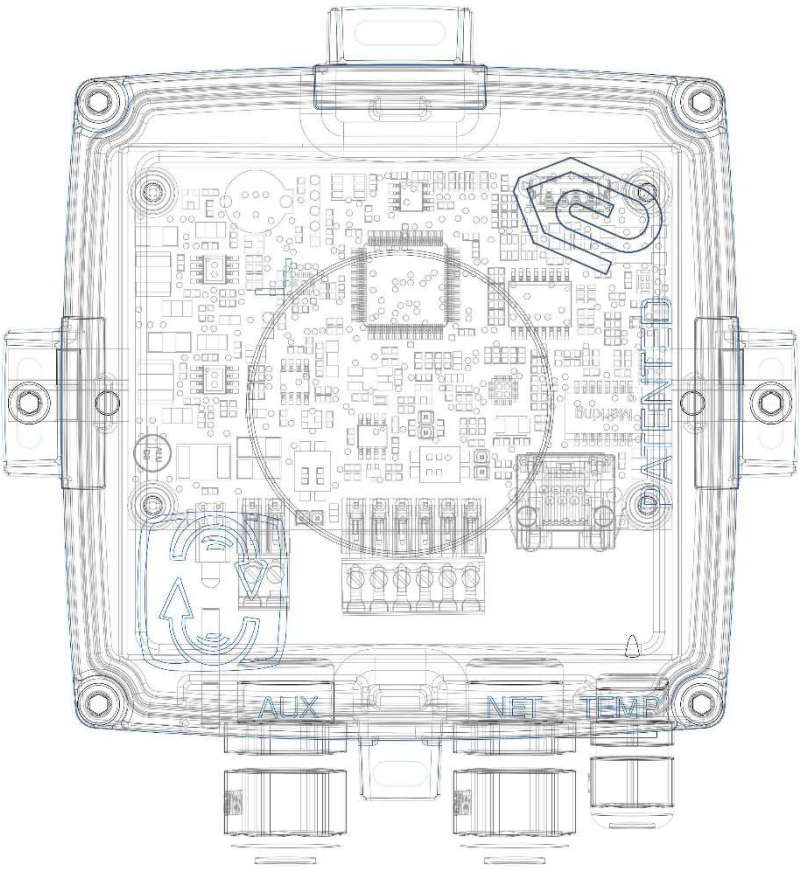
motive
power transmission

FERMAI
PREDICTIVE MAINTENANCE

DOCTOR 4.0

A UNIVERSAL EXPANDABLE INFORMATION SYSTEM COMPRISING OF
SENSORS + GATEWAY + PLATFORM + PUSHNOTIFIER, OPEN, AUTOTUNING, IIOT, MACHINE LEARNING AND A.I.

technical manual



INDEX

1. INTRODUCTION

We have seen

- toy sensors that had to be thrown away when the battery was low,
- disposables that provide a number per day or hour (and how do you know, for example, if the vibrations were an alarm or if someone was using a hammer nearby?),
- mouths filled with the word "artificial intelligence" when there were only 2 neurons (vibration, heating), and it was not even able to understand if a machine was off or on
- experts mentioning "machine-learning" when it had to us the ones to affirm in advance a tolerance for each value taken,

It was nice to see a number in an app and sell it as a solution... But how useful was it really?

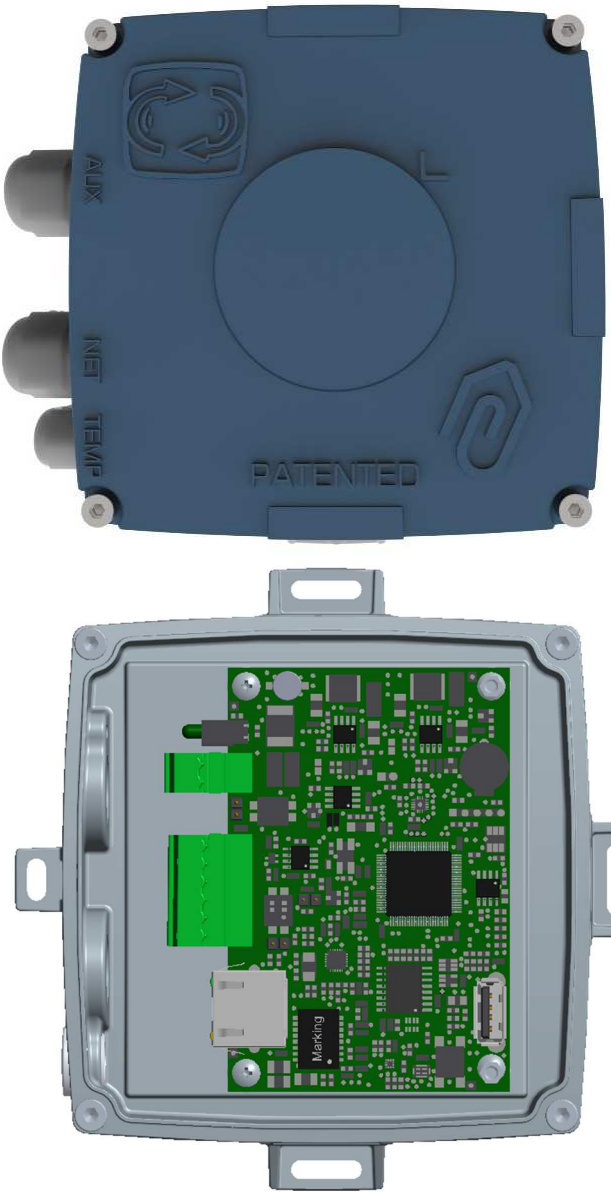
But, what if we now had a universal expandable permanent detection system, consisting of gateway + platform + pushnotifier, open, autotuning, IoT, machine learning,
all-in-one and not a complicated set of pieces, incorporating the brightest artificial intelligence for anomaly detection? And that it not only receives data, but that it can also send remote commands from an app ("slow down", "stop", etc.)?

We would then find ourselves in front of something that can really do predictive maintenance but, above all, that can do much more than that.

A dream? No, it's already there. We invented and patented it. It's called DOCTOR 4.0

Industrial invention patent No. 102021000024412

Predictive maintenance is just one of its possible uses. The FERMAI IIoT portal is open, application-independent, and simplifies integration
With DOCTOR 4.0 data, you can for example monitor the productivity of a plant or a machine, the flow or pressure of a pump, a fan, or a compressor, the fluid contamination, the energy consumption, you can control the quality, etc. etc.


AUX
IGN
TEMP
PATENTED
Marking

2. USE

DOCTOR 4.0 is usually used to analyse the operation of a motor, but it can be used universally for different purposes. It can be applied not just on motors, but also on gearboxes, pumps, fans, etc ...
DOCTOR 4.0 can be connected to any motor size, type, power, and speed, because, thanks to the sending of a data packet per second, it learns normal and abnormal operation by itself.
Even if DOCTOR 4.0 detected data can be expanded by connecting further sensors, it all already includes in its hardware sensors of


temperature [°C]


vibrations [mm/sec]


noise (dB),


magnetic flux [Wb]

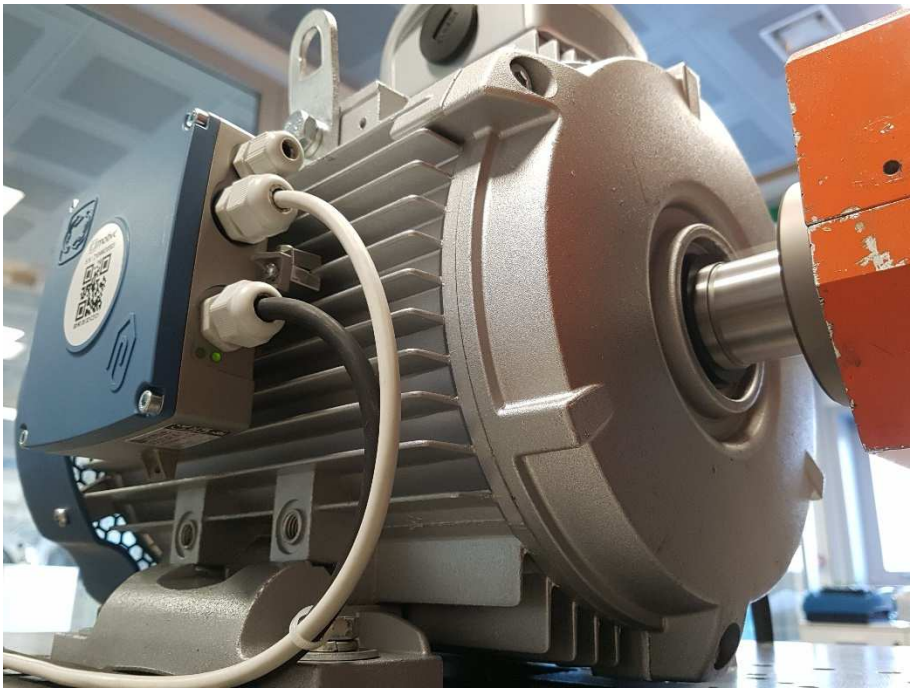

partial and total working time [h]

By connecting via the portal to its cloud platform https://doctor.fermai.it/ , you can

- Geolocalize;
- Understand the normal operation of the machine;
- See and manage temperature, vibration, noise and flow thresholds.
- Receive push notifications of abnormal trends,
- Send commands from your app (power on, off, change of speed, etc).

