

HOOS operating system

Components and roles

HOOS technology

HOOS is a new *artificial oil lifting technology* focusing on medium and heavy oil reserves. In contrast with traditional technologies, it replaces the vertical pumping with *vertical transportation*. This innovation allows the technology to:

Increase production time

Decrease workovers

Reduce energy and costs

Surface unit

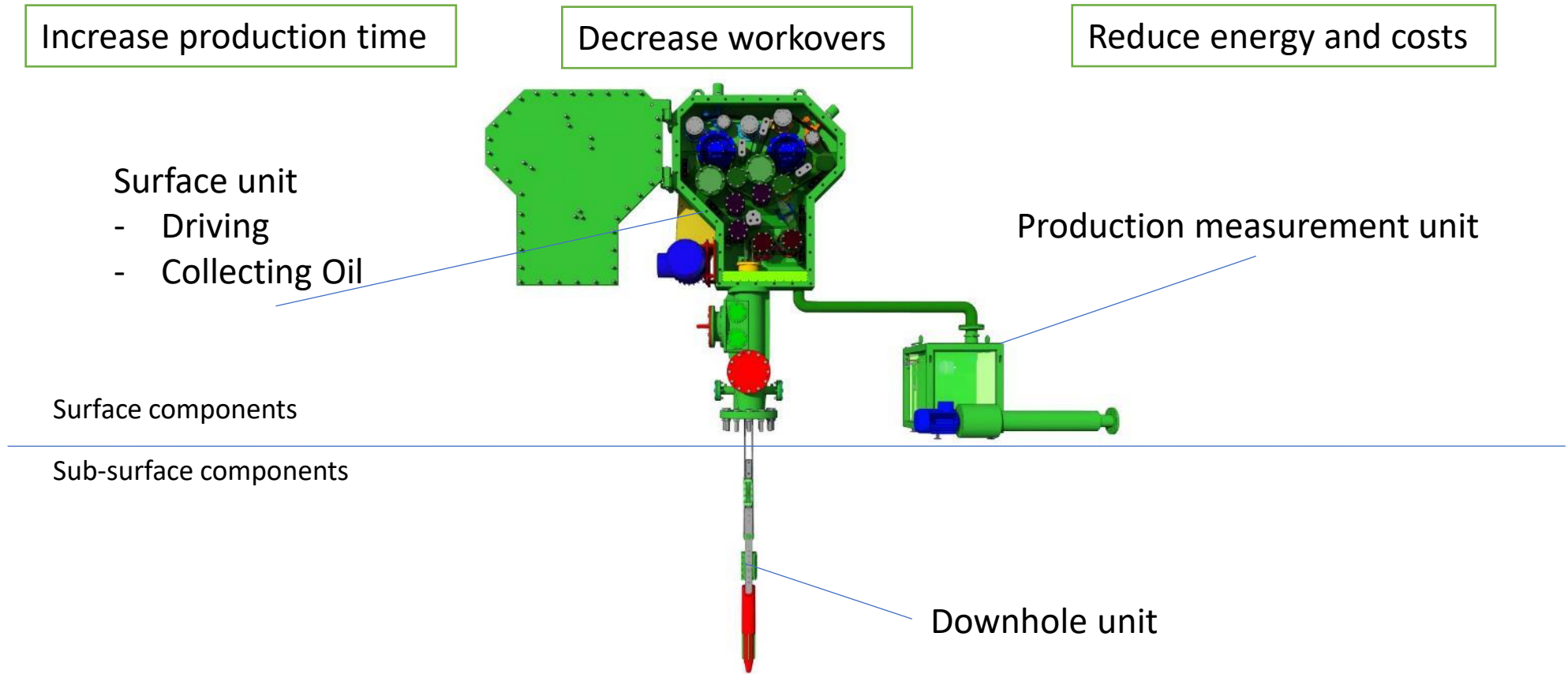
- Driving
- Collecting Oil

Production measurement unit

Surface components

Sub-surface components

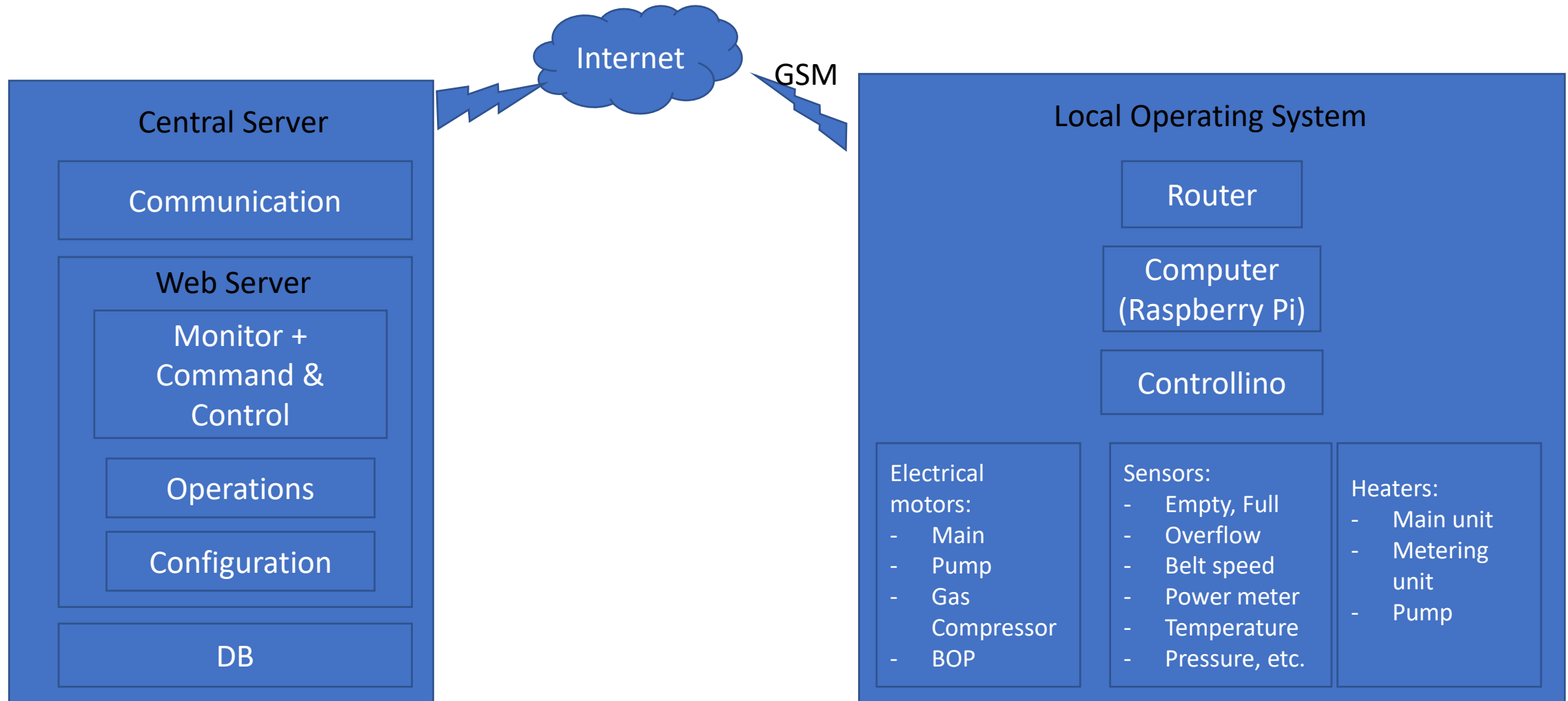
Downhole unit



Technology generals

- The technology is designed for artificial lift of underground liquids, especially heavy crude oil
- Locations are generally remote with little or no access
- Technology should properly function in harsh environment conditions: day and night, summer or winter, desert or Siberian locations
- Human intervention should be reduced to none in production mode
- Installation should be made idiot-proof, for non-specialist people

General components architecture



Central Server

- Generic name, made of:
 - Communications Server – one server communicates to many local operating systems (OS) in a client-server architecture
 - Web Server – web accessible interface for various functions
 - Database Server – storage

