RT-flex Training

Function of the RT-flex Control System
WECS-9520
The RT-flex engine control consists of

- Internal engine control **WECS-9520** and the

- External **Propulsion Control System** (PCS) (not Wärtsilä supply) with
  - Remote Control (ECR, Bridge)
  - Safety System
  - Electric Governor
  - Alarm Monitoring System
## RT-flex control system

### Control Systems Overview

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**RT-flex control system**

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Basic RT-flex concept

Basic Schematic of the Wärtsilä RT-flex system with electronically controlled common-rail systems for fuel injection and exhaust valve operation.
Engine control system WECS-9520

- The WECS-9520 is the core engine control, it processes all actuation, regulation and control directly linked to the engine:
  - Common rail monitoring and pressure regulation
  - Injection and exhaust- and start valve control and monitoring
  - Interfacing external systems via CANopen or MOD Bus
  - Engine performance tuning, IMO setting and -monitoring

- WECS-9520 has no central computer but each cylinder has its own FCM-20 module for the cylinder related- and common functions.
These FCM-20 modules are mounted directly on the engine and communicate via internal **System CAN Bus**. An operator access to the WECS-9520 is integrated in the user interface for the propulsion control system and flexView.

WECS-9520 is neither an engine remote control system nor a safety system.
Remote control system:
Kongsberg Maritime, NABTESCO, Lyngsø

- The remote control is the operator interface to the engine. Selectable control panels deliver following manoeuvring commands to the WECS-9520 via CANbus or MODbus connection:
  - Start, Brake air
  - Stop
  - Ahead
  - Astern
  - Air run
  - Slow turning
  - Slow turning failure reset

- The remote control processes the engine telegraph command with internal settings (scaling, load program etc.) to a speed reference signal for the governing system.
RT-flex control system

Kongsberg Maritime
Electronic governor system:
Kongsberg Maritime, NABTESCO, Lyngsø

- The electronic governor system supplies the fuel command for the WECS-9520 and regulates the engine speed.

- The fuel command is calculated from the speed reference signal of the RC-system in relation to the engine load. Fuel limiter in the governor system limit the fuel command depending on actual speed and charge air pressure to avoid engine operation beyond the propeller law curve (smoke & torque limiter).
Safety system:
Kongsberg Maritime, NABTESCO, Lyngsø

- The safety system activates slowdowns and shutdowns in case of overspeed or other abnormal conditions of the engine or its auxiliary equipment. The function with the RT-flex engine is similar to the conventional RTA engines, with some different / additional functions:
  - WECS-9520 uses redundant BUS communication with safety system
  - The safety system (not WECS-9520!) directly activates the hardwired emergency-stop solenoid to depressurize the fuel common rail
Additionally the safety system delivers some digital outputs to WECS-9520 via CAN Module bus or MODbus:

- Inverted main bearing oil shutdown signals for starting and dry-running protection of the control-oil pumps.
- Shutdown signal to WECS-9520, to activate WECS-internal shutdown responses.

WECS-9520 failures requesting speed reduction are activated through AMS to the safety system.
Alarm monitoring system:
Any possible system with class approval

- The monitoring system receives alarm messages, divided in two groups:
  - Some general failures alarm signals are hardwired via E130 and E90 for following general failures:
    - Leakage Alarms: Rail Unit, Supply Unit, Injection Components
    - Fuel Pressure Actuator Failure
    - Fuel Pump Outlet Temp Deviation Monitoring
    - Servo Oil Flow Monitoring (Dynex pumps only)
    - WECS-9520 Power Supply Monitoring
Other WECS-9520 failure signals are transmitted via redundant (module-) bus connection:

- The standard WECS-9520 execution uses a Modbus interface to send failure messages to the AMS via WECS-9520 modules FCM-20 #3 and FCM-20 #4.
- If both propulsion control and alarm monitoring systems are from Kongsberg Maritime (*Autochief C20* and *Datachief C20*), then the monitoring system can access WECS-9520 directly via CANopen interface to FCM-20 #1 and FCM-20 #2 and no Modbus connection is required.
WECS-9520 failures on the AMS:

