1	110	
Bus PT Pri. Voltage	V	10	30000	1	110	Reserved
Bus PT Sec. Voltage	V	10	600	1	110	Reserved
Gen. Sens. CT Pri Current	A	0	60000	1	200	
Gen. Sens. CT Sec Current	A	0.1	5	0.1	1	
AVR CT input Terminal	A	1	5	-	1	1 A or 5A only
Gen. CCC CT Pri. Current	A	0	60000	1	500	
Gen. CCC CT Sec. Current	A	0.1	1	0.01	1.00	

C: AVR/ FCR

Parameter	Unit	Min.	Max.	Res	DFLT	Description
AVR mode Setpoint	V	*	*	0.1	110	min. = min. setpoint * rated value max. = max. setpoint * rated value
AVR mode min Setpoint	%	0	100	0.1	90	
AVR mode max Setpoint	%	100	120	0.1	110	
AVR mode Traverse Rate	sec	10	400	1	40	
AVR Preposition Setpoint	V	*	*	0.1	110	min. = min. setpoint * rated value max. = max. setpoint * rated value
FCR mode Setpoint	A	*	*	0.01	0	min. = min. setpoint * rated value max. = max. setpoint * rated value
FCR mode min Setpoint	%	0	100	0.1	0	
FCR mode max Setpoint	%	0	200	0.1	150	
FCR mode Traverse Rate	sec	10	400	1	40	
FCR Preposition Setpoint	A	*	*	0.01	0	min. = min. setpoint * rated value max. = max. setpoint * rated value

D: VAR/PF

Parameter	Unit	Min.	Max.	Res	DFLT	Description
VAR/PF Voltage Band	%	0	50	0.1	20	
VAR mode Setpoint	kVAR	0	*	0.1	0	min. = min. setpoint * rated apparent power max. = max. setpoint * rated apparent power
VAR mode min Setpoint	%	-100	100	1	0	
VAR mode max Setpoint	%	-100	100	1	60	
VAR mode Traverse Rate	sec	10	400	1	40	
VAR Preposition Setpoint	kVAR	*	*	0.01	0	min. = min. setpoint * rated apparent power max. = max. setpoint * rated apparent power
PF mode Setpoint	pu	*	*	0.01	0.9	min. = min. setpoint, max. = max. setpoint
PF mode min Setpoint	pu	-0.5	-1	0.01	-0.6	minus sign means under excitation
PF mode max Setpoint	pu	0.5	1	0.01	0.6	
PF mode Traverse Rate	sec	10	400	1	40	
PF Preposition Setpoint	pu	*	*	0.01	0.9	min. = min. setpoint, max. = max. setpoint

E: Startup and Auxiliary

Parameter	Unit	Min.	Max.	Res	DFLT	Description
Soft Start Level	%	0	90	1	15	
Soft Start time	sec	1	200	1	10	
Soft Start Delay	sec	0	200	1	0	Version 1.22 or later
Buildup Detect Zone	%	0	20	1	0	Version 1.22 or later

Parameter	Unit	Min.	Max.	Res	DFLT	Description
Soft Start Level 2	%	0	90	1	50	Version 1.22 or later
Soft Start time 2	Sec	1	200	1	5	Version 1.22 or later
Soft Start Delay 2	Sec	0	200	1	0	will be added next version
Reactive Droop compensation	%	-30	30	0.01	4	
CCC Droop compensation	%	-30	30	0.01	6	
Under Frequency mode		0	1		0	0 = Std, 1 = max. flux
Under Frequency Corner Frequency	Hz	15	90	0.1	57	
Under Frequency Slope	V/Hz	0.1	3	0.1	1.5	
Aux. Input Type		0	8		0	0 = +/-10V bipolar 1 = 4 …20mA bipolar 2 = 0 …+10V bipolar 3 = 1 …+5V bipolar 4 = 0 …20mA bipolar 5 = 0 …+10V unipolar 6 = 1 …+5V unipolar 7 = 4 …20mA unipolar 8 = 0 …20mA unipolar ● input type 2 … 8: (V1.22 or later) ● input type 0 … 4: input signal is converted with -10 to +10 ● input type 5 … 8: input signal is converted with 0 to +10
Aux. input Summing Type		0	1		0	0 = inner Loop, 1 = Outer Loop, 2 = Both
Aux. input AVR Gain		-99	99	0.01	0	
Aux. input FCR Gain		-99	99	0.01	0	
Aux. input VAR Gain		-99	99	0.01	0	
Aux. input PF Gain		-99	99	0.01	0	
F: Gain						
AVR mode Loop gain K_G	%	0	1000	0.1	10	
AVR mode K_P		0	1000	0.1	100	
AVR mode K_I		0	1000	0.1	50	
AVR mode K_D		0	1000	0.1	5	
AVR mode T_H	ms	1	99	1	5	D-term sampling interval
AVR mode T_F	ms	0	99	1	1	D-term filtering time constant
FCR mode Loop gain K_G	%	0	1000	0.1	25	
FCR mode K_P		0	1000	0.1	80	
FCR mode K_I		0	1000	0.1	25	
VAR mode Loop gain K_G	%	0	1000	0.1	70	
VAR mode K_I		0	1000	0.1	1.5	
PF mode Loop gain K_G	%	0	1000	0.1	70	
PF mode K_I		0	1000	0.1	1.5	
OEL Loop gain K_G	%	0	1000	0.1	300	
OEL K_I		0	1000	0.1	5	

Parameter	Unit	Min.	Max.	Res	DFLT	Description
UEL Loop gain K_G	%	0	1000	0.1	40	
UEL K_I		0	1000	0.1	1.0	
SCL Loop gain K_G	%	0	1000	0.1	200	
SCL K_I		0	1000	0.1	2.5	
SCL T_D	ms	0	500	1	50	

G: Digital IO (Input and Output)

Relay 1 Gen. OV		0	1		0	0 = Not assigned, 1 = Assigned
Relay 1 Gen. UV		0	1		0	
Relay 1 Gen. OC		0	1		0	
Relay 1 Exc. OC		0	1		0	
Relay 1 Loss of Field		0	1		0	
Relay 1 Loss of Sens.		0	1		0	
Relay 1 Loss of Power		0	1		0	
Relay 1 Reverse Sens.		0	1		0	
Relay 1 Open Diode		0	1		0	
Relay 1 Short Diode		0	1		0	
Relay 1 Short Circuit Output		0	1		0	
Relay 1 START Status		0	1		0	
Relay 1 FCR Status		0	1		0	
Relay 1 Sec Unit		0	1		0	
Relay 1 Local mode		0	1		0	
Relay 1 mode mismatch		0	1		0	
Relay 1 Upper Setpoint Limit.		0	1		0	
Relay 1 Lower Setpoint Limit.		0	1		0	
Relay 1 OEL Statue		0	1		0	
Relay 1 UEL Statue		0	1		0	
Relay 1 SCL Statue		0	1		0	
Relay 1 F/V Limiter Status		0	1		0	
Relay 1 Logic		0	1		0	0 = Normal open, 1 = Normal close
Relay 1 Function Gen. OV		0	1		0	0 = Not Assigned, 1 = Assigned
…						…
Relay 2 Logic		0	1		0	0 = Normal open, 1 = Normal close
Relay 2 Function Gen. OV		0	1		0	0 = Not Assigned, 1 = Assigned
…						…
…						…
Relay 3 Logic		0	1		0	0 = Normal open, 1 = Normal close
Relay 3 Function Gen. OV		0	1		0	0 = Not Assigned, 1 = Assigned
…		0	1		0	…
PROG digital input 1 Function		0	20		0	0 = None 1 = Preposition 2 = Secondary Unit 3 = Local Request 4 = Secondary Soft Start (V1.22 or later)
PROG digital input 2 Function		0	20		0	Same as PROG digital input 1 Function
PROG digital input 2 Function		0	20		0	Same as PROG digital input 1 Function