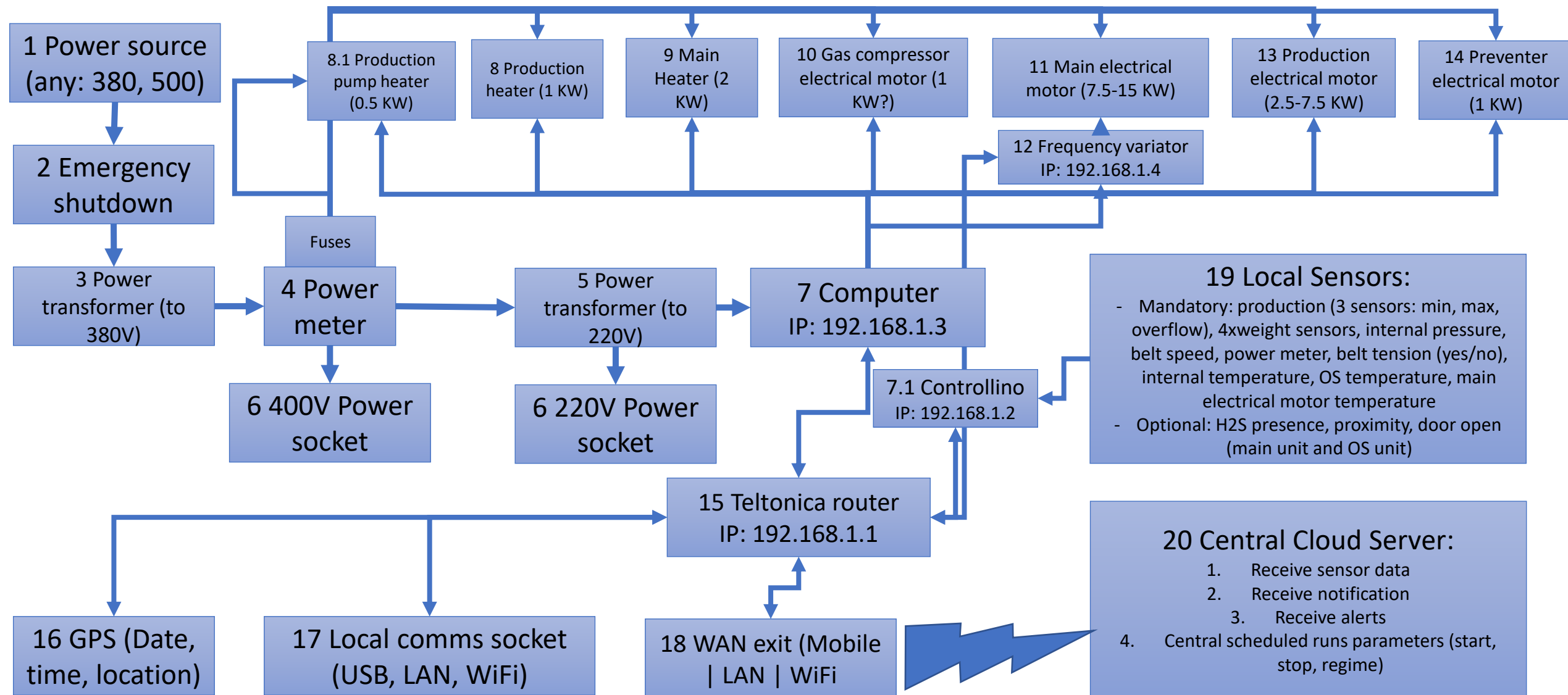
Communications Server

- Handles communication with a large number of local operating systems (OS) installed in the oilfields
- Communication is opened by the OS in a client server architecture, where OS is the client
- Client reports logs and local data and requests operating updates and commands
- Priority order of sync is: commands (start, stop, change operation mode), operating updates (status of electrical motors, status of sensors, today's production, total power used, voltage, etc.), data (historical data (since last reporting) of recorded sensor values) and logs (success and failure of operations, etc.)
- Communication is recurrent and ad-hoc. Ad-hoc communication is used to report results of just received commands, recurrent communication for all the rest (scheduled, every few minutes or so, depending on a pre-set value (higher costs – lower communication))

Web Server

- Different functions: monitor, command & control, operations and configuration
- Monitor, Command & Control
 - Distinct app
 - User name restricted to list of applications
 - Select the application (usually customer and field name)
 - Dashboard per application (z wells in total, x wells active, y running, total production vs target production during the day, alert messages if any) and Select the well option
 - Monitoring info: quick status (system on, last power details, last sensor status, last heaters status, last electrical motor status)
 - Command & Control:
 - Set operation modes (local/remote and manual/automatic)
 - Manual = only manual control of all parameters, automatic = computer control, either local or central server
 - Local = local computer control only, Remote = running data is first downloaded from central server then executed locally
 - If available: start button, stop button, increase rpm, decrease rpm, set rpm, start different heating, start other electrical motors
- Operations and configuration
 - Distinct app
 - Already implemented