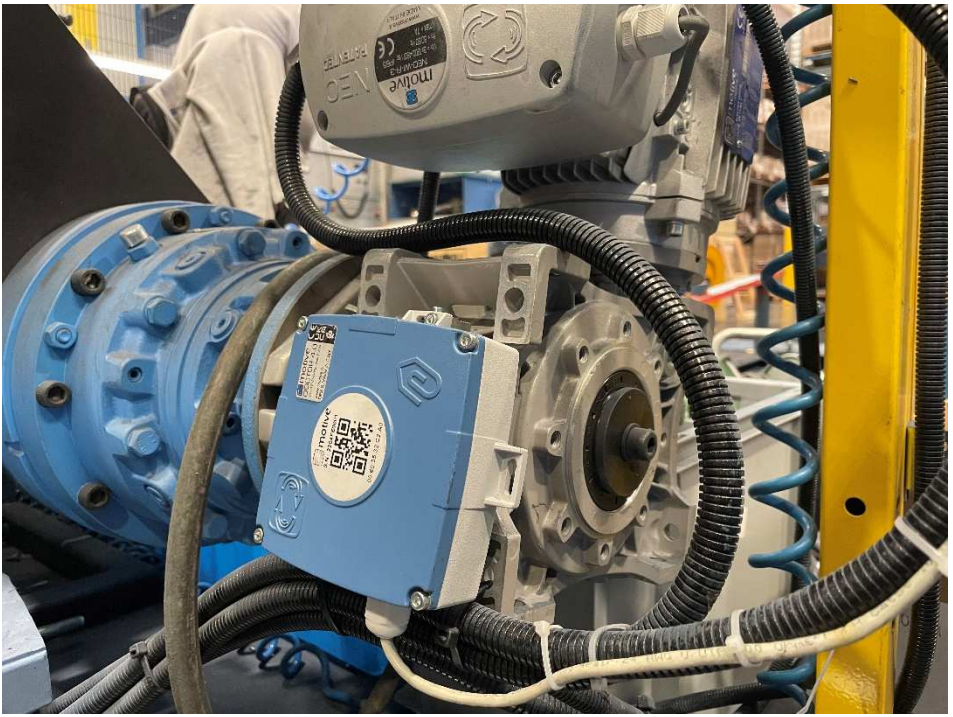
DOCTOR 4.0 is not a "disposable" whose useful life is that of its batteries and which, in order to save on battery life, must severely limit the data that can be transmitted. DOCTOR 4.0 is supplied directly from the line (12-24Vdc power supply), or via PoE (Power over Ethernet).
In this way the granularity of the data can be one packet sent per second, thus allowing to really understand what is happening on the machine being monitored.

DOCTOR 4.0 does not require additional external devices to operate (plc, data loggers, etc.). It is connected directly to the cloud platform



3. TECHNICAL DATA

	Symbol	U.d.M.	DOCTOR 4.0
Protection index	IP		IP65 (optional IP68)
Power supply	V_{1n}	V	12-24 Vdc
Operating ambient temperature	T_{amb}	°C	-20°C + 80°C
Maximum relative humidity	% (40°C)		5 … 85 without condensation
Power consumption	W		4
Stand-by losses	W		2

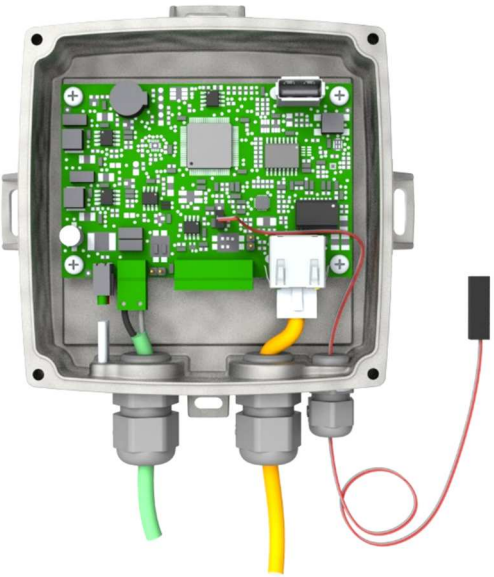


4. DETECTED PARAMETERS

DOCTOR 4.0 is equipped with an MQTT gateway that allows you to read the main values of the machine and send them via internet to FERMAI cloud platform where the data are processed.
There is no need neither of additional edge software connection modules, nor edge software, message brokers, additional data processing modules, data loggers or additional cloud connection modules

DOCTOR 4.0, when mounted on board of any electric motor, detects:

1) Surface **temperature** [°C]. It is the surface temperature of the item (motor, gearbox, machine, etc) that DOCTOR 4.0 is in touch with, and it is measured by means of its NTC thermal probe.
   This NTC probe can be left inside DOCTOR 4.0 or it can be positioned in direct contact with the monitored item, where it is considered more useful, for a more sensitive detection;



parameter	value	unit
Resistance value at 25 °C	4.7K to 100K	Ω
Tolerance on R_{25}-value	± 1; ± 2; ± 3	%
$B_{25/85}$ value	3435 to 4190 K	K
Tolerance on $B_{25/85}$-value	± 0.5; ± 1.0; ± 1.5	%
Operating temperature range at zero power	-55 to +125	°C
Thermal time constant τ	≈ 5	s
Dissipation factor 10	10	mW/K
Thermal gradient*	< 0.05	K/K
Min. dielectric withstanding voltage between terminals and lug	1500	V_{AC}
Min. insulation resistance between terminals and lug at 500 V_{DC}	100	MΩ

If the probe wire supplied is too short, replace the probe with one on the market having the following minimum requirements:

- NTC probe
- Resistance value at 25 °C = 10KΩ
- Range = -55°C +125°C

2) magnetic **flux** [Wb] of the motor (when connected onto a motor). Measured by means of an internal magnetometer

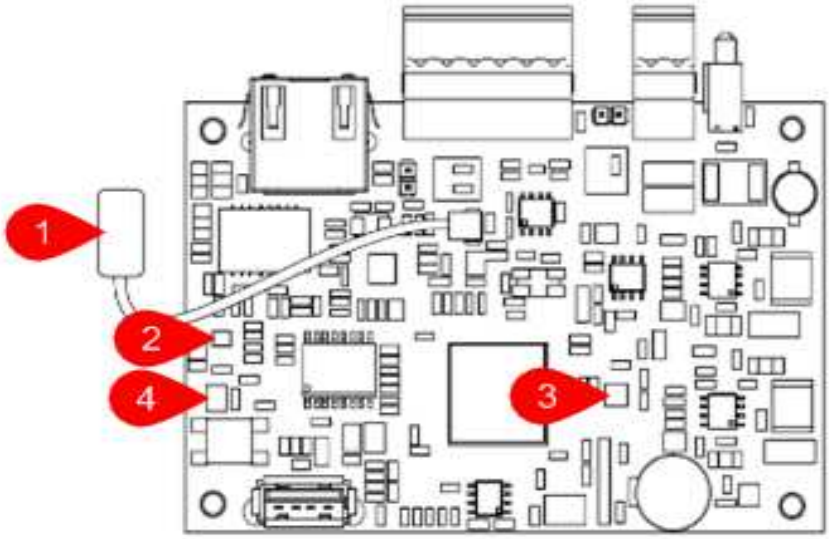
parameter	Min.	Typ.	Max.	Unit
Operating temperature range	-40		+85	°C
Linear acceleration sensitivity	-7%		+7%	mg/LSB
linear acceleration sensitivity change vs temperature		0.01		%/°C
Linear acceleration zero-g level offset accuracy	-80	±40	+80	mg

3) **vibrations** [mm/sec]. Measured by means of the built-in accelerometer;

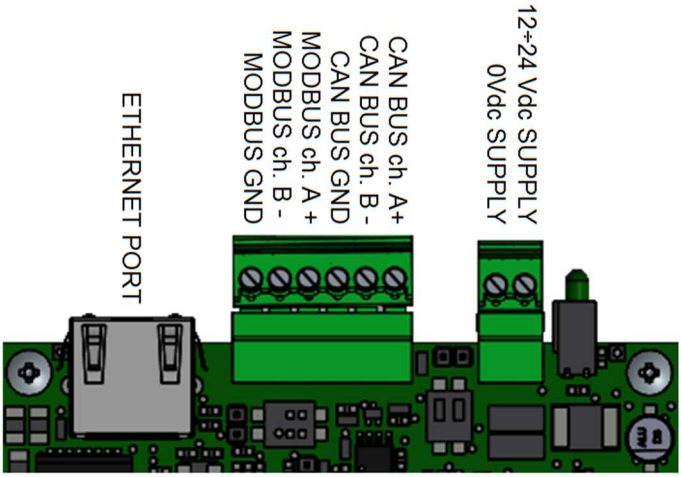
parameter	Min.	Typ.	Max.	Unit
Operating temperature range	-40		+85	°C
Linear acceleration sensitivity	-7%		+7%	mg/LSB
linear acceleration sensitivity change vs temperature		0.01		%/°C
Linear acceleration zero-g level offset accuracy	-80	±40	+80	mg