H: Protection

Parameter	Unit	Min.	Max.	Res	DFLT	Description
Gen. Over Voltage Enabled		0	1		0	0 = Disable, 1 = Enable
Gen. Over Voltage Level	%	100	150	0.1	120	
Gen. Over Voltage Delay	sec	0.1	60	0.1	5	
Gen. Under Voltage Enabled		0	1		0	0 = Disable, 1 = Enable
Gen. Under Voltage Level	%	40	100	0.1	80	
Gen. Under Voltage Delay	sec	0.1	60	0.1	5	
Gen. Over Current Type		0	3		0	0 = Disable 1 = Constant Time 2 = Std Inverse 3 = Preload Inverse
Gen. Constant OC Level	%	50	500	0.1	115	
Gen. Inverse OC Level	%	50	150	0.1	105	
Gen. Inverse OC Pre Load	%	0	90	0.1	90	
Gen. Over Current Delay	sec	1	600	1	5	In case of Inverse time over current: based on (pre load = 0.9, trip OC level = 1.5)
Exciter Over Current Type		0	3		0	0 = Disable 1 = Constant Time 2 = Standard Inverse 3 = Preload Inverse
Exciter Constant OC Level	%	50	250	0.1	115	
Exc. Inverse OC Level	%	50	150	0.1	105	
Exciter Over Current Delay	sec	1	600	1	15	Preload is internally fixed with 70%
Loss of Field Enabled						
Loss of Field Level	%	0	50	0.1	10	
Loss of Field Delay	sec	0.1	60	0.1	5	
Loss of Sens. Enabled		0	1		0	0 = Disable, 1 = Enable
Loss of Sens. Balanced Level	%	0	100	0.1	70	
Loss of Sens. Unbalanced Level	%	0	100	0.1	25	
Loss of Sens. Time Delay	sec	0.1	60	0.1	0.5	
Loss of Sens. Option		0	2		0	0 = None 1 = Transfer to FCR 2 = Fixed PWM 3 = Shutdown
Loss of Power Enabled		0	1		0	0 = Disable, 1 = Enable
Loss of Power Level	%	0	50	1	10	% of dc link voltage
Loss of Power Delay	sec	0.1	200	0.1	60	
Loss of Power Option		0	1		1	0 = None, 1 = Reset Soft Start Time
Open Diode Enabled		0	1		0	0 = Disable, 1 = Enable
Open Diode Ripple	%	0	100	0.1	10	
Open Diode Delay	sec	0.1	60	0.1	2	
Short Diode Enabled		0	1		0	0 = Disable, 1 = Enable
Short Diode Ripple	%	0	100	0.1	20	
Short Diode Delay	sec	0.1	60	0.1	1	

I: Limiter

OEL Enabled		0	1		0	0 = Disable, 1 Enable

Parameter	Unit	Min.	Max.	Res	DFLT	Description
OEL Option		0	3		3	0 = MCB Or GCB 1 = GCB 2 = ON Line 3 = Dynamic (V1.22 or later)
OEL Off-Line Hi Level	%	0	500	1	200	100% = no load excitation current
OEL Off-Line Hi Time	sec	0	60	0.1	3	
OEL Off-Line Low Level	%	0	200	1	150	100% = no load excitation current
OEL Hi Level	%	0	500	1	300	100% = rated excitation current
OEL Hi Time	sec	0	60	0.1	3	
OEL Mid Level	%	0	300	1	180	100% = rated excitation current
OEL Mid Time	sec	0	200	0.1	10	
OEL Low Level	%	0	200	1	135	100% = rated excitation current
UEL Enabled		0	1		0	0 = Disable, 1 Enable
UEL Curve Type		0	1		0	0 = circular , 1 = segment
UEL Circular Reactive Power	%	5	50	1	40	100% = rated apparent power
UEL Segment Real power 1	%	10	29	1	20	100% = rated apparent power
UEL Segment Real power 2	%	30	49	1	40	
UEL Segment Real power 3	%	50	69	1	60	
UEL Segment Real power 4	%	70	89	1	80	
UEL Segment Real power 5	%	90	110	1	100	
UEL Segment Reactive power 1	%	5	50	1	40	100% = rated apparent power
UEL Segment Reactive power 2	%	5	50	1	35	
UEL Segment Reactive power 3	%	5	50	1	30	
UEL Segment Reactive power 4	%	5	50	1	25	
UEL Segment Reactive power 5	%	5	50	1	20	
SCL Enabled		0	1		0	0 = Disable, 1 = Enable
SCL Accept PF	pu	0.60	1.00	0.01	0.90	Version 1.22 or later
SCL Hi Level	%	0	500	1	350	100% = rated current
SCL Hi Time	sec	0	60	0.1	3	
SCL Low Level	%	0	150	1	125	100% = rated current

APPENDIX B. MATHEMATICAL MODELS

General

This appendix describes the mathematical model of HDEC2000 unit's software controller (function block). All detailed information of mathematical model (e.g. setpoint tracking model) is not mentioned in this appendix, but the major and important math model is only described for understanding. The exciter machine model is shortly described in this appendix since there is no responsibility by voltage regulator.

The most of mathematical models are designed based on the IEEE421.5-2005. However, all elements are not perfectly same as IEEE standard due to some modification of math model through the performance improvement and configuration convenience.

If not specified, all parameters (or gains) are expressed as per unit quantities (based on rated generator voltage, rated generator current and rated excitation current) and seconds. However, in case of base excitation current, the no load excitation current or air gap line excitation current may be used together with rated excitation current because of the convenience of use. All gains and time constants mentioned in this appendix can be estimated and configured by the use of setup software.

Simplified overall functional block diagram (some elements are omitted for the purpose of simplification) of HDEC2000 voltage regulator is shown in Figure B-1.
The overall control block consists of cascade structure. The AVR, FCR, OEL and SCL controllers are positioned to the inner loop and others are positioned to the outer loop.