- Total 6 different groups of WECS-9520 failures are transmitted via CAN/Modbus to the alarm monitoring system:
  - **Passive Failures**
    - Failures of redundant sensors, busses or components
  - **Common Failures**
    - Cylinder unit failures without redundancy or common system failures that do not cause any speed reduction
  - **Cylinder Failures**
    - Any cylinder unit failures that cause a slowdown via AMS
  - **Rail Pressure Failures**
    - Common rail pressure failures that cause a slowdown via AMS
  - **Cylinder Lubrication Malfunction (Pulse Lubrication only)**
    - Any cylinder lubrication malfunction that causes a slow down via AMS
  - **WECS-9520 Critical Failures**
    - System critical failures that cause immediate stopping of main engine and cannot be overridden by safety system
Bus systems used for WECS-9520:

- CANopen System Bus
- CANopen Module Bus
- ModBus
- SSI Bus
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RT-flex control system

Control Room

Lyngsoe

ModBus #1 & #2

WECS-9520

CANopen System Bus

ECR Manual Panel

flexView

Engine room

Rail Unit

2 x 230VAC

Power Supplies

RT-flex Engine

Local Manual Panel

Starting Valve

VCU

3x ICU

CO Pump

Actuator for Fuel Pump

Servo oil Pump

Cyl. Lubrication Modules

CANopen Module Bus #4

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The WECS-9520 system is built with a single multifunctional electronic module FCM-20 = Flex Control Module 20. One FCM-20 is mounted per cylinder in a cabinet (E95) below the rail unit. An additional online spare module FCM-20 is located in the SIB Shipyard Interface Box (E90). The modules communicate between each other on a fast internal CANopen system bus. Additionally each module has got two module busses (1x CANopen, 1x MODbus) that are used for communication to external systems (PropCS, ALM), backup control panels, actuators (size IV). The internal module layout and the cable trays in the rail unit entirely separate circuits with high EMC noise, like power cables or pulsed current lines (PWM, rail valves) from sensitive low power lines like databus cables and sensors.
Terminator resistors

- At each end of the Bus cable a terminator resistant of 120Ω MUST be installed to avoid signal reflection.
RT-flex control system

FCM-20 Module

HW version 004

HW version 006
FCM-20 Hardware I/O

On the upper left-hand side of the FCM-20 are the interface plugs for the high/pulsed power outputs. LED’s indicate I/O condition. Some change their colour in case of failures or short circuits. Blink codes give detailed failure information.

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- **Injector 1 Railvalve**
- **Injector 2 Railvalve**
- **Injector 3 Railvalve**
- **Exhaust V/v Railvalve**
- **Start Pilot Valve**
- **24VDC out, Ctrl-Oil Pps**
- **Auto. Main Start Valve**
- **Supply Man. Ctrl. Panels**
- **Servo Oil Pump Actuator**
- **Power Supply 24vDC OK**
FCM-20 Hardware I/O

On the lower right-hand side are the interface plugs for low power signals and databusses. LED’s indicate FCM-20 module & I/O condition. Some change their colour in case of failures or short circuits. Blink codes give detailed failure information.

RT-flex control system

Low Power I/O

- FCM/20 Cylinder # Identification Error
- Fuel Qty. Feedback ok / Failure
- Exhaust V/v Position 1 FB ok / Failure
- Exhaust V/v Position 2 FB ok / Failure
- Analogue In 1 (Rail Pressure, Charge Air…) / Failure
- Analogue In 2 (Rail Pressure, Charge Air…) / Failure
- Analogue in 3 (Spare) / Failure
- CA Sensor 1 Short Circuit Power Supply
- CA Sensor 2 Short Circuit Power Supply
- CA-Sensor 1 Master / Clock or Data Failure
- CA-Sensor 2 Master / Clock or Data Failure
- CAN System Bus 1 Master / Bus Failure
- CAN System Bus 2 Master / Bus Failure
- CAN Module Bus 1 Traffic / Bus Failure
- MODbus Traffic
- Digital Input 1 (Turning Gear Engaged; TDC Pick-up)
  - Digital Input 2 (Pressure Switches)
  - Analogue Out (Fuel Actuator Set point)
- Power Supply Failure
- Module ready, SW OK
- Failure on Module
- Not Applicable
The internal FCM-20 functions within the WECS-9520 can be separated in two groups:

- **Cylinder Related Functions**
- **Common Functions**
Cylinder related functions:

- For synchronizing the valve control timing with the crank angle, each FCM-20 reads and processes the crank angle signals from the SSI-Bus and calculates speed, angle and rotational direction of its cylinder.
- Start-, injection- and exhaust valve control according to settings in data container and commands and parameters received across CANopen System bus.
RT-flex control system

Cylinder Related Function Interface

- Injection Control Unit
  - 2 or 3 Rail valves
- Exhaust Control Unit
  - 1 Rail valve
- Start Pilot Valve
- Exhaust Valve Position Feedback
  - 4-20 mA
- Fuel Quantity Feedback
  - 4-20 mA
- Crank Angle Sensors
  - 1 Clockbus
  - 1 Databus

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Common functions:

- Fuel- and servo oil rail pressure regulation and monitoring, control oil pumps control
- Storage and processing of tuning data (IMO, engine-specific and global settings)
- Internal WECS monitoring (power supply, SW-watchdog, CRC- & HW-checks)
- Calculation and processing of common control variables (VIT, VEC, VEO, engine state)
- Interface to propulsion control system and to backup panels in CR and LC
- Failure indications with help of module LED's
- Aux. blower request at low charge air pressure
Selector buttons for manoeuvring commands.

Start Air is released as long as AH / AS buttons are pressed. The engineer can decide, when and for how long start- or brake air is supplied.

Select Speed or fuel control mode

Speed or fuel commands are set with a dial button on the RC supplier part of the CR / LC panels.

Last command is stored, when taking over to other panel or from remote to manual control.

Speed control mode is only possible, if the speed governor system in the PCS and the bus connection is operational.

Similar panels are installed in ECR and Local Control Panel. All necessary information is shown on the display:

- Speed and / or Fuel Command
- Start Interlocks
- Safety events (SHD, SLD, OVSPD)
- Rail pressures

WECS-9520 MANUAL CONTROL

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RT-flex control system

Manual Control Panels

- **AIR RUN**
  - Releasing starting air in ahead direction to blow engine on air, as long as button is pressed.

- **SLOW TURNING**
  - Releases a slow turning sequence.
  - Slow turning failures are indicated in the display. Reset slow turning failure with pushbutton:

- **SOUND OFF - ALM ACKN.**
- **AUX BLOWER PRESEL.**
- **AUX BLOWER STOP**

- **START AHEAD**
- **START ASTEMIN**
- **STOP**

**Pre-selects blowers for automatic mode; start / stop depends on actual charge air pressure.**

**starts blowers manually, if both charge air sensors fail.**

=> **Display:** Aux. Blower Man. Ctrl. / No Blowes running

**Stops blowers during automatic mode only if engine is not running.**

**In manual mode stops blowers at any time.**

- **SAFETY SYSTEM RESET**
  - Resets shutdowns on the safety system.

- **SHD OVERRIDE**
  - Overrides shutdowns if pressed once, next pressing releases override (see to red LED indication).

- **SOUND OFF - ALM ACKN.**

If the Ackn. button is pressed for more than 5 seconds, WECS-9520 SW info and all necessaryIMO check values are indicated in the screen until button is pressed again.
Rail valves:

The rail valves are ultra-fast switching (~2 ms) electro-hydraulic solenoid valves. Due to the high actuation current and the thermal load on the solenoid coils, they must not be energized for more than 4.5 ms. This “on”-time is sampled, monitored and limited by WECS-9520.

Rail-valves are bi-stable, i.e. selected position remains until counter-direction is set by WECS-9520.