4) **noise** (dB), measured by means of an internal microphone

parameter	Min.	Typ.	Max.	Unit
Sensitivity	-29	-26	-23	dBFS
Operating temperature range	-40		+85	°C
–26 dBFS sensitivity		±3		dB



CARD PIN OUT:



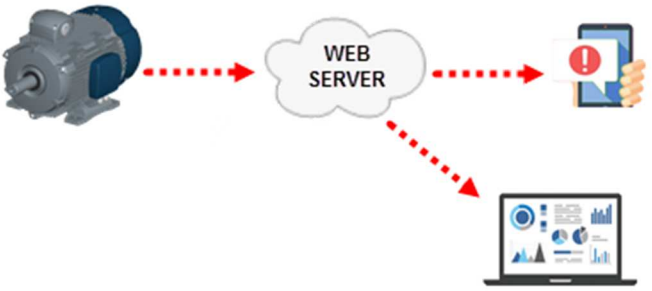
Terminal pin	Description
12+24Vdc SUPPLY	Power input 12-24V
0Vdc SUPPLY	Power input 0V
CAN BUS ch. A+	Channel A+ for CANBUS communication
Can BUS ch. B-	Channel B- for CANBUS communication
CAN BUS GND	Ground for CANBUS communication
MODBUS ch. A+	Input A+ for MODBUS communication
MODBUS ch. B-	Input B- for MODBUS communication
MODBUS GND	Ground for MODBUS communication

5. OPERATION

The collected data is sent to the FERMAI portal via the company's internet network.

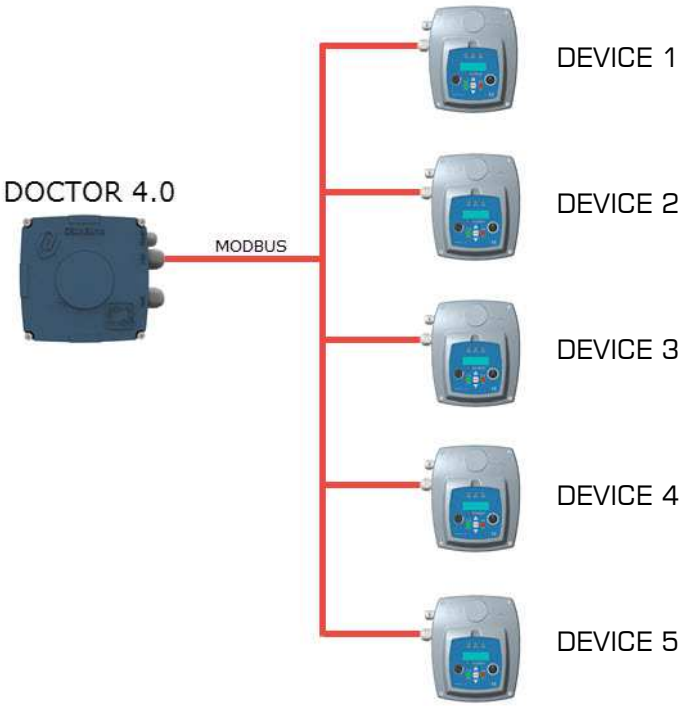
The web server receives the data sent by DOCTOR 4.0, and processes them in an algorithm based on machine learning.

If the value turns out to be out of the ordinary, the portal will automatically notify the user of the anomalous event via email



Access to the server is divided into three levels: managers, companies, users (See paragraphs 9.2, 9.3, 9.4)

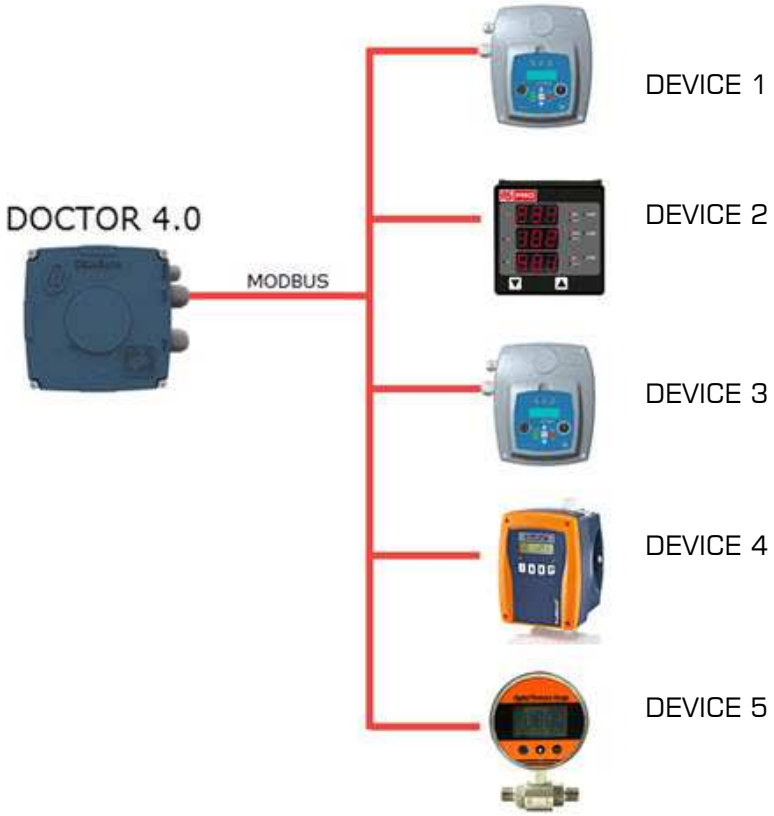
The Modbus RS-485 connection allows you to connect 5 external devices to the DOCTOR 4.0.
These can also be Variable Frequency Drives with mod-bus port, such as the NEO and NANO series by Motive srl (www.motive.it)



Each device can be connected to one or more modbus nodes of DOCTOR 4.0. For each modbus node it is possible to read and or write a maximum of 5 parameters. The parameters can be selected by the user, for

example voltage, current, revolutions, power, frequency (see par. 10.1.7 Configuration-Modbus)

DOCTOR 4.0 allows you to connect not only inverters, but also other devices (pressure meters, flow meters, piece counters...) via MODBUS.



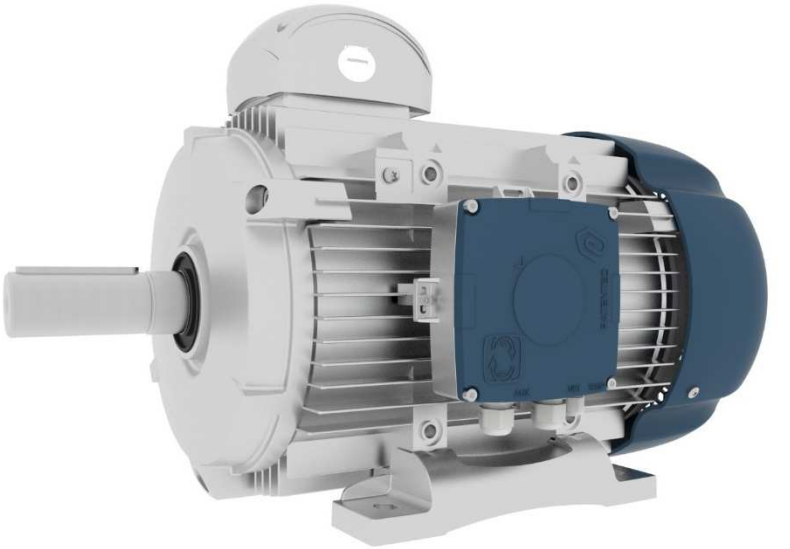
6. MECHANICAL FIXING

Preferably, but not necessarily, DOCTOR 4.0 is mounted directly on the the electric motor body (we recommend the motors of MOTIVE www.motive.it, but it can be connected thanks to its terminals to any other motor brand whose body is provided with cooling fins). The fixing kit make it connectable to any motor size.

Mounting onto the motor is preferred because DOCTOR 4.0 is also able to detect the magnetic flux of the same.