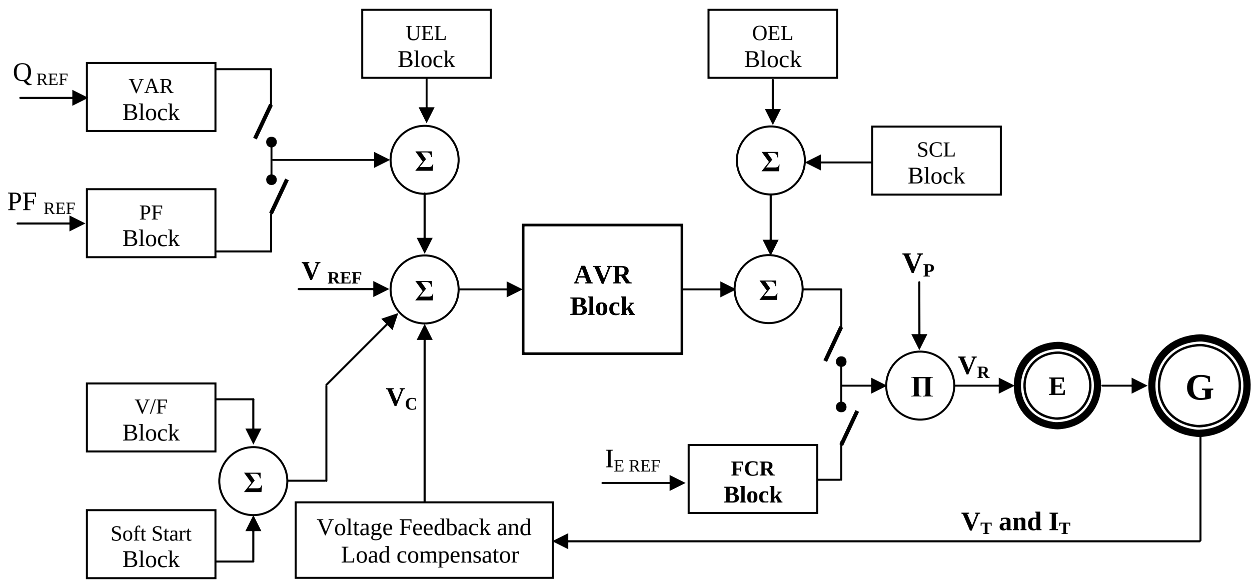


Figure B-1 Simplified Overall Function Block Diagram of HDEC2000 Regulator

Terminal Voltage Feedback and Load Compensator Model

The terminal voltage feedback and load compensation models are designed based on IEEE421.5-2005 Synchronous machine terminal voltage transducer and current compensator models, but simplified. A block diagram of the terminal voltage feedback and the load compensator is shown in Figure B-2.

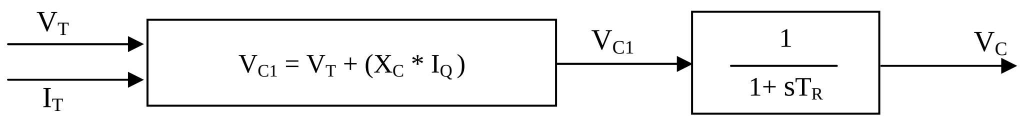


Figure B-2 Block Diagram of Voltage Feedback and Load Compensator

Where: V_T = Measured generator terminal voltage

I_Q = Reactive component of generator current, I_T * sin(φ), sin(φ) means reactive power factor.

X_C = Reactive Droop (positive: reactive droop, negative: line drop or transformer drop)

T_R = Time delay of sensing process including hardware filter circuit, typically 8 …10ms

Reactive Droop is configuration parameter of HDEC2000 unit in [pu]

The vector sum of generator voltage and imaginary reactive voltage drop is transferred to feedback loop of AVR controller. This leads that the generator terminal voltage drop is linearly proportional to generator reactive power (or reactive current).

If cross current compensation (CCC) function is enabled, the reactive current (I_Q) and Reactive Droop (X_C) are replaced by present unbalanced reactive current and [CCC Droop] configuration parameter.

Automatic Voltage Regulation Model with Exciter Machine

The block diagram of AVR controller designed under the basis of the AC8B model of IEEE421.5 with brushless rotating exciter model (AC5A model of IEEE 421.5 standard) is shown in Figure B-3. The AVR controller is PID controller having scaling (loop) gain Kg, proportional (K_P), integral (K_I) and derivative (K_D) gains. And all of four gains are adjustable depending on excitation system configuration and machine (main and exciter) characteristic (time constant and reactance).

The combination of AC8B (regulator) and AC5A (exciter) model has been widely adopted in the industrial application for the purpose of modeling due to the simple structure of AC5A exciter model rather than the complex AC8B exciter model, or due to the un-availability of detailed information of exciter.

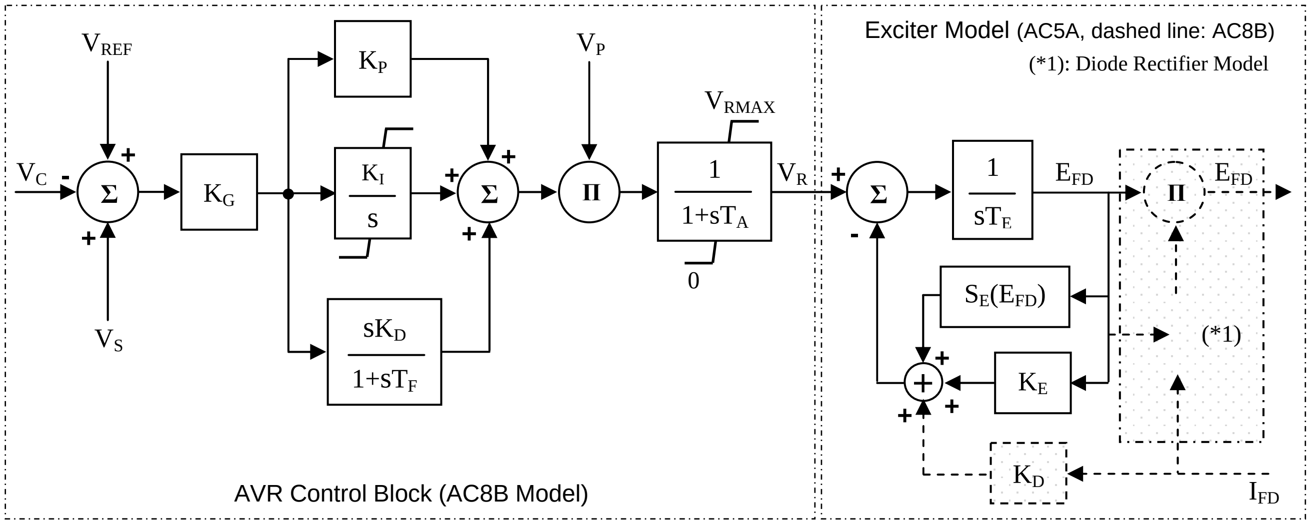


Figure B-3 Block Diagram of AVR Controller and Simplified Rotating Exciter

In case of modeling with complete AC8B excitation system model, below modifications may be applied.

- The diode rectifier model may be added.
- The term of E_{FD} (field voltage of AC5A model) may be replaced by V_{EX} (exciter armature voltage).
- The saturation factor $S_E(E_{FD})$ may be replaced by $S_E(V_{EX})$, and obtained from no load saturation curve . (The saturation factor is obtained from load saturation curve in case of AC5A model).
- One more feedback loop (gain K_D loop of exciter) for compensating armature reaction may be added.