Components of OS



Operations

- The local operating system will permanently maintain a table with installed hardware and relevant information about every piece of hardware
- The hardware configuration will be synced with the central server
- At system start-up and power down as well as at every executed command (start electrical motor, stop electrical motor, start heater, etc.) system will monitor the status of involved component.
- At start-up/shut-down the system will perform a health check for the entire hardware configuration table: router, GSM comm, Controllino, every electrical motor, heater and sensor
- The health check is specific for every entry, for example: router should respond to local ping, GSM should respond to external ping, Controllino should report some data, power meter should report data through Controllino, internal temperature sensor should report data, frequency variator should respond to comm protocol, electrical motors should increase power used, heaters should increase power used, sensors should report data

Logs and reporting

- Every command or major function should be able to log activity in a general log format:
 - Operation code (table of codes to be developed)
 - Date and time
 - Result (success, failure)
 - Alert level (0 = emergency, 1=priority, 2=normal, 3=low)
 - Message content (GPS coordinates for start and stop operation, other relevant messages to be reported;
- Example:
 - Start Operation at 07:30 AM GMT, GPS coordinates XXX.XXX
 - Entering sleep mode at
 - Start main unit heating at
 - Stop pumping at
 - Temperature level at Is
- Logs will remain stored for a short period of time on the local computer. Once reported, they are deleted; should the internet connection fail or not be installed. Long term logging should be enabled
- Logs refer to operation and their root is a message. Info collected from sensors is Data and the structure differs from sensor to sensor (production level sensors are on/off temperature and pressure are numbers while power meter reports a large number of parameters (voltage, amperage, frequency and powers)).

1. Power source

- Power source is an external power source, either connected to main power grid, locally generated or renewable sources
- Input power shall be always considered as alternative power
- Main power grid delivers different voltages: in Romania and all ex-communist block is 500V, in western Europe is 400V, North-America and GCC area follow different standards
- Some locations feature low or unstable power characteristics: 10-20% variations in voltage, loss of power if harsh conditions (high winds, heavy rains)
- Protection from power variation should always be considered

2. Emergency shutdown

- The operating system will be featured with emergency shutdown switch
- The reasons for operating the switch vary from risks of loosing expensive equipment to loosing human lives
- Once operated, the emergency shutdown switch will disconnect the operating system from the external power source, abruptly cut the power of all systems and shut down the local operations

3. Power transformer

- Should the external power source be different from 400V, a conversion to 400V alternative power is required, as the standard electrical motors and heaters are designed for 400V alternative power
- Element is optional and for cost efficiency reasons will be installed when necessary only

4. Power meter

- Operating system will feature an internal power meter, having as main functions:
 - Record all power consumed or generated by the whole operating system, be it alternative power or continuous power
 - Record external power source parameters: Voltage, Frequency, Active power, Reactive power, Capacitive power, differences between phases, others
 - Report all this information to the local computer in order for the information to be stored locally and further uploaded to the central server
 - Provide on the spot information regarding power used or external power quality, through a local display
- Consumption is not necessary to be recorded per individual consumer and it will be recorded globally per system

5. Power transformer to 220V

- A local power transformer to 220V is needed
- Continuous power is used to power up local computer and telecom equipment, as well as charging external tools and devices through the 220V power socket
- Protection from external power source spikes might be considered: abrupt increase or decrease in voltage, others.