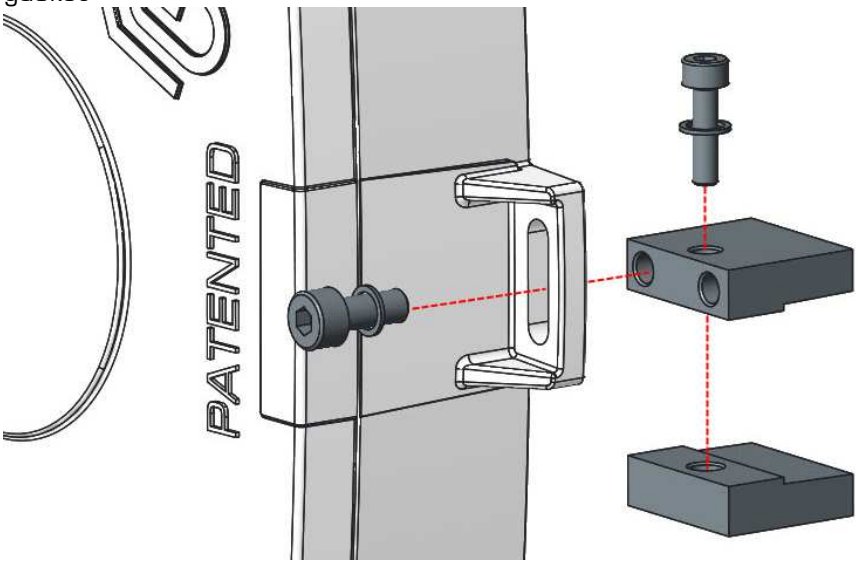
The fixing kit is composed as follows:

- 2 upper fixing, code *DOCFIXSUP*,
- 2 lower fixing, code *DOCFIXINF*,
- 2 gaskets to be inserted between the fixings, code *DOCFIXGSK,*
- 2 allen screws M4x10 + 2 growers M4,
- 2 allen screws M4x14 + 2 growers M4

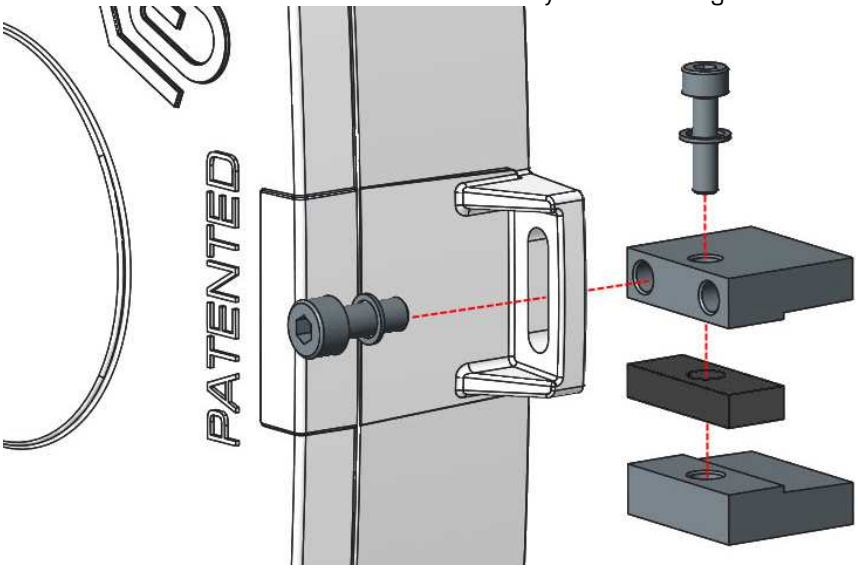


Taking the DELPHI series Motive www.motive.it electric motors as an example, the first distinction is between aluminum motors and cast iron motors:

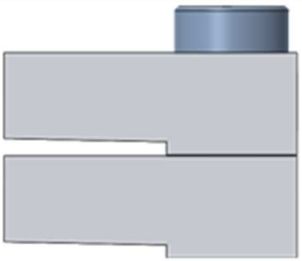
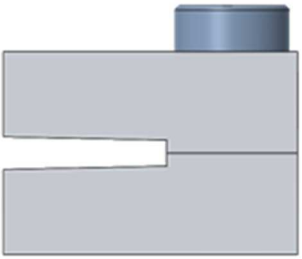
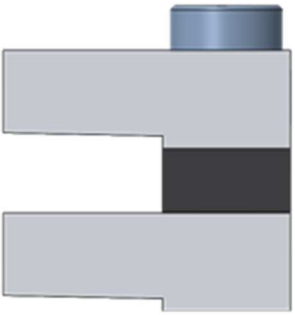
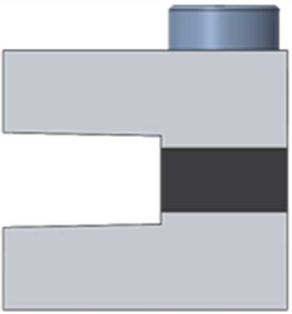
• for aluminum motors it is not necessary to use the intermediate gasket



• for motors size 160-400 it is necessary to use the gasket



In detail, (with Motive electric motors DELPHI series):

motors IEC size 56 ÷ 71	
motors IEC size 80 ÷ 132	
motors IEC size 160 ÷ 315	
motors IEC size 355 ÷ 400	

7. CONNECTION

7.1 Cables connection

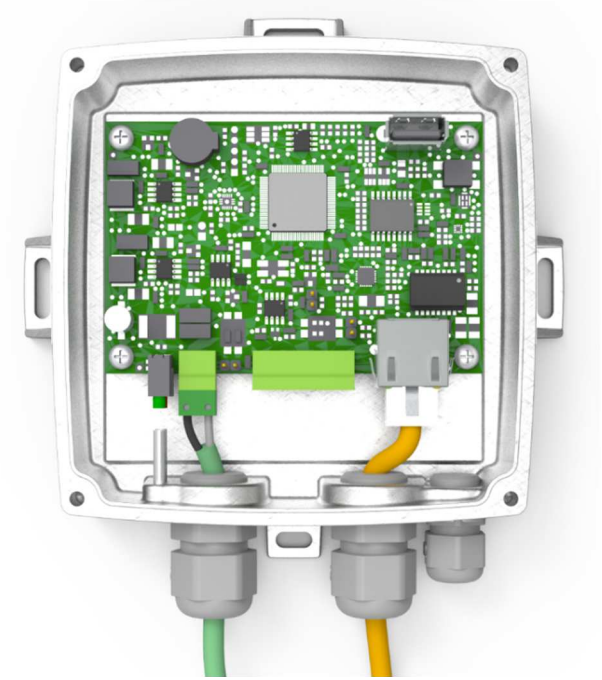
The only way to have a functioning artificial intelligence is to have frequent data transmission (DOCTOR 4.0 sends one data packet per second). You can do nothing with one data per hour. This implies the need for a direct power supply of the DOCTOR 4.0, since the energy required to power such frequent data transmission would exhaust the batteries in a couple of days.

Furthermore, the sending of the data must be secure, free from interference. For this, it was decided to connect to the network using a regular Ethernet cable.

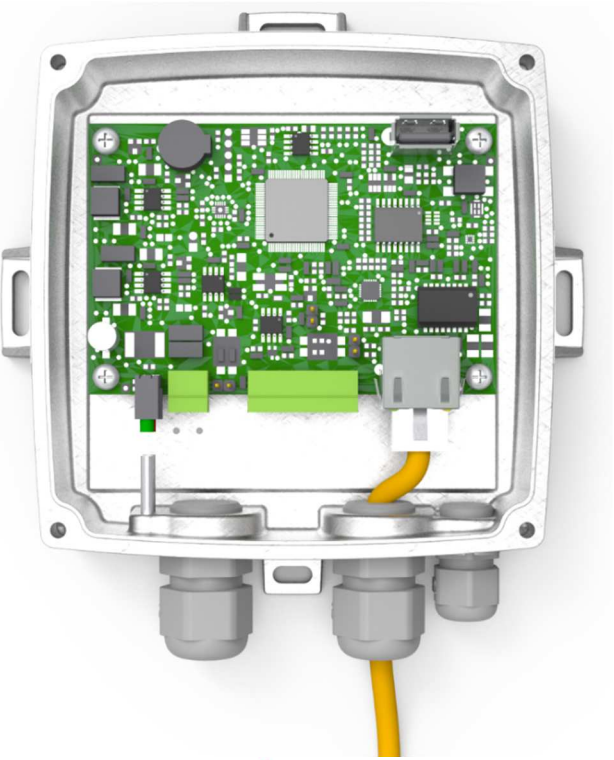
DOCTOR 4.0 can therefore be powered in two alternative ways:

Power supply via terminals

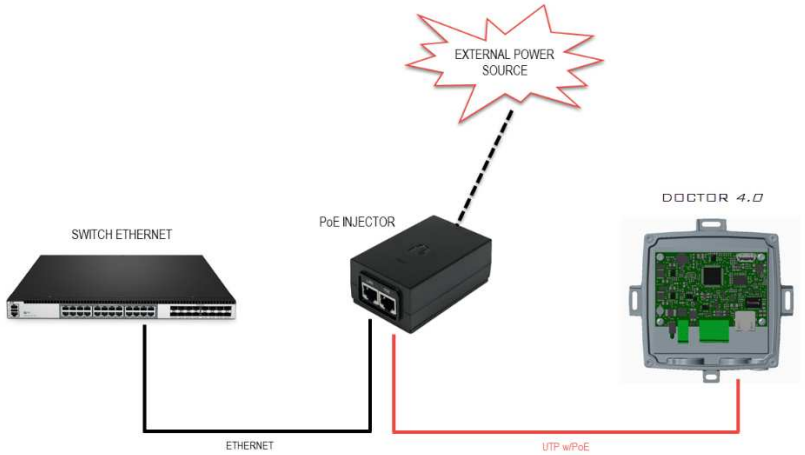
12÷24 Vdc SUPPLY
0Vdc SUPPLY



Of course, first you have to pass the cables through the gland without its connector, and then crimp the connectors