The maximum output voltage V_{RMAX} of voltage regulator is equal to DC Link Voltage, and below formulas can be roughly applied for DC Link Voltage calculation. Also these rules can be applied in case of FCR model.

DC Link Voltage = 1.41* input ac voltage for three phase excitation power

DC Link Voltage = 1.25 * input ac voltage for single phase excitation power

DC Link Voltage = 0.98 * input dc voltage for dc power supplied

The term of Dc Link Voltage is: internal dc excitation power voltage of regulator through rectification and smoothing process from excitation input power

The time delay T_A in the hardware power stage including software code executing interval is typically zero due to high switching frequency of power module (IGBT) compared with generator and exciter time constant.

The loop gain K_G determines the overall response of AVR feedback loop. Generally, this loop gain depending on excitation input power voltage (V_P) and the no load excitation voltage is obtained from below formula. But to obtain more fast (or stable) response, the AVR loop gain may be adjusted in a range of between 50 and 300% of calculated value.

$$\mathbf{K_G = U_{EO} / DC\ Link\ Voltage}$$

Where: U_{EO} is excitation voltage corresponding to rated generator voltage with no load in [V]

DC Link Voltage is internally rectified voltage from excitation power input in [V]

The PID gains K_P, K_I and K_D are custom designed for the best performance for each generator and exciter system and can be estimated by setup software. The filtering time constant T_F is used for reducing (improving) the influence caused from feedback loop sensing noise and typically zero for the purpose of modeling.

Field Current Regulation Model

The block diagram of FCR controller is shown in Figure B-4. The model of rotating exciter same as mentioned above (the exciter model in Figure B-3) is not shown. The FCR controller is PI controller having scaling (loop) gain K_G, proportional (K_P) and integral (K_I) gains, and all three gains are adjustable. If AVR operating mode is selected, the FCR control block is disabled.

The loop gain K_G determines the overall response of FCR feedback loop. Generally, the loop gain depending on excitation input power voltage (V_P) and the nominal excitation voltage can be obtained from below formula.

$$\mathbf{K_G = U_{EN} / DC\ Link\ Voltage\ [pu]}$$

Where: U_{EN} is the nominal excitation voltage in [V]

DC Link Voltage is internally rectified voltage from excitation power input in [V]

The PI gains, K_P and K_I, are tuned by user for stable excitation current control depending on the excitation winding time constant. The tuning of PI gains may be simple due to first order time delay of excitation winding.

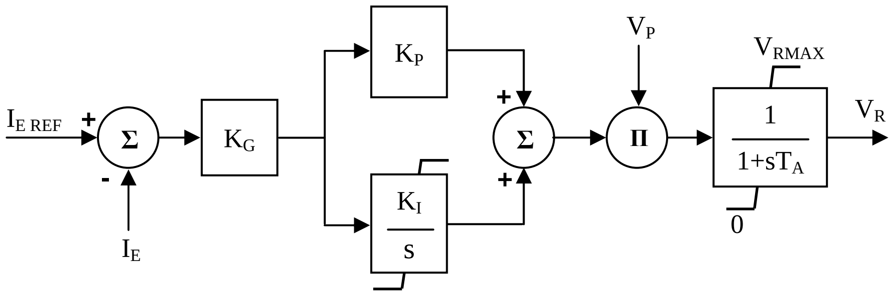


Figure B-4 Block Diagram of FCR Controller

VAR/PF Controller Model

The block diagram of VAR controller is shown in Figure B-5. The VAR controller is type II summing type PI controller of IEEE421.5. And the controller is positioned to the outer loop of cascade structure. If FCR operating mode is selected, the VAR control block is disabled. The VAR/PF controller cannot be enabled in the voltage supporting machine (see IEEE421.5) but can be enabled in the voltage following machine.

The control output (V_{VAR}) of VAR controller is summed with setpoint (reference) of AVR controller, and the VAR controller operates slowly compared with AVR controller. The VAR control block consists of scaling (loop) gain (K_G) & integral gain (K_I), and both gains are adjustable. Two gains are tuned so that the control action may have slow response.

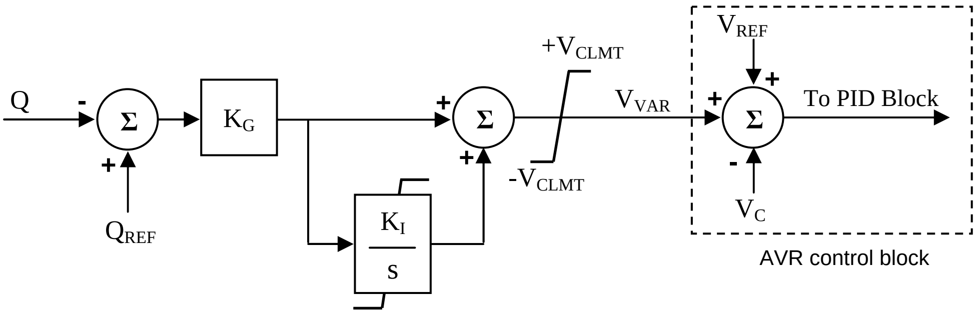


Figure B-5 Block Diagram of VAR Controller

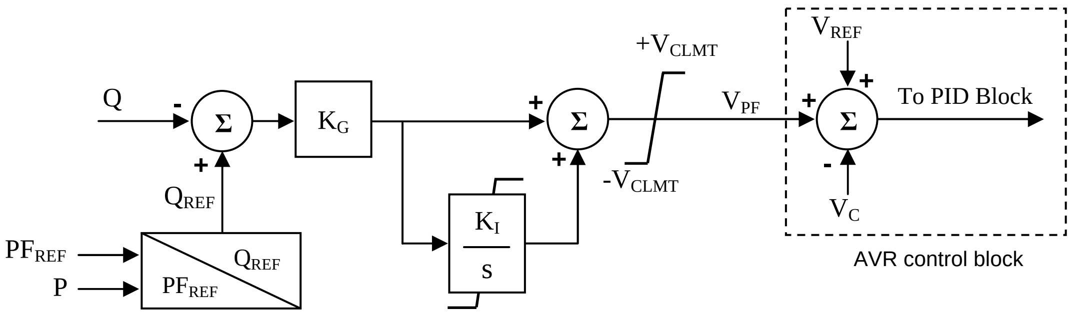


Figure B-6 Block Diagram of PF Controller

The output limit of VAR controller V_{CLMT} depending on the boundary of grid (power network) voltage and the control margin is configured by setup software, and typical range is 0.1 …0.15[pu].

The block diagram of power factor (PF) controller is shown in Figure B-6. The PF controller is type II summing type PI controller of IEEE421.5. The PF controller is same as VAR controller except PF setpoint (PF reference) input.
The PF setpoint is transferred to the summing point of PF controller through conversion process (from PF reference to VAR reference by using of present active power and PF reference) to obtain PI gain similar with VAR controller.