6. 400V and 220V power sockets

- A local alternative power socket is required for installation/uninstallation/maintenance activities: welding, cutting, belt operations, others
- A local continuous power socket is required for installation/uninstallation/maintenance activities: small tools, charging mobile equipment used for diagnostics and operations
- The power sockets will be protected from external elements: heavy rain, extreme temperatures, mud and dust

7. Computer

- The local computer is an industrial programmable device
- Can be either PLC, Raspberry or any other appropriate device
- Able to automatically restart in case of malfunction
- Loads date, time and gps location from external gps. GPS is used for security, time is used for scheduling.
- Has a local, non-routable IP address and it is protected from external un-authorized access
- Loads work-orders from the main server as well as reports data and events to it
- Controls start and stop scenarios of the external devices: electrical motors, heaters
- Implements control loops in case of malfunction
- Has a local database to store collected data and events not reported to the central server
- Apart from recording data from sensors and power meter, every initiated, successful or unsuccessful action should be logged (event and timestamp) as well as durations: start main electrical motor, start production electrical motor, stop production electrical motor, duration of production electrical motor run, stop main electrical motor, etc.
- Unit configuration must be stored local and updated (command line get/set functions, server configuration changed message or automatic diagnostic, if possible). Heaters or electrical motors might vary in size or might be missing.
- Command is either local or remote, execution is either manual or automatic.
- Local command means computer execute scheduling according to local data, remote means it follows central server orders.
- Manual execution overrides command mode to local and executes only local orders. That is, no automatic functioning. Automatic execution follows the command mode, either local or remote.
- Hardware switch is required for manual execution to enforce health and safety rules.

8. Production heater

- This is the metering unit heater. In practice, the production (oil, water, sand) accumulates for somewhere 30-120 minutes in the metering unit, at the surface. In cold weather, the liquid might get dense, stop flowing and even freeze. The result is the production is not evacuated and local spilling might occur.
- To prevent this, the liquid will be heated using computer controlled ATEX heater . Size is approx. 1 KW and might vary.
- Predefined variables are stored locally and either loaded from the server or manually written at well configuration; Command line get/set functions to be implemented
- There are two possible cases: (1) auto start before liquid evacuation (signal from full sensor (max inductive sensor), heat predefined time (Time1) then start production electrical motor to evacuate production, or (2) auto start when the outside temperature is lower than predefined minimum temperature (TempMin), heat predefined time (Time2), take a break that depends on the TempMin (for example at -10 Celsius the break is 2 minutes while at -20 Celsius the break is 1 minute and at -30 there is no break) and start a new heating cycle
- Control loop: computer verifies power consumption before heating launch and after it. If no significant difference, error code is issued.

8.1. Production pump heater

- This is heater of the surface pump connected to the metering unit. Depending on the outside temperature, the surface pump might fail to start due to internal error or freezing of the liquid inside.
- There are actually two possible heaters: the pump heater and the main line heater. Only extreme weather conditions will ask for main line heater, but they should be considered as two individual devices operated in the same manner.
- To prevent this, the pump will be heated using computer controlled ATEX heater . Size is approx. 0.5 KW and might vary.
- Predefined variables are stored locally and either loaded from the server or manually written at well configuration; Command line get/set functions to be implemented
- There are two possible cases: (1) auto start before liquid evacuation (signal from full sensor (max inductive sensor), heat predefined time (Time1) then start production electrical motor to evacuate production, or (2) auto start when the outside temperature is lower than predefined minimum temperature (TempMin), heat predefined time (Time2), take a break that depends on the TempMin (for example at -10 Celsius the break is 2 minutes while at -20 Celsius the break is 1 minute and at -30 there is no break) and start a new heating cycle
- Control loop: computer verifies power consumption before heating launch and after it. If no significant difference, error code is issued.

9. Main unit heater

- This is heater of the main surface unit. Depending on the outside temperature, the liquid within the surface unit might accumulate and lead to surface unit start failure or to over-accumulation of the liquid insight.
- To prevent this, the main unit will be heated using computer controlled ATEX heater. Size is approx. 2 KW and might vary.
- Predefined variables are stored locally and either loaded from the server or manually written at well configuration; Command line get/set functions to be implemented
- There are two possible cases: (1) auto start before main unit starts, heat predefined time (Time1) then start main unit, or (2) auto start when the outside temperature is lower than predefined minimum temperature (TempMin), heat predefined time (Time2), take a break that depends on the TempMin (for example at -10 Celsius the break is 2 minutes while at -20 Celsius the break is 1 minute and at -30 there is no break) and start a new heating cycle
- Control loop: computer verifies power consumption before heating launch and after it. If no significant difference, error code is issued.