Power supply via ethernet cable with PoE switch

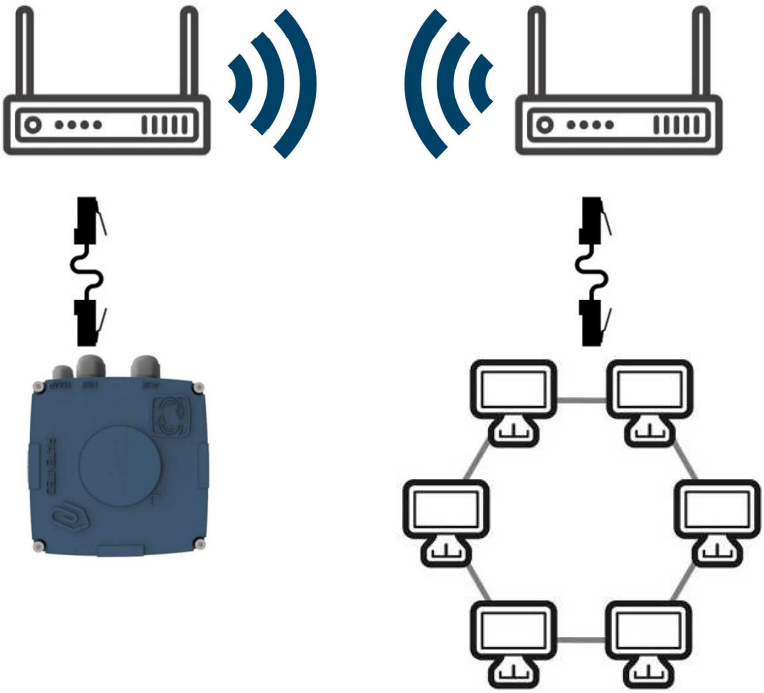


7.2 Wireless Connection

If you need to install DOCTOR 4.0 in a place that cannot be reached by an Ethernet cable from the network, you can do the following:

7.2.1 Connection via Wi-Fi router bridge

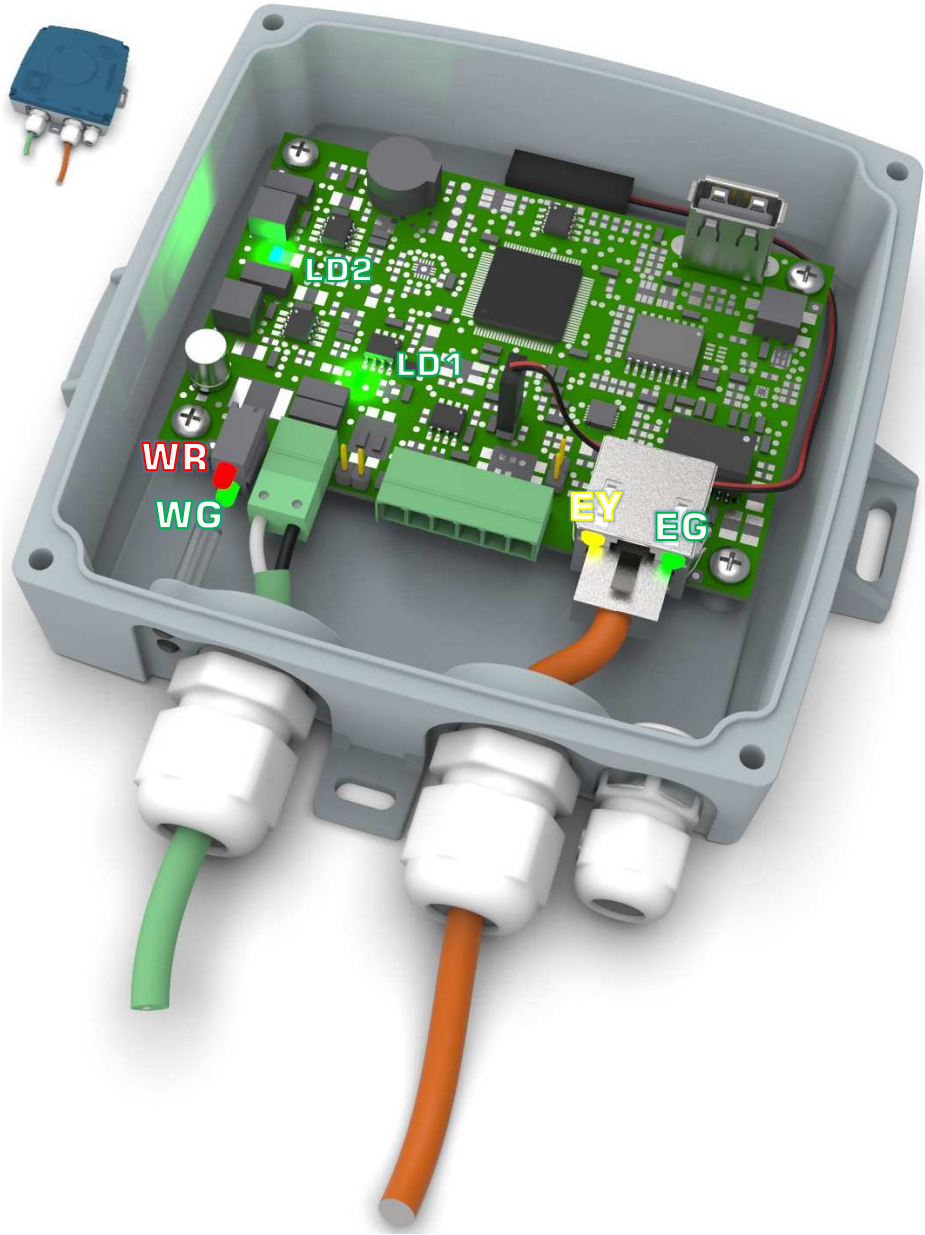
Obtain Wi-Fi connectivity via router (bridge) in order to enable DOCTOR 4.0 integration to the company network.



7.2.2 Connection via portable Wi-Fi router with SIM

It is possible to connect DOCTOR 4.0 to a mobile network via a portable Wi-Fi router equipped with a SIM having an internet subscription.

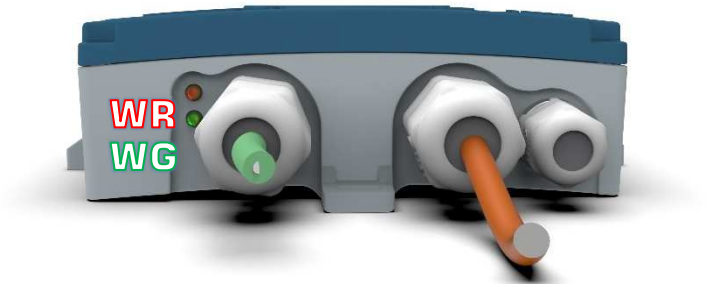
7.3 Leds:



EG: it is the ethernet Activity LED, and it is solid green when the Ethernet Link has been established. It flashes when there is network traffic and it is off when DOCTOR 4.0 is not attached. If off, check the cable connection.
If it shows a slow blink, you have a configuration error: the default configuration is with DHCP client on. Check your DHCP server configuration (Chap.: 10.1.7 Configuration).

EY: It blinks when there is data traffic between DOCTOR 4.0 and the network. It can also be solid on, when there is a high sampling rate

LD1 and **LD2** are on when DOCTOR 4.0 is correctly power supplied



WR: when this red light is on, we have an anomaly (for example, the ethernet cable is disconnected of the network is absent)
If **WR** in on, that means that you can't reach FERMAI portal: check DNS and firewall configuration and allow full access to *doctor.fermai.it*
WG: It blinks when DOCTOR 4.0 is sending data, therefor each second. If it is off, check the power supply and the firewall of the network

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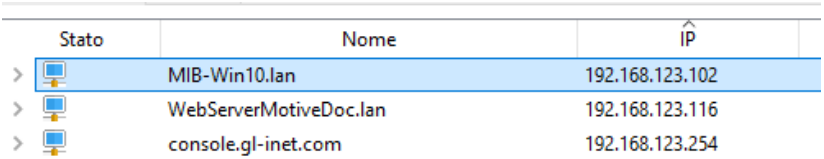
EG	EY	WR	=
off	off	on	wiring error or network switch port error
on	Not blinking	on	wiring error or network switch port configuration error
on	blinking	on	network configuration error (switch, firewall, DNS, etc)
on	blinking	off	with WG blinking too, communication with portal is OK

7.4 Connections problems?

First check the leds. If all leds are saying that anything is OK, but still there are connection problems, the problem is in your network configuration.