After installing or replacing a bi-stable valve, its position (open or close) is unknown. To make sure the valves are always in the safe “No injection” and “Exhaust valve closed” position when the engine is stopped, WECS-9520 sends set-pulses to all rail valves in regular intervals (~10 s).
Crank angle detection:

Without direct mechanical crank angle transmission to the control elements for fuel injection and exhaust valves it is necessary to measure the actual crank angle electrically. The crank angle sensors for WECS-9520 have an absolute angle resolution, therefore the exact crank angle value is present immediately after powering up.

Two such angle transmitters are connected with serrated belts to a specially designed drive shaft. This application prevents transmission of axial and radial crankshaft movements to the sensors.

Each sensor transforms angle data from an optical code disk into a bit frame. The FCM-20 modules read these bit frames from a SSI bus (Synchronous Serial Interface Bus).
To synchronize the messages between FCM-20 modules and CA-sensors, each SSI bus has its own clock bus, the bit frames itself are sent via its data bus.

The two last FCM-20 are clock bus masters (e.g. #11 & #12 on a 12-cyl. RT-flex). I.e. FCM-20 #(last-1) supplies clock pulses to sensor 1 and the other modules on bus 1. FCM-20 #(last) supplies clock pulses to sensor 2 and the other modules on bus 2.

Signals from both CA sensors are processed and checked for errors within each FCM-20.

Sensor angle values are compared with TDC pulse signals from a pick-up on the flywheel. If the TDC signal does not match with a sensor’s crank angle sector around 0°, a common failure, cylinder failure or critical failure (engine stops) is initiated by the WECS-9520 (depending on the deviation angle).

The final master angle value is calculated from the measured angles and used to determine crankangle, engine speed and direction of engine rotation.
Injection control:
(volumetric injection control)

Each FCM-20 calculates the necessary injection timing for its own cylinder by processing the crank angle signal and the fuel command received from the speed control.

Normal operation
Some degrees before the piston reaches TDC, the FCM-20 calculates the correct injection begin angle, taking VIT and FQS into consideration. Further a deadtime is added to compensate the time-difference between the injection command from the control system and the real injection begin. The deadtime is measured during the injection cycle by comparing the elapsed time between command release and begin of movement fuel quantity sensor. The fuel quantity sensor further gives a feedback of the amount of injected fuel and is compared with the fuel command. Injection begin and end are triggered and actuated by the FCM-20.
Schematic Layout of an Injection Unit

When the railvalves are switched to “Injection”, fuel is supplied from volume \( V \) through injection control valves 3.41 to the fuel nozzles. During fuel displacement the fuel quantity piston moves inwards and delivers a feedback signal analogue to the injected fuel quantity to the FCM-20, which compares this value with the fuel command received from electronic governor.

When the desired amount of fuel has been injected, the FCM-20 switches the railvalves to “return” position. A second time delay appears, before the quantity piston movement is terminated. This injection return delay is compensated inside the WECS-9520. After the injection control valves interrupted the fuel supply to the injector nozzles, due to the rising pressure in space \( P \) the fuel quantity piston moves back to its initial position.
In the upper graph the red curve shows a simplified injection curve, as given by the fuel quantity sensor during one injection stroke. The blue curve shows the command timeframe between the injection- and return commands to the railvalve coils. After an initial quantity piston movement of 4% the ramp is considered as injection. The time elapsed between the injection command and this point is the begin deadtime. At the return command the piston movement still continues until the end of the return deadtime. This maximum injection value is used by WECS-9520 for actual fuel command processing. The injection return overshoot is compensated by the external speed regulator (by adopting fuel command until desired engine speed is reached).
Low load operation:

At low engine load the WECS-9520 cuts out one or two of the three injection valves per cylinder. This is used to avoid visible smoke emission and to reduce fuel consumption. During any fuel injection the pressure of the injected fuel can only be controlled after an initial peak. To inject a certain fuel volume with one nozzle takes longer than with 2 nozzles. This longer injecting time allows a larger part of the fuel to be injected with a controlled pressure and thus improved atomization for an optimized combustion.