10. Gas compressor electrical motor

- This is the electrical motor of the gas compressor. Depending on the accumulated gas inside, the gas compressor might be fitted or not.
- To prevent the accumulation of gas and pressure inside the main unit, a gas compressor is fitted to the main unit, powered by ATEX electrical motor. Size is approx. 2 KW and might vary.
- Predefined variables are stored locally and either loaded from the server or manually written at well configuration; Command line get/set functions to be implemented
- There are two possible cases: (1) auto start, evacuate predefined time (Time1) then take predefined break, or (2) auto start when the inside pressure is higher than predefined maximum pressure (MaxInternalPressure), evacuate until pressure drops below minimum pressure (MinInternalPressure)
- Control loop: computer verifies power consumption before evacuation launch and after it. If no significant difference, error code is issued.

11. Main electrical motor

- This is the electrical motor of the main unit. Always present, ATEX electrical motor. Size is approx. 7.5 KW and might vary.
- Predefined variables are stored locally and either loaded from the server or manually written at well configuration; Command line get/set functions to be implemented
- Control loop: computer verifies power consumption before evacuation launch and after it. If no significant difference, error code is issued. If too high difference, error code is issued, start sequence is interrupted, alternative variables are considered: try again restart (max 3 times), reverse polarity and attempt start backwards direction
- Start sequence: the rpm of the main electrical motor is increased with a predefined number of rpm (IncrementRPM) at a predefined time (IncrementSpeed) until reaches desired rpm speed (ProductionRPM)
- Stop sequence: the rpm of the main electrical motor is decreased with a predefined number of rpm (DecrementRPM) at a predefined time (DecrementSpeed) until it stops. Emergency Stop abruptly breaks the operation
- If abrupt increase in power consumption is detected, emergency stop should be initiated and error code is issued.
- If main electrical motor overheats (internal temperature sensor), control loop is initiated and error code is issued.

12. Frequency variator and power inverter

- Helps control the rpm and rotation sense of the main electrical motor.
- Predefined variables are stored locally and either loaded from the server or manually written at well configuration; Command line get/set functions to be implemented
- Start and stop sequence: of the main electrical motor are controlled through the frequency variator. Might vary in size and characteristics. Used also to heat the box of the operating system in cold weather – please suggest algorithm.
- In case the main electrical motor rotation needs to be reversed, the power inverter is used.

13. Production electrical motor

- This is the electrical motor of the metering unit. Not always present, ATEX electrical motor. Size is approx. 7.5 KW and might vary.
- Predefined variables are stored locally and either loaded from the server or manually written at well configuration; Command line get/set functions to be implemented
- Production electrical motor is started when receiving signal from MaxProductionSensor and stopped when receiving signal from MinProductionSensor.
- Control loop: computer verifies power consumption before evacuation launch and after it. If no significant difference, error code is issued. If to high difference, error code is issued
- If abrupt increase in power consumption is detected, emergency stop should be initiated and error code is issued.

14. Preventer electrical motor

- This is the electrical motor of the blow out preventer unit. Not always present, ATEX electrical motor. Size is approx. 1.5 KW and might vary.
- Predefined variables are stored locally and either loaded from the server or manually written at well configuration; Command line get/set functions to be implemented
- Preventer electrical motor is automatically started when receiving signal from Pressure Sensor and has to locking positions. On a predefined high pressure, the preventer locks on the belt only. On a extremely high pressure, the preventer should cut the belt and lock metal over metal.
- This is high priority task and once is activated, everything stops and error code is issued. After error code is reported, full power goes down.
- Control loop: computer verifies power consumption before lock and after it. If no significant difference, error code is issued.

15. Communications

- Communications slot is a gateway of the system to the outer world
- 16. GPS is used for (1) a reliable date and time server, date and time to be updated every machine boot or every day, whichever occurs first and (2) physical location of the system. Once a day or at every system boot the operating system reports the exact GPS location to the server. Depending on the licence and security, the server might respond OK or KO. If KO, the system deletes itself and then shuts down.
- 17. Local comms socket is used for a number of purposes: (1) download recorded data that was not sent to the server and if no connection to the server is possible, (2) debug the system or (3) update the system software
- 18. WAN exit might be any possible WAN connection. Default is GSM (any xG), LAN connection or satellite communication is possible. WiFi is a nice to have feature, as long as it is usable for 16. or 17. previously specified and as long as it is secured.