Now, to fix the problem proceed with these checks:

1. Find the right IP: if you have a DHCP network you can find it, or you can make a Network Scan (like Advanced IP Scan)



2. If you can find it, configure the write ip address of your DOCTOR 4.0 (par. 10.1.7 Configuration-Net)

Still connection problems? Well, like when you connect also a printer to your network, there could still be some hidden obstacles (firewall, DNS filtering, Content filtering, etc.)

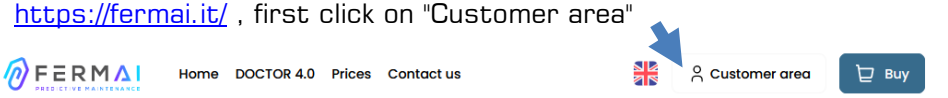
The easy way to check it is: take a laptop, connect it to the same Ethernet cable of your DOCTOR 4.0 and try to browse www.fermai.it

If needed, check deeply in your lan/firewall connection.

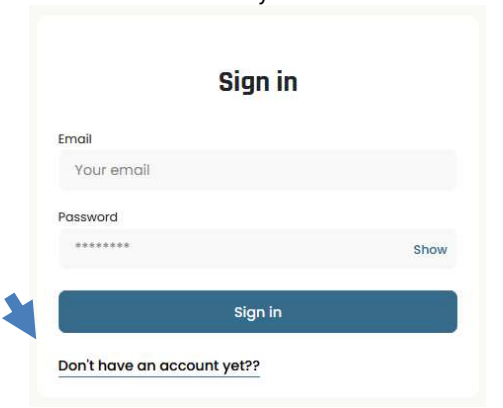
In general, we suggest that any IIoT device, like DOCTOR 4.0, should have separated LAN zone without any kind of restriction, first of all for security reason.

8. REGISTRATION

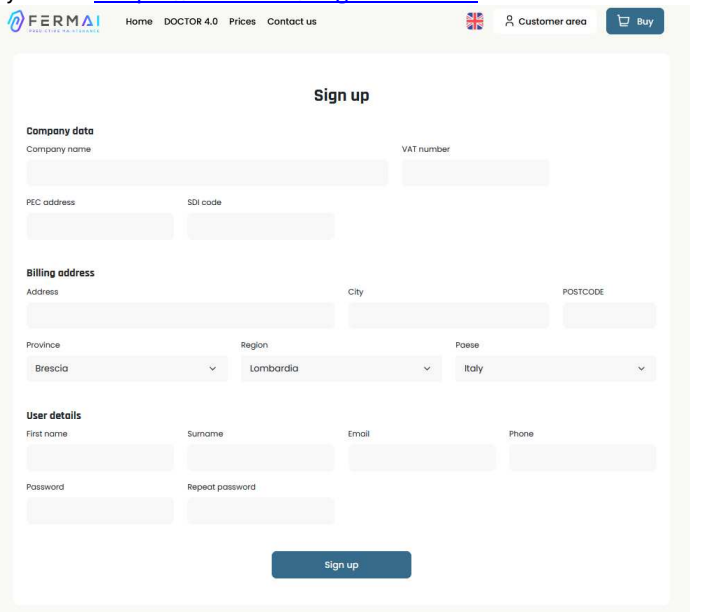
Before you can activate a DOCTOR 4.0 you must have entered your company data and created your login profile. With the browser, from the site https://fermai.it/ , first click on "Customer area"



Then click on “don’t have an account yet??”.



It will take you to https://fermai.it/registrazione



Enter your company data here. Choose a password. Your account name will be the email you enter here.
After registering, you will receive an email confirming the creation of your account

Only with an account will you be able to purchase or activate a DOCTOR 4.0. DOCTOR 4.0 purchases and the portal subscription will be linked to your account. The more DOCTOR 4.0 you will buy over time, the less their purchase will cost you and the less the subsequent activation will cost you

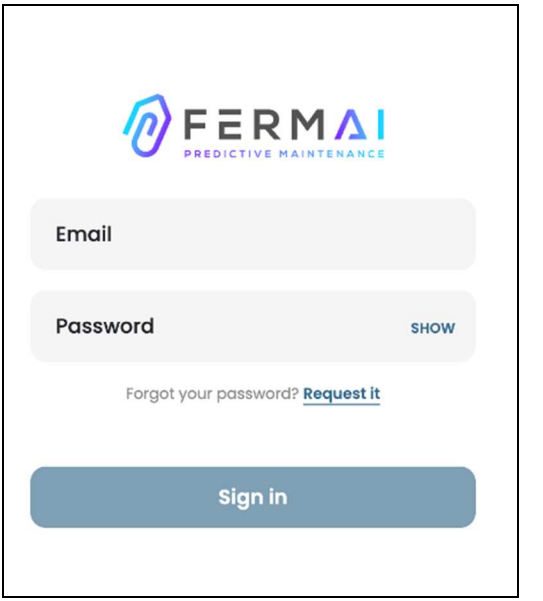
NOTE: If you are a system configurator qualified by FERMAI and you have received from FERMAI a special "manager" enabling profile (see chapter 10.3),
log in with the given “manager” profile and input the company data in the “companies” section (see chapter 10.4) via "add". Then impersonate the client company to continue the DOCTOR 4.0 activation with the company account.

9. ACTIVATION

Each DOCTOR 4.0 is activated via the FERMAI app (available for Android and IOS).

To download the FERMAI app, just connect to the site: https://doctor.fermai.it/login

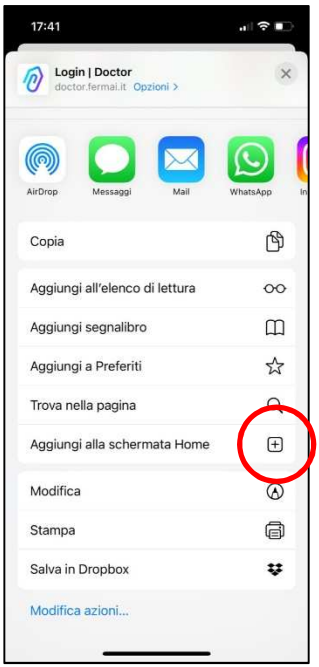
After connecting to the site, a login screen is shown; to access the portal you need to enter your credentials.

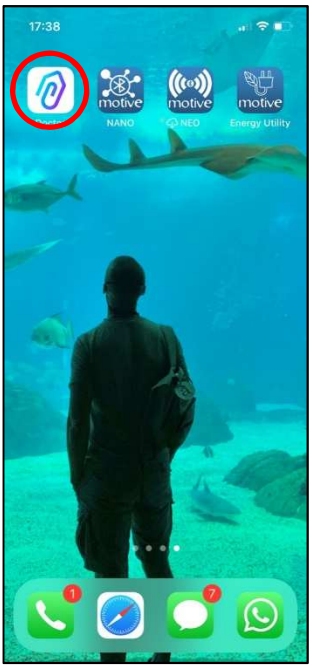


After entering the website, you can download the app, as follows

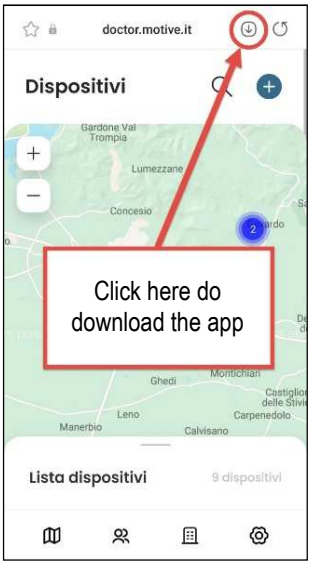
iOS

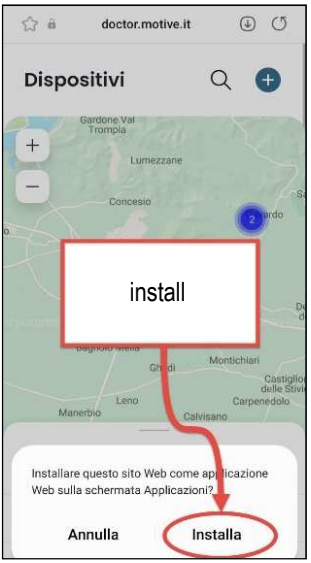
After connecting to the site https://doctor.fermai.it/
a login screen is shown, in order to access the portal it is necessary to enter the login credentials.
This is how to add the app into your smartphone or tablet:



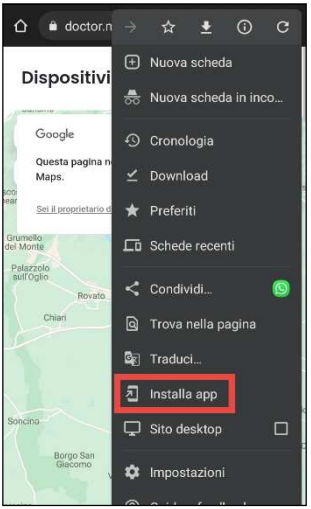


After connecting to the site https://doctor.fermai.it/ , simply go to the web page settings and click on the "install app" item and it will be downloaded automatically.