Over Excitation Limiter Model

The block diagram of OEL controller is shown in Figure B-7. The OEL controller is summing type PI controller, and the controller is positioned to the inner loop of cascade structure. If FCR operating mode is selected, the OEL control block is disabled.

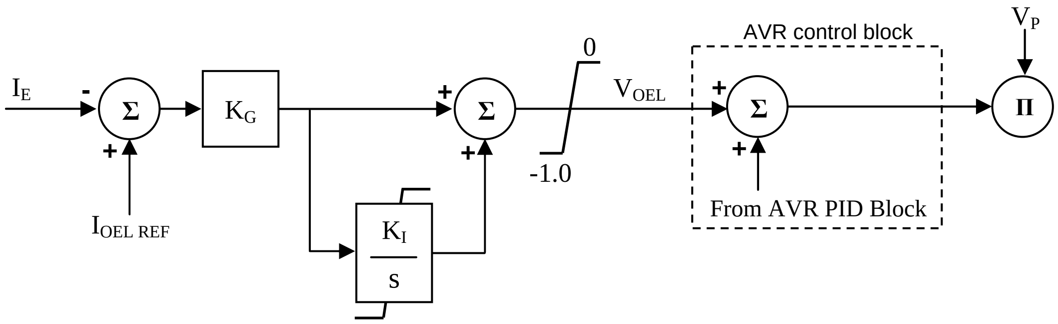


Figure B-7 Block Diagram of OEL Controller

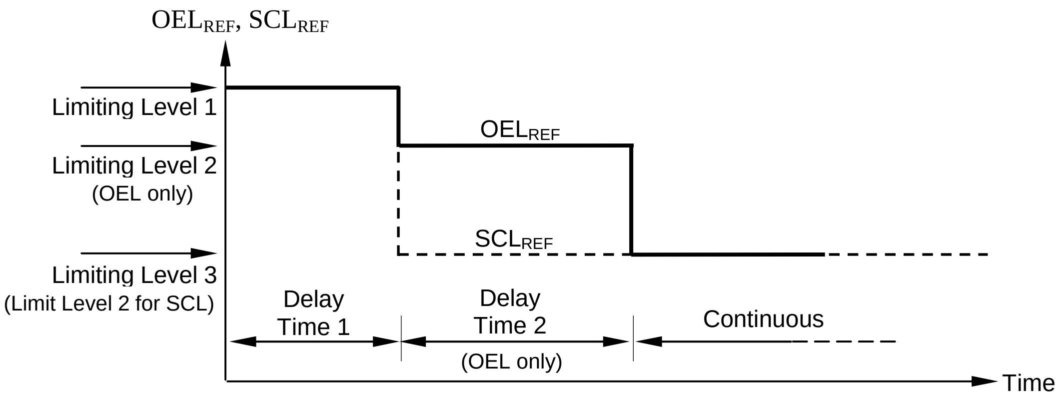


Figure B-8 Typical Operating Characteristic of OEL and SLC Reference

The control output (V_{OEL}) of OEL controller is summed with the control output of AVR controller. The OEL control block consists of scaling (loop) gain (K_G) and integral (K_I) gain, and two gains are adjustable.

The operating characteristics of OEL controller are designed with three constant (configurable) limiting levels and two constant (configurable) time delays. If the excitation current exceeds the allowable safe level (and if the level is maintained for the duration of pre-defined delay time), the excitation current may be reduced (limited) instantaneously up to the OEL reference by mean of OEL reference reduction. The operating characteristic is shown in Figure B-8.

When the excitation current is decreased lower than the limitation level (limiting level 3 in Figure-B8) by external load reducing or by external condition change, the control output of OEL block is not immediately returned to zero level but gradually returned to zero to prevent much voltage overshoot due to the sudden changing of control output. Also, in this case, the limiting level-3 is maintained as OEL reference for duration of cool-down time, and cool-down time is depending on control output of OEL controller.

Stator Current Limiter Model

The block diagram of SCL controller is shown in Figure B-9. The SCL controller is summing type PI controller having two control gains (proportional gain K_P and integral gain K_I) two control gains are adjustable. The controller is positioned to the inner loop of cascade structure, and the control output is summed with the control output of AVR controller. If FCR operating mode is selected, the SCL control block is disabled.

The operating characteristics of SCL controller are designed with two constant (configurable) limiting levels and one constant (configurable) time delays. The typical SCL curve is shown in Figure B-8.

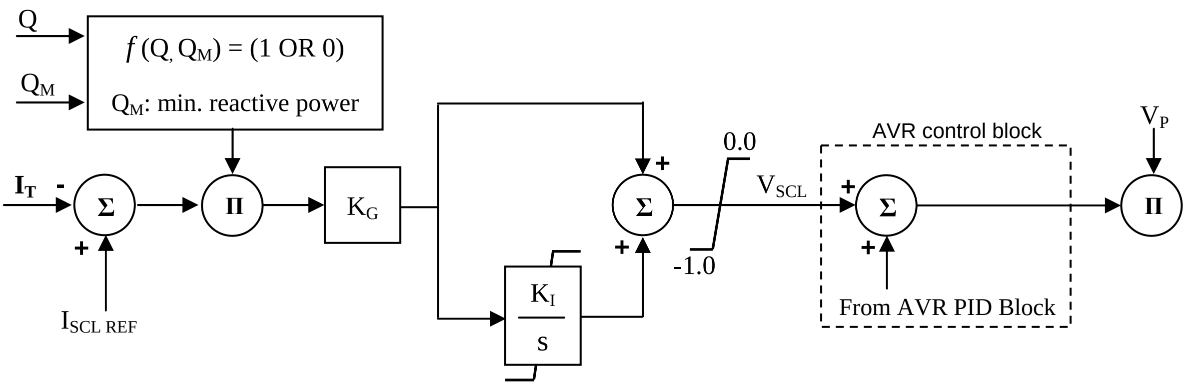


Figure B-9 Block Diagram of SCL Controller

The SCL controller reduces the control output if the stator current exceeds the predefined safe operation level and the measured reactive power is higher than minimum specified reactive power (Q_M in the block diagram). Even though, the stator current exceeds the limitation level with under excitation region (or actual reactive power is less than minimum specified level), the SCL controller disregards the excessive current. In case of under excitation condition, the UEL controller may be used instead of SCL controller due to the inherent characteristics of synchronous machine (normally, the exceeded current over than nominal value is not permitted with under excitation condition, however the SCL limitation level may be settled with higher than nominal value).

In case of permanent single operation (not paralleled), If the generator is operated with passive load such as lighting load, and the minimum specified reactive power is settled with zero, the SCL controller disregards the under excitation (or less reactive power) condition.

When the stator current is decreased lower than the limitation level (limiting level 2 in Figure-B8) by load reducing or other external condition change, the reset characteristic of control output is similar to OEL controller.

Under Excitation Limiter and Model

The block diagram (UEL reference block is simplified) of UEL controller is shown in Figure B-10. The UEL controller is summing type PI controller, and the controller is positioned to the outer loop of cascade structure. If FCR operating mode is selected, the UEL control block is disabled.