19. Local sensors recap

- The local sensors are of critical importance to the system proper functioning and will be ATEX sensors, designed for industrial use.
- Mandatory sensors are (1) 3 production sensors: min (inductive sensor signalling the metering system is empty), max (inductive sensor signalling the metering system is full), overflow (inductive sensor or volume sensor or radar sensor signalling the metering system is overflowed), (2) weight sensors or any type of other sensor measuring real time production, (3) internal pressure, (4) belt speed, (5) belt tension (yes/no), (6) internal/external temperature, (7) OS temperature, (8) main electrical motor temperature
- Optional sensors are: (1) H2S presence, (2) proximity, (3) door open (main unit and OS unit)

19. Production volume sensors

- Max sensor is mounted within the metering unit of HOOS. The role is to signal when the production accumulates and the metering unit is full. This sensor is simple ON/OFF and does not offer any indication to the instant production capacity or speed. Signal from this sensor triggers action logging and starting procedure of the metering unit electrical motor (heat first the metering unit, the electrical motor, then start it).
- Min sensor is mounted within the metering unit of HOOS. The role is to signal when the production is eliminated and the metering unit is empty. This sensor is simple ON/OFF and does not offer any indication to the instant production capacity or speed. Signal from this sensor triggers action logging and stopping procedure of the metering unit electrical motor (stop heat is necessary, then stop the electrical motor).
- Overflow sensor is mounted within the metering unit of HOOS. The role is to signal if the production is not eliminated due to various possible errors. This sensor might be simple inductive sensor or a complex sensor signalling the accumulated volume or weight of the production, therefore meeting two system functions. Should the production over-accumulates, the system issues specific error message code and permanently stops until the error is market solved.
- The weight sensors or any type of other sensor measuring real time production have the role of recording real time production. Depending on the real time production, the system might automatically change its parameters, if configured to do so. That is, there will be a special “Artificial Intelligence” routing programmed, as to automatically optimize different run parameters: duration of a production cycle, number of cycles and production (belt) speed. That is, the system might auto-configure for maximum productivity or for maximum efficiency.
- Maximum productivity might meet 2 case scenarios (1) the well potential is big and the system should take out maximum production per day. This setting implies increasing the speed of the belt as long as the production increases and the max speed of the electrical motor is not reached. (2) the well potential is rather small and a number of production cycles are needed per day, combined with the max efficiency speed of the production belt.
- Maximum efficiency involves reaching a target or above target production with minimum power consumption. That is, at different belt speed, both the production and the power consumption vary. The scope of the system is to achieve lowest possible power consumption for the same daily production.

19. Internal pressure sensor

- Internal pressure sensor is mounted inside the main production unit. The main production unit is usually isolated from the exterior, therefore the pressure might be different. The role of this sensor is to monitor pressure inside the main production unit, which is the same as the pressure inside the well.
- Should the well operate at higher pressures and require blowout prevention system, then the pressure sensor will be mounted inside the blowout prevention system.
- The internal pressure of the well is used by different subsystems of the HOOS, (1) logging to database, (2) security check before opening the unit, (3) gas compressor command subsystem and (4) blowout prevention system
- Internal pressure should be read at a speed of one sample per second.
- On a normal scale, logging the pressure speed should decrease as the pressure remains constant or varies little. That is, at the beginning of the routine, the logging will be done every second. Supposing the pressure remains constant for 10 logging cycles, then the logging speed should decrease at one sample logged every 2 seconds. After the next 10 logging cycles with near-constant pressure, the logging speed decrease at one sample every 5 seconds. Then every 10 seconds, 30 seconds and 1 minute. The logging speed should not be lower than once per minute. However, should the pressure start to build up, the logging cycle should be immediately decreased at once per second.
- A security check should be allowed before opening the unit. To simplify the operation, a local display should be available to read the inside pressure. The decision to open the unit or not remains with the operator.
- The gas compressor command system uses current internal pressure to determine start/stop, the speed of the compressor electrical motor and duration of the operation. A configurable map of the running parameters should be implemented within the system, that is, for a given pressure and pressure increase/decrease inclination in the past 30 seconds, a correspondent value set for start, stop and speed of the compressor electrical motor should be determined.
- Blowout prevention system might be manual or automatically controlled. Whether manual or automatic setup, alert will be issued when pressure exceeds a predefined value or when the pressure increase inclination exceed specific predefined value. In manual setup, issuing the alert correlates with stop of the production subsystem and start at full power of the evacuation subsystems: gas and liquids. When automatic setup, the blowout prevention system closes on the production belt and isolates the surface from the underground pressure.