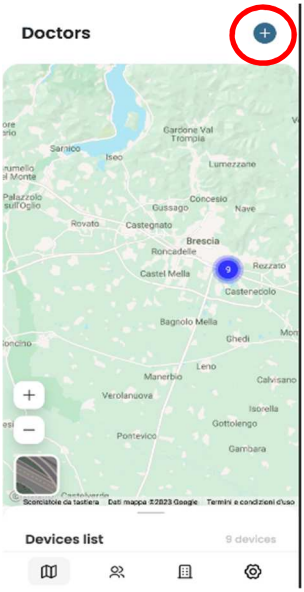




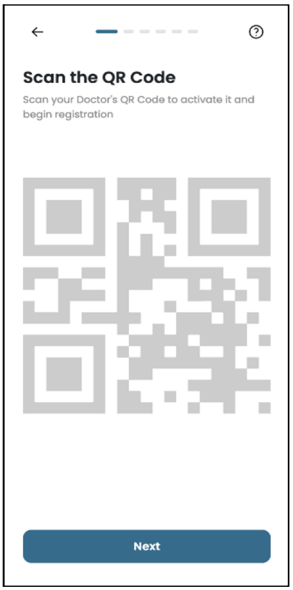
Or:



Press the button to add a new DOCTOR 4.0.



Once selected, you will be asked to scan a QR code.



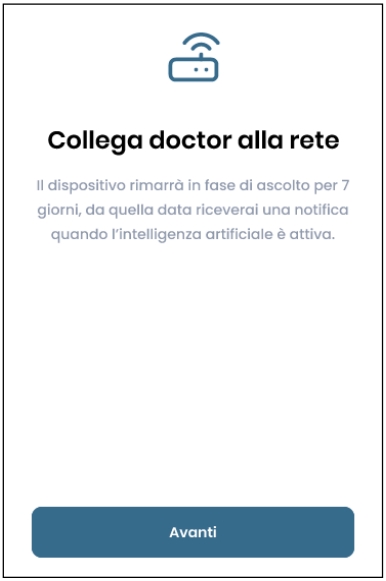
The QR Code can be found on the lid of the DOCTOR 4.0.

If detected correctly, the following message is displayed:

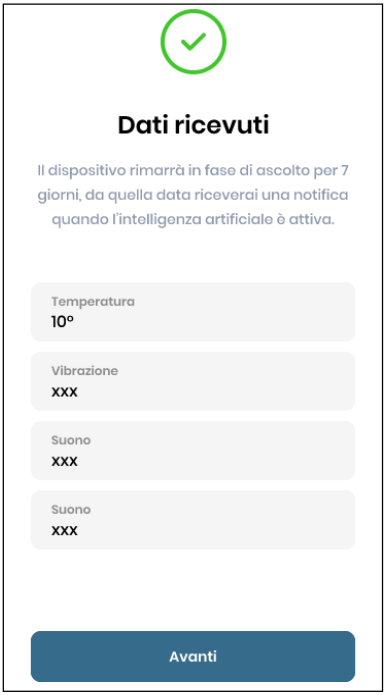
If the message “Invalid code” appears, the device has already been installed and cannot be reinstalled.

After configuring the new DOCTOR 4.0, the app shows the installation steps

1. For the communication with the app and with FERMAI portal, DOCTOR 4.0 must be connected to the company network (in case of communication problems, see also Par. 10.1.7 Configuration-network), and this network to internet,



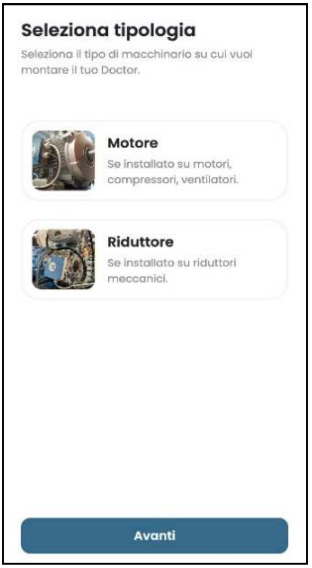
If the connection has been established, it begins to record and memorize the detected data, showing them on a screen



2. Chose the use;

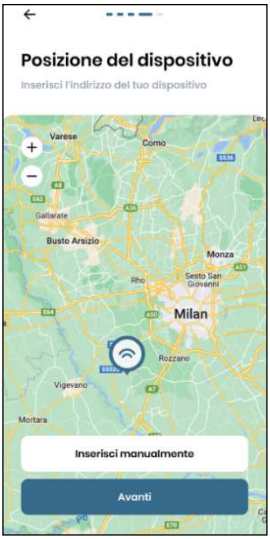
-On a **motor**;

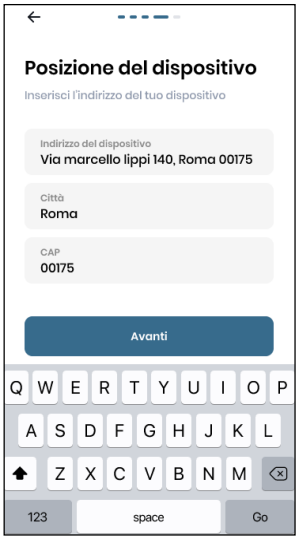
-Select **gearbox** for any only-mechanical machine to exclude the magnetic flux data from the A.I.



3. Chose the name of this DOCTOR 4.0

4. The app automatically identifies the DOCTOR 4.0 position via Google Maps, otherwise it is possible to enter the position manually.





5. Insert the photo. You can insert the photo of DOCTOR 4.0 or of the machine to which it is applied. It is used to facilitate visual recognition on the list of DOCTOR 4.0 installed

Once all steps are completed, the message “Doctor activated” is displayed. DOCTOR 4.0 is therefore ready, but in “machine learning” mode for a month.
After a month, it will be notified the activation of the artificial intelligence and of the calculated “AI” alarm thresholds.

NOTE: DOCTOR 4.0s can only be added and activated from the app. It is not possible to do it from the web.

10. FUNCTIONS

After configuring the DOCTOR 4.0, access the portal from the site https://doctor.fermai.it/.
Alternatively, you can also get there from the Fermai website https://fermai.it/login, first clicking on "Customer Area",

make the login, and then click on “Go to the portal”

The functions on the left of the FERMAI portal and app are:

1. View and locate on a map and view all activated DOCTORs 4.0;
2. View the daily working time and total machine time;
3. View the parameters of the connected Modbus connected devices (eg: VFDs, or pressure transducers, etc.) and of the built-in ones (flux, temperature, vibration, sound);
4. Display of the status of each DOCTOR 4.0 (online with machine working, online with machine not working, offline, in alarm);
5. Alarms communication management
6. Maintenance Management: Plan and record maintenance based on real working time;
7. Chose up to 5 parameters of each Modbus connected devices
8. View the automatic alarm thresholds of the A.I.
9. Establish alarm thresholds manually
10. Telecontrol
11. Integration

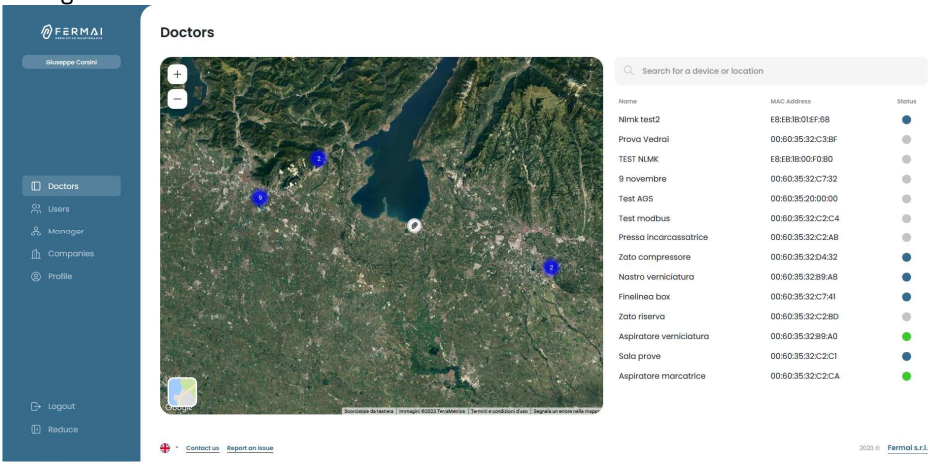
Users management

Profile management

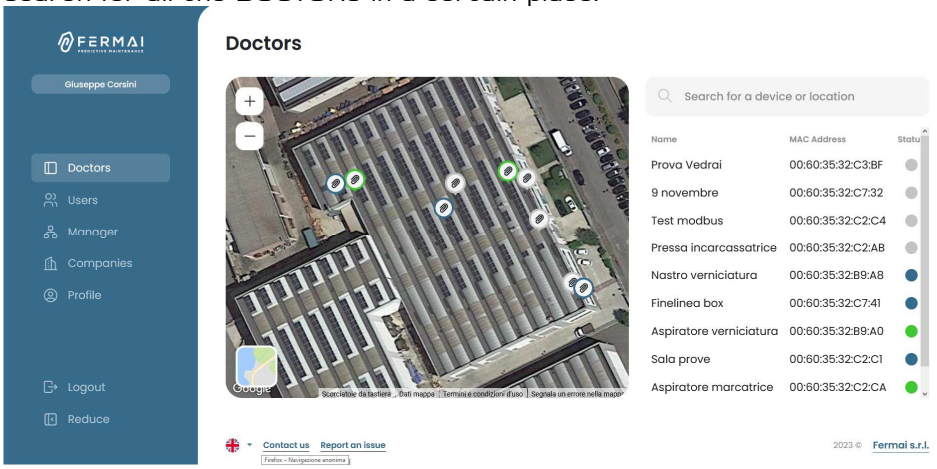
10.1 Doctors

10.1.1 View and locate DOCTORs

By clicking on "Doctors" it is possible to view a map, which shows the points where the DOCTORs 4.0 are located, facilitating their recognition.