The control output (V_{UEL}) of UEL controller is summed with the setpoint (reference) of AVR controller. The UEL control block consists of scaling (loop) gain (K_G) and integral gain (K_I), and both gains are adjustable.

The PI gains K_G and K_I may be tuned to the higher level than the gains of VAR/PF controller in order to get out from the unstable operating condition when the generator reactive power is lower than the UEL reference.

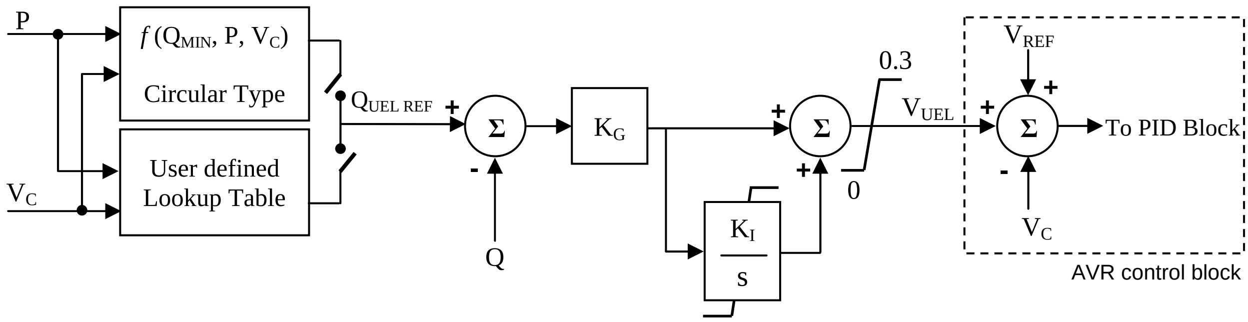


Figure B-10 Block Diagram of UEL Controller

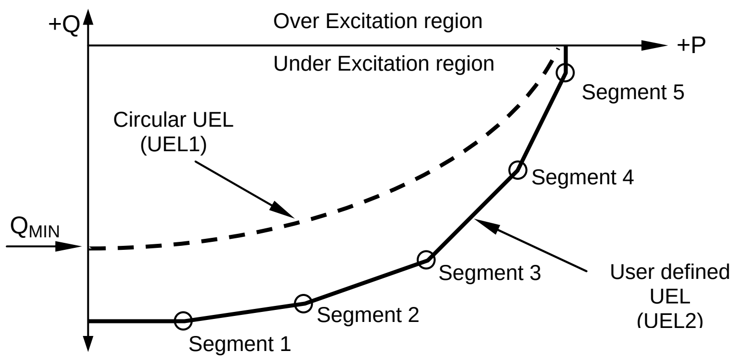


Figure B-11 Typical UEL Curve of Circular Characteristic and Piecewise linear Type

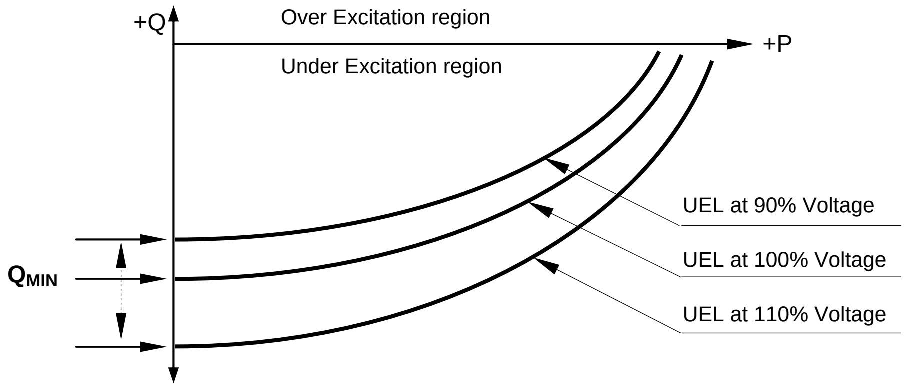


Figure B-12 Typical Circular UEL Curve with different Generator Voltage

The HDEC2000 regulator supports both types of UEL model (type UEL1 and type UEL2) of IEEE 421.5 standard, and only one UEL model is selected by user. The first type UEL1 (called with circular characteristic UEL) is corresponding to the Circular UEL of HDEC2000 regulator and the second type UEL2 (called with piecewise linear UEL or multi segment UEL) is corresponding to Segment UEL of HDEC2000 regulator. The typical UEL curves of two UEL models are shown in Figure B-11, and the typical Circular UEL curve with different voltage level is shown in Figure B-12.

Any case of UEL model selection, the UEL reference is not fixed but calculated (or interpolated) value based on the present active power, generator voltage and pre-defined reactive power segments configured by user (and active power segments configured by user in case of UEL2).
If generator reactive power is lower than the calculated UEL reference, the excitation current may be increased until the reactive power is above UEL reference.

Soft Start Function Model

The block diagram of soft start function is shown in Figure B-13. Soft start function block is enabled in both cases of AVR mode and FCR mode. The control output of soft start function block is summed with the setpoint of AVR controller (and FCR controller).

The soft start function block is designed for smoothing generator voltage buildup with minimal overshoot while desired time from excitation on event.

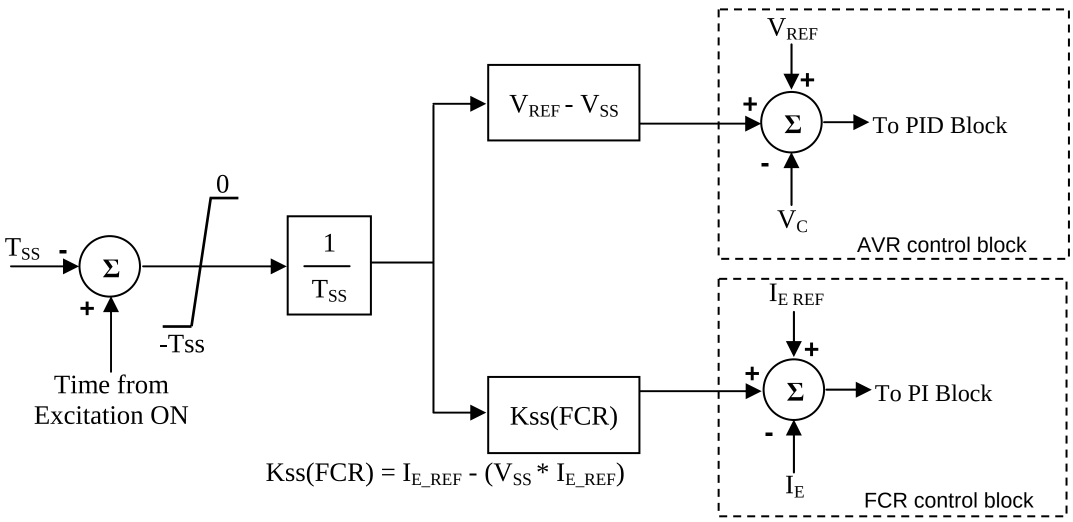


Figure B-13 Block Diagram of Soft Start Function

When excitation on command is detected, the soft start function block linearly increases the AVR setpoint from Soft Start Level (V_{SS}) to nominal AVR Setpoint through Soft Start Time (T_{SS}). The both parameters (soft start level and soft start time) are adjustable. In case of FCR mode, the soft start function block reduces FCR Setpoint based on the soft start level (V_{SS}).