20. Belt speed sensor

- Belt speed can be determined using two separate methods: (1) programmatical calculation and (2) direct measurement
- For each well and each unit final configuration, there is a certain reduction between the main electrical motor rpm and internal driving pulleys rpm. This reduction depends on the following pulley diameters: (1) main electrical motor transmission pulley diameter, (2) big pulley diameter of the intermediary reduction, (3) small pulley diameter of the intermediary reduction, (4) external pulley diameter of the driving pulley
- The formula for the electrical motor rpm reduction is:
$$\text{DrivingRPM} = \text{MotorRPM} * (2)/(1) * (4)/(3)$$
- The formula for the belt speed is:
$$\text{Speed} = \text{DrivingRPM} * (\text{Driving+Chain})\text{Diameter} * \text{PI}$$
- (Driving+Chain)Diameter is fixed, XXX mm
- Should the two speeds, calculated belt speed and recorded belt speed differ by a percentage higher than a predefined value, say $\text{SPEED_MAX_DIFFERENCE} = 3\%$, that means the belt is slipping on the driving unit and then correction loop should be applied, by gradually decreasing the electrical motor rpm. An alert message should be issued. After the belt slipping is removed, speed increase should be resumed if necessary.
- If by resuming the speed increase the belt slipping is found again and then the third time, a general error should be issued and the system should halt.

21. Belt tension sensor

- Belt tension sensor should be a on/off sensor or similar that detects when the downward path of the belt is not tensioned
- Due to the heavy adverse environment the production belt meets underground, it is possible that the downhole unit to malfunction of the belt to hang somewhere or the upward-downward belts to enter oscillation and stick one to each other. This might cause the downward path of the belt to loose tension
- While the tension is lost, the belt might accumulate inside of the driving unit produce damage
- Should the belt loose the tension, immediate action to reduce the belt speed should be taken. That is, the main electrical motor rpm should be reduced to a very small predefined value. Once the belt speed is reduced and the tension is regained, the belt speed should be increased again, if necessary.
- Should the belt loose tension second and then third time or maintain loose tension for a time longer than a predefined value, the unit should stop and an error message should be issued.

22. Internal/external temperature sensor

- External temperature sensor measure ambient temperature.
- Internal temperature sensor is actually an ATEX protection sensor, mounted inside main driving unit.
- That is, the internal temperature inside the main driving unit might only rise if:
 - There is excessive sunny outside: we determine this by measuring outside temperature with different sensor
 - The heating device is activated: we know this is happening as it is ordered by the system
 - There is a malfunction and metal by metal wearing generated excessive temperature: this is the default scenario, after previous two scenarios are checked.
- In all cases, should internal temperature exceed a maximum absolute value, say 100 Celsius, an error message should be issued and the unit should stop until the situation that generated increase temperature is removed: outside temperature lowers, heating device is stopped or malfunction is removed
- A too low external temperature value, generates start of heating devices: OS internal heater, main unit heater, metering unit heater, metering pump heater or line heater. Each of them have different low temperature preset values and act differently, therefore different functionality will be implemented.

23. OS temperature sensor

- OS temperature sensor measure temperature inside the automation box.
- Should the temperature be higher than a predefined value, cooling device should be activated, with adaptive power according to cooling needs
- Should the temperature be higher than a max predefined value, an error message should be issued and device should stop. This might happen in two distinct situations:
 - There is fire inside the automation box or nearby – permanent stop
 - The outside temperature is too high – stop for a number of hours until temperature expects to lower
- Should the temperature be lower than a predefined value, heating device should be activated, with adaptive cooling according to heating needs
- Should the temperature be lower than a min predefined value, an error message should be issued and device should stop. This might happen only if the outside temperature is too low – stop for a number of hours until temperature expects to get higher

23. Main electrical motor temperature sensor

- The sensor measure main electrical motor temperature and it is built-in sensor inside the motor.
- The main electrical motor temperature will rise in case of electrical motor malfunction or operating longer time outside the optimum turation range. That is, first measure to fix it is to adapt the main electrical motor rpm so that the lost power is reduced. Should this not be possible, an error message will be issued and a full stop of the unit is executed.