To avoid thermal stress to cylinder liners, the active nozzles are cycled every 20 minutes. Cycling from one nozzle to another is done with a 10 seconds time delay between each cylinder to prevent smoke emission due to “cold” fuel injected through the new active hot nozzle.
Sequential cut-out of injection nozzles for smokeless slow-steaming

Smokeless operation at low speed

Usual operation
3 nozzles in unison

Alternative
2 nozzle operation

Alternative
1 nozzle operation

smokeless operation down to 12% rpm R1
Exhaust valve control:

The exhaust valve is opened by servo oil pressure and closed by an air spring, same as with conventional Sulzer engines. A partition device isolates the servo oil from the oil for the exhaust valve actuation. The stroke of the valve spindle is measured by 2 analogue position sensors for a feedback to the WECS-9520.
Detailed functional description of the exhaust valve control:

- The **valve opening angle** is calculated in each FCM-20 according to measured crank angle, nominal opening angle and VEO: “Variable Exhaust-Valve Opening”.

- The exhaust rail valves are triggered to the “Open” position. Servo oil pressure operates the exhaust control valve which supplies the servo oil to the space below the partition device. The partition device piston compresses the oil in the actuator pipe, which finally opens the exhaust valve spindle.
The time between the “Open” command and the initial movement of the spindle is measured. It is called **opening deadtime**.

This deadtime will be considered by switching the rail valve a little earlier for compensation of hydraulic and mechanic delays.

Analogue to the above mentioned, the **valve closing angle** is determined and controlled by the FCM-20 including the **VEC**: “Variable Exhaust-Valve Closing” and a **closing deadtime**.
The signal „Exhaust valve open” is triggered after 15% opening stroke already where for the “Exhaust valve closed” signal a closing stroke of 85% is needed. Therefore, the “Exhaust valve close deadtime” shown in the flexView is much longer than “Exhaust valve open deadtime”.
FQS, VIT:

These functions are known from the conventional RTA engines:

- **FQS:** Fuel Quality Setting
  - Manual offset for the injection timing

- **VIT:** Variable Injection Timing
  - Advance / retard injection according to engine load for optimized fuel consumption and NO\textsubscript{x} emission.

Different from the RTA engines, the injection angles for the RT-flex are no more related to the firing pressure (advanced injection begin => “+”, retarded => “-”), but to the Crankangle (CA) between 0° - 359.9°.

As a result, an advanced injection begin or FQS setting [higher firing pressure] (e.g. +1.0° according to RTA philosophy) is now -1.0° in relation to the earlier injection angle (e.g. 2° instead of 3° CA).
FQS, VIT:

The VIT angle calculation for the RT-flex depends on **RPM, charge air pressure** and (new) **fuel rail pressure**.

This 3rd parameter is introduced to compensate differences in injection timing resulting from different fuel rail pressures.

Higher fuel pressure causes advanced injection and higher $P_{\text{max}}$.

Thus the injection begin angle is retarded a bit with increasing fuel pressure.
**RT-flex control system**

**VEO, VEC:**

The VEC is known from the conventional RTA84T-B/D engines:

- **VEC:** Variable Exhaust-valve Closing
  
  Adopting compression pressure to keep the firing ratio \( \frac{P_{\text{max}}}{P_{\text{compr}}} \) within permitted range during advanced injection.

- **VEO:** Variable Exhaust-valve Opening
  
  Keeps the exhaust gas pressure blowback constant by earlier valve opening at higher speed for fuel economy and less deposits at piston underside.

**VEC and VEO are calculated by WECS-9520 and can not be changed manually!**
Fuel pressure control

- Low load: High pressure to optimize combustion (reduce smoke)
- Middle load and CMCR load: Low pressure to comply with IMO emission regulations
- Service load: High pressure to optimize fuel consumption

Example:

Rail pressure varies over engine load.
Starting

- Already at standstill the actuators respond to the existing pressure in the fuel rails and set their output accordingly. With depressurized common rail the lever output is 95-100% depending on WECS-9520 parameters.