Under Frequency (V/F or V/Hz) Limiter Model

The block diagram of under frequency limiter (UFL) is shown in Figure B-14. UFL function block is enabled in case of AVR mode only. The control output of UFL function block is summed with the setpoint (reference) of AVR controller.

The UFL function block is designed for protecting the generator from damage due to excessive magnetic flux caused by low-frequency operating condition.

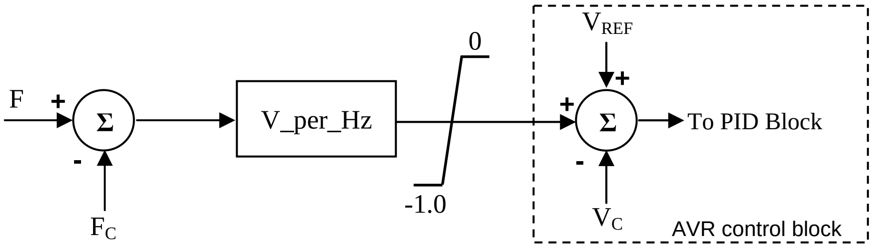


Figure B-14 Block Diagram of Under Frequency Limiter

If the generator frequency is lower than the corner frequency (F_C), the UFL function block reduces the AVR setpoint based on the corner frequency and the reduction slope (V_per_Hz). The two parameters (corner frequency and the reduction slope) are adjustable. The reduction slope is typically 0.8 …1.5 [V/Hz].

APPENDIX C. SPECIFICATIONS

Excitation Power Input

Phase: 1 or 3 phase power

Frequency: 40 to 400Hz

Nominal Input voltage range:

- 56 to 260Vac for single phase and three-phase (for PMG and station power application)
- 56 to 250Vac for single phase and three-phase (for shunt power application)

Maximum permissible Input voltage:

- 275Vac continuous for PMG power and station power
- 250Vac for shunt power, over than 250V (nominal secondary voltage of shunt transformer) is not permitted due to the transient overshoot.

Maximum continues current: 20A for 1 phase, 13A for 3-phase.

Minimum shunt power for voltage buildup (typical):

6Vac without control power

3Vac with control power

1) For optimum dynamic response, input voltage level may be higher than 2 times of nominal.
2) For proper control precision, the input voltage level may be less than 4 times of nominal.
3) The magnitude of Input current is depending on the excitation current.
4) DC power source not exceed 360V is also available in case of no AC supply is available.

Excitation Power Output

Continuous current: 15Adc

Over load (maximum 10s): 30Adc

Maximum continuous control voltage: 150Vdc

Current reduction: 0.5A per ℃ for ambient temperature > 60℃

1) Maximum 18Adc can be supplied continuously (ambient temperature <= 45℃.)
2) The controllable output voltage level is depending on the input voltage level.

Control Power Input

AC Input voltage: 60 to 230Vac, 50/60Hz, 120Vac is preferred.

DC Input voltage: 60 to 125Vdc

Burden: 50VA for AC, 30W for DC

1) No control power is required normally.
2) Control power must be supplied for below cases, in these cases, either AC or DC power source is accepted, but only one source is available.
   - Redundant system by Dual HDEC2000 units.
   - Residual voltage is lower than 6Vac in case of shunt power application (the residual voltage is measured at excitation input terminals),

   In case of second case, the pre-excitation power may be supplied alternatively during start up.

Generator Voltage Sensing Input

Burden: Maximum 1VA per phase

Phase configuration: 1 or 3 phase

Frequency: 50/60Hz

Input range: 110V, 220V or 460V

Input range selection: Selected by software automatically

Generator Current Sensing Input

Burden:

Less than 1VA for control (reactive droop) and monitoring

2VA for reactive differential compensation (CCC)

Phase configuration: 1 phase

Frequency: 50/60Hz

Range:

1A or 5A for control (reactive droop compensation) and monitoring

1A for Reactive differential compensation (cross current compensation)

Auxiliary Analogue (Remote Setpoint) Input

Voltage input: ±10V, (0 …10V or 1 …5V also available)

Current input: 4 to 20mA, (0 …20mA also available)

Input impedance: 100kΩ for voltage input, 150Ω for current input

Contactor (Digital) Input

Input Type: Dry contactor or potential free PLC open collector output (Dry contactor preferred)

Electrical rating: 24Vdc (open), 5mAdc (close)

Number of inputs:

7 inputs for fixed function

3 inputs for programmable function

Fixed input functions:

Excitation on/ off (Start/ Stop) command

FCR select (Auto/ Manual) command

Raise setpoint command

Lower setpoint command

Status of grid circuit breaker (GCB)

Status of machine circuit breaker (MCB)

Alarm reset command

Programmable input functions:

Preposition setpoint

Secondary unit

Local request

Secondary Soft Start

Digital Contact (Relay) Output

Type: Dry contact

Contact switching rating:

- 24Vdc, 5A
- 125Vdc, 0.2A
- 120/240Vac, 10A

Contactor continuous rating:

- 24Vdc, 5A
- 125Vdc, 5A
- 120/240Vac, 10A

Number of contactors:

- 1 relay output for watchdog fault
- 3 relay outputs for programmable logic

Assignable event: All operating statuses and fault events

Relay logic: Programmable NO or NC

(If NC logic is selected, contact is enabled while internal control power up)

Communication Ports

Com 0: RS232, on front panel, DB-9 connector for factory setup and commissioning

Com 1: CAN Port, on Right side DB-9 connector for redundant system (not supported now)

Com 2: RS-485, on Left side screw terminals for remote control and monitoring (read only now)

Regulation Mode and Performance

Control mode and accuracy:

- AVR mode: ±0.25% of the nominal voltage @ ±0.1% stability
- FCR mode: ±1.0% of the nominal excitation current
- VAR mode: ±2.0% of the generator nominal apparent power
- PF mode: ±0.02 PF of the power factor setpoint
- Ready Mode: Excitation Off (in case of shunt power application with no control power)

Parallel compensation mode: Reactive droop and Reactive differential (cross-current)

Parallel compensation droop range: 0 to ±30%

Soft start function: 0 to 90% Start level, 1 to 200s Buildup time

Supported limitation function:

- Over excitation limitation
- Under excitation limitation
- Stator current limitation
- Under frequency limitation

Supported protective function:

- Over voltage, Under voltage
- Over current (constant time and inverse time characteristic)
- Over excitation (constant time and inverse time characteristic), Under excitation

Loss of sensing, Loss of power

Open diode, Short diode

Short circuit protection of excitation output (supported by hardware)

Mode mismatch

Bump less operating mode transfer (internal tracking): support

Redundant configuration (Auto-tracking between two HDEC 2000 units): not activated now

Measuring Parameter of Front Panel Display (Range and Accuracy)

Generator voltage: 0 to 150% of input range, <1% (50/60 Hz)

Generator current: 0 to 140% of input range, <1% (50/60 Hz)

Active power: 0 to 200%@PF=1.0 of input range (voltage * current), <1% (50/60 Hz)

Frequency: 10 to 90Hz, ±0.1Hz

Power Factor: -0.5 to +0.5 PF, <0.02 pu

Excitation current: 0…38Adc, ±0.15A or ±1.0% of full range (whichever is greater)

Status Monitoring of Front Panel Display

Active control mode

Setpoint of active operating mode

Start, Stop status

Functional limiter status

Primary, Secondary unit status (redundant configuration)

All fault event supported by HDEC2000 unit

LED Function of Front Panel

Control power ON/OFF

Local control status

Remote control status

Setpoint limitation status

Fault event status

Environment

Operating temperature: -20 to 60 °C

Storage temperature: -20 to 70 °C

Operating humidity: 5 to 95% Related humidity (non-condensation)

Shock: IEC 60068-2-27

Vibration: IEC 60945

Physical Characteristics

Weight: 4.5kg

Dimension: 304 × 205 × 175 (H × W × D)

Protection class: IP20

CE Certifications

Applicable EC Directives

- Low Voltage Directive (2006/95/EC)
- EMC Directive (2004/108/EC)

Applicable Standards

- EN 61010-1 (2001 Second edition):
  Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use, Part1: General Requirements

- EN 61000-6-2 (2005)
  Electromagnetic compatibility (EMC) – Part 6-2: Generic Standard – Immunity for industrial environments

- EN 61000-6-4 (2007)
  Electromagnetic compatibility (EMC) – Part 6-4: Generic Standard – Emission standard for industrial environments

Revision History

Firmware Revision

Version	Date	Description
1.00	Sep 09, 2009	• Initial release (beta version for first commercial release) • Non-commercial version, internal pre-development. • Below functions are included (all basic functions are tested and verified.) - adoption of true rms sensing algorithm - four operating modes (AVR, FCR, VAR, PF) - reactive droop compensation function - soft start function - under frequency limitation function - auxiliary analog input processing for AVR, FCR, VAR mode - OEL function
1.01	Jan, 09 - 2010	• First commercial version • SCL function is added • Interpolation filter of VAR/PF control block output is added • Bug Fix of RS232 communication routine
1.10	Apr, 10 - 2010	• Minor bug fix of firmware V1.01 • D term filtering function of AVR mode is added • Auxiliary input function for PF mode is added • MCB, GCB status for HDCM software (communication parameter) is added • PF setpoint processing (linear scaling) function is corrected
1.11	May 09, 2010	• Beta version for next official release (V1.20) • Bump-less mode transfer (internal tracking) function is added • Digital filter of VAR/PF controller output is added • Below protective functions are added - generator over voltage - generator under voltage - generator over current - exciter over current - loss of field - Loss of sensing - loss of power - short Circuit Output - mode mismatch - diode fault monitor • UEL function is added • Setpoint auto save function is added
1.20	Oct 21, 2010	• The completed version for most operational functions • MODBUS communication function (read only) is added • RS232 protocols and EEPROM access algorithm are improved

Cont. Firmware Revision …

Version	Date	Description
1.21	Nov 30, 2010	• Minor bug fix of firmware V1.20 • Firmware version display function is added • Droop setting save function via front panel is corrected - droop setting via front panel is not saved with earlier version • Setpoint display format is corrected refer to user's manual • Fault message display function is corrected - only one fault message (last occurred) is displayed with earlier version
1.22	Apr 16, 2011	• Improved release of firmware V1.20 and V1.2.1 • Time dividing algorithm of each processing block is optimized • Upgrade of user interface (front panel) function - single page display function is expanded with multi page display function - parameter configuration function via front panel is supported - some operational function via front panel is added - fault information display based on text message is replaced with fault ID - UFL message is changed with [V/F] message from [UFL] - setpoint limitation status is assigned (added) with front panel [Limit LED] • Ready Mode function for shunt application with no control power is added • Secondary soft start function and related function is added - [Soft Start Level 2] and [Soft Start Time 2] parameters are added - [Soft Start Delay] and [Buildup Detect Zone] parameters are added - Secondary soft start programmable digital input function is added • Kinds of analog input are expanded - 0 …10V, 1 …5V and 0 …20mA range are added - Unipolar option is added • Setpoint Auto Save function is changed - FCR mode Setpoint Auto Save function is removed - stop event detection algorithm is improved • Differentiation algorithm of AVR controller is changed - error differentiation is adopted from differentiation of generator voltage • Control algorithm of SCL block is changed - SCL function with under excitation region is disregarded - SCL error prediction algorithm is improved. • Control algorithm of UEL block is improved - limiting level of UEL control output is changed (from 0.5 to 0.3) - UEL activation logic is changed (exception logic is added) - UEL reference calculation algorithm (voltage dependency) is added • On-line, Off-line OEL Option (dynamic option) is added • Internal tracking option parameters are added - Enabled option is changed to Auto Manual Only option. - From VAR/PF to AVR option is added - All Mode option is added

Version	Date	Description
1.23	May 29, 2011	• Minor improve version of firmware V1.22 • The limiting function of analog input signal is added • Setpoint limiting boundary of inactive operating mode is changed - Out-of-bounds analog input is disregarded for bump-less mode transfer function • Soft start parameters are replaced depending on the generator voltage • bug fix for AVR mode setpoint display on the front panel • bug fix of Dynamic OEL option
1.24	Oct 17, 2011	• Front panel display format change - Analog page format of monitor mode is changed

HDCM Software Revision

Version	Date	Description
1.00	Sep 09, 2009	• Initial release • Non- commercial version, for internal pre-develop
1.01	Jan 09, 2010	• First commercial version • Configuration parameters for firmware version 1.01 are added
1.10	Apr 10, 2010	• Configuration parameters for firmware version 1.10 are added
1.11	May 09, 2010	• Configuration parameters for firmware version 1.11 are added
1.20	Oct 21, 2010	• Configuration parameters for firmware version 1.20 are added • Control gain estimation function is added • MODBUS communication parameters are added • RS232 communication protocols is improved
1.21	Apr 16, 2011	• Update for firmware revision (V1.22) • Default parameter for some function (e.g. UEL) are changed

Manual Revision

Version	First Release	Description
A	Sep 09, 2009	• Initial release • Non- commercial version, for internal pre-documentation only
B	Jan 15, 2010	• First commercial version • Revision for firmware V1.01 and HDCM software V1.01
C	Nov 30, 2010	• Update for firmware revision (V1.1 …V1.21) • Update for HDCM software revision (V1.1 …V1.20) • CE certificate is added • Mathematical models are added
D	Apr 10, 2011	• Update for firmware revision (V1.22 …1.24) and HDCM software V1.21 • SCL mathematical model is changed • UEL mathematical model is changed • UEL definitions are changed - Internal UEL is changed with Circular UEL - Customized UEL is changed with Segment UEL • Description for excitation on control logic is added • Control gain estimation algorithm is improved • Some typical range of control gains are changed