- Fuel Pump Unloading Function: Keep the fuel pump actuator at zero during start for the first 180° crank angle in case the fuel rail pressure is above e.g. 200bar.

- WECS-9520 monitors the fuel rail pressure and releases engine firing as soon as a minimum required fuel rail pressure is reached.

- Starting air is cut-off at a certain speed limit set in the RCS system.
Engine Running

- 2 transmitters supply the actual value from the fuel rails. For faster response of the dynamic pressure regulation, any change of the fuel command for the speed control is additionally transmitted as feed forward to the control loop.

- FCM-20 #3 or FCM-20 #4 calculates the necessary rail pressure and the output signal to the actuators (4-20 mA signal range).

- The fuel pumps charge up the fuel rail pressure via intermediate fuel accumulator. The resulting pressure in the rail depends on the quantity of supplied oil coming from the supply unit and the outgoing fuel to the injectors.
Pressure Regulation

- The jerk-type fuel pumps react to a new actuator setting only with the next following delivery stroke. This generates a deadtime until the pumps can compensate against a raising or falling fuel rail pressure.

- To change the fuel rail pressure, a new fuel command is needed. For faster response of the dynamic pressure regulation any fuel command change is additionally transmitted as feed forward to the control loop.
Shutdown

A shutdown from the Safety System is performed as follows:

- The safety system releases the pressurized intermediate fuel accumulator to the fuel return line by opening the hydraulic fuel shutdown valve 3.07 via emergency stop solenoid 3.08 (ZV7061S).

- WECS-9520 triggers the fuel actuator outputs to zero for terminating fuel feed to the rail unit, while the engine is not yet stopped.

- Injection commands are blocked by the WECS-9520.

- The red lever is NOT meant for emergency stop.
RT-flex control system

Servo & Control Oil Circuit “Bosch”

Some size 4 engine only

Ctrl. Rail 3.75

Em. Feedvalve 4.29

Exhaust Valve Drives

Servo Oil Rail 4.11

Exhaust Valve Drives

Servo Oil Rail 4.11

Feedpressure Ret. Valve 4.27

Safety Valves 3.73-B

Pressure Retaining Valves 3.73-A

Safety Valve 4.23

Servo Oil Pumps 4.15

Collector 4.52

P-Transmitter 4.77

Supply Unit Drive

FCM#20 1

FCM#20 2

FCM#20 3

FCM#20 4

FCM#20 5

FCM#20 n

System-bus CANopen

Module-bus CANopen

Control Oil Pumps 3.72

Control / Servo Oil Supply, fine filtered

to inj. rail valves
The servo oil rail pressure is controlled depending on the engine load. At part load the pressure is reduced, as due to the lower firing pressure, the servo oil pressure must be adopted to adjust the opening speed of the exhaust valve.

- A FCM-20 uses fuel command and speed as engine load reference to calculate the necessary setpoint for the servo oil pressure. Each servo oil pump is controlled by a different FCM-20.

- **Dynex**: A pulse-width modulated current signal is supplied to solenoids mounted on the control plate of the pumps. This signal is setting the output of the axial pumps and the servo oil supply to the rail.

- **Bosch**: Pressure command and engine direction are delivered via CAN bus to the electronic controller cards for the pump.

- With engine at standstill, the control oil circuit feeds the servo oil rail with approximately 75 bar, adjusted at pressure reducing valve 4.27.
The control oil pump(s) supply an oil pressure of 200 bar to operate injection control valves and to prime the servo oil rail (with reduced pressure), when the engine is at standstill.

- Control oil pressure is adjusted at pressure retaining valves on the control oil block.
- A dry-run protection in case of low bearing oil pressure is provided within the WECS-9520 software.
- Bosch Pumps:
  - From standstill until 50% engine load both pumps are running.
  - At higher engine speed one of the pumps is switched off and restarts only if the control oil pressure delivered by the remaining pump drops below 170 bar.
- Dynex Pumps
  - Always one pump is running over the entire engine load range.
- In single pump mode, the active pump changes after each new start to the stand-by pump to have similar operating hours on both pumps.
The opening and closing of the starting pilot valves 2.07 is controlled by the corresponding FCM, depending on the crank angle.

The nominal opening angle is 0°, closing angle is 110°. For engines with a large cylinder number the closing angle can be reduced in order to save starting air.

The automatic starting valve 2.03 is activated by solenoids ZV7013C and ZV7014C via FCM-20 #1 and FCM-20 #2, if the remote control sends a START signal over the bus.

For slow turning and slow turning failure reset the remote control sends separate signals to FCM-20 #1 and FCM-20 #2. The slow turning speed can be adjusted in the WECS-9520 parameters by adopting pulse cycles.

Additionally an Air Run signal enables to blow the engine with start air.
RT-flex control system

Starting Valve Control
Redundancy, emergency operation with damaged control parts:

**Flex Control Module FCM-20**

- If a FCM-20 fails, the corresponding cylinder is cut out, all other cylinders remain operative.

- Any FCM-20 module can be exchanged with the online spare. The respective software and parameters are already stored within the online spare module and no software download or reprogramming is necessary.

- When installing a new FCM-20 module from stock it must first be installed in the E90 box (Cylinder “0”) as online spare.
System CAN Bus, Module Bus (CANopen or MODbus) and SSI Bus (CA)

- Always two busses are active. If one bus is interrupted, shortened or else, the second bus is still available for communication. Engine operation is not interrupted.

WECS-9520 power supply (E85/E87)

- All modules have two redundant power supplies.

Sensors

- All vital sensors and transmitters are existing twice and their mean values are used for controlling the engine. If one sensor fails, WECS-9520 indicates the specific sensor failure and continues to work with the remaining one.
Crank angle sensor

- If one of the two crank angle sensors is out of order, WECS-9520 stays operational with the remaining crank angle sensor.

☠️ But at least one sensor has to be operational !!

TDC- Pick-up

- A damaged TDC sensor is signaled by the WECS-9520 monitoring system, but will normally not stop or slow down the engine operation (=> else disconnect sensor).
Fuel quantity sensor

- With a damaged fuel quantity sensor, the corresponding FCM-20 uses the average injection begin deadtime of all other cylinders to calculate the injection begin angle and injection quantity is controlled by time (Time control mode) with ICU quantity piston speed.

Exhaust valve position sensor

- Each exhaust valve has two redundant position sensors. If both fail, the FCM controls the exhaust opening and closing valve angles with fixed opening and closing deadtimes.
Fuel pumps and actuators

- If a fuel pump / actuator is damaged, the connected regulating linkage(s) can be blocked manually in full delivery position. The corresponding fuel pumps deliver max. pressure. The remaining actuator(s) regulate(s) at a lower output, the fuel pressure control valve 3.06 limits the rail-pressure to 1’050 bar.

- Damaged fuel pumps need to be lifted up with a tool and the other pumps need to deliver a higher output. It might be required to raise the booster inlet pressure.

Servo oil pumps

- With one damaged servo oil pump the engine remains operational at full load, with 2 (or more) damaged pumps operation is possible at part load only.

Control oil pumps (some engine types only)

- If a control oil pump fails, the servo oil rail feeds the control oil circuit via non-return valve 4.29, until the second control oil pump builds up pressure. With both control oil pumps damaged, emergency operation is possible with exclusive oil supply from servo oil rail.
Fuel shut down valve / Emergency Stop valve

- With fuel shutdown valve 3.07 or the emergency stop solenoid 3.08 damaged, shutdown / emergency stop commands are processed by only blocking injections commands and triggering fuel actuator output to zero by WECS-9520. Stopping the engine is always possible.

Remote Control / Speed Control System

- With remote- or speed control out-of-order, the engine can still be operated in fuel control mode from the back-up panel in the engine control room or from the local control panel.

- If the speed control is still operational, the WECS-9520 panels allow either fuel control mode or speed control mode from the manual control panels.

- The manual control panels are a part of the WECS-9520 control system and offer specified functionality, independent from the propulsion system manufacturer.