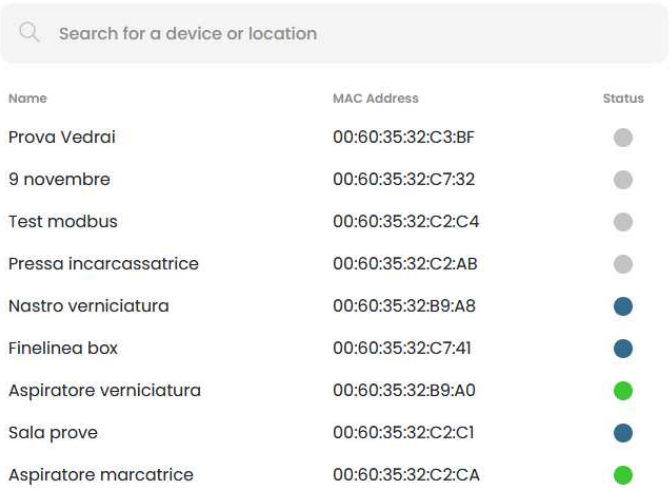


By zooming in, you can always see all the installed DOCTORs 4.0 in greater detail. It is also possible to specify a geographical location to search for all the DOCTORs in a certain place.



Alongside (for the desktop version) or below (for the mobile version) is the list of DOCTOR 4.0 devices that are shown on the map. By zooming forward/backward in the map, the list of devices is also modified, showing only those that are identified within the map.

The list of devices shows the DOCTOR 4.0 names (previously chosen during the configuration phase), their MAC addresses (those printed on the DOCTOR 4.0 cover, but viewable only in the desktop version) and their



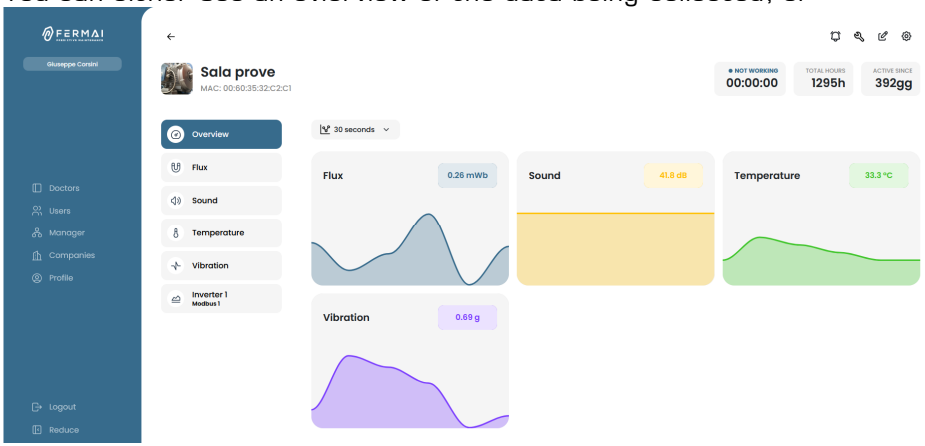
current status.

The status is indicated with 4 different colors:

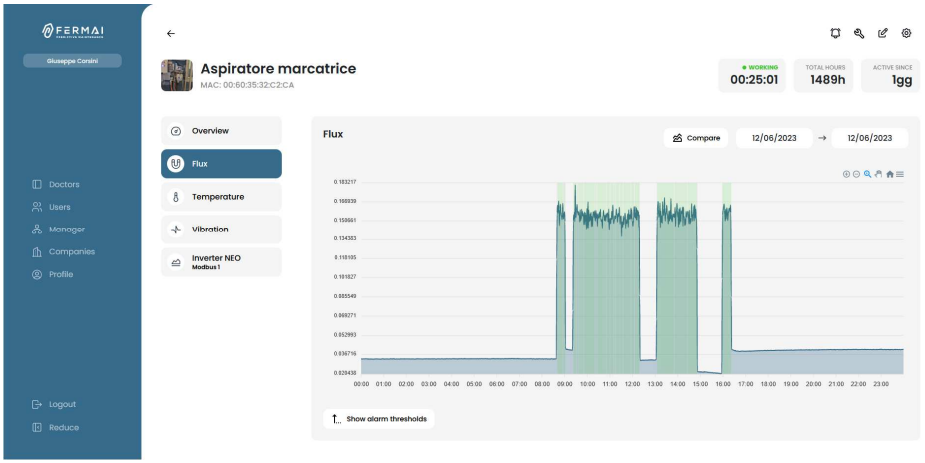
- Green: The machine is on
- Red: The machine is in an alarm state
- Blue: The machine is off, but DOCTOR 4.0 is connected
- Gray: DOCTOR 4.0 is offline

It is possible to manually modify the position in the settings of each DOCTOR 4.0 (see modification paragraph)

From the list of DOCTORs 4.0 it is possible to choose the one whose data you want to see,
You can either see an ovierview of the data being collected, or



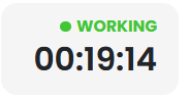
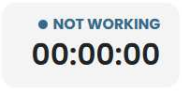
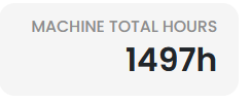
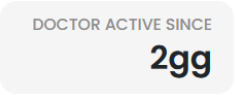
a detail of the data collected over tim for each parameter



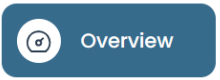
10.1.2. Work time and total time

Although not directly connected to the machine power supply, DOCTOR 4.0, thanks to an algorithm linked to flux and vibration data, is able to recognize when the machine is on or off, and therefore count the operating hours. This will be very useful for maintenance planning (see maintenance paragraph 10.1.5)

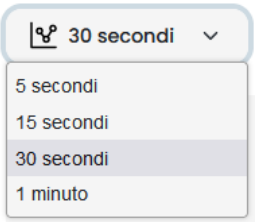
This is an example of what you find displaied on the top of the screen of the portal, after that you select a DOCTOR 4.0:

	it is the time in which the machine has been switched on during the day from 00:00 o'clock, in hh:mm:ss When the machine is off, it shows: 
	It is the total operating time of the machine since its installation (=hours counted since DOCTOR 4.0 was activated on the machine + the initial working hours that can be entered manually)
	is the number of days since DOCTOR 4.0 was activated

10.1.3. Viewing detected parameters



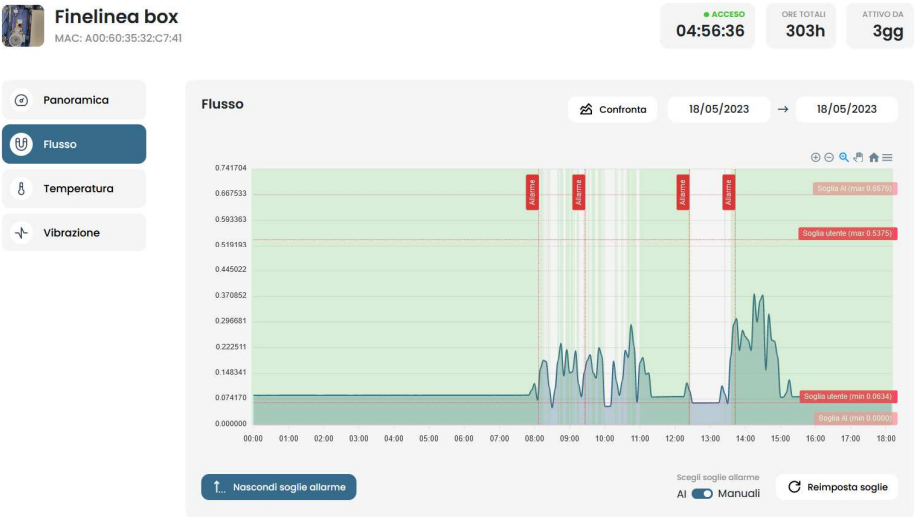
: it shows an overview of the data acquired in real time, in a range of 30 seconds.
The display frequency can be freely changed with a range between 5 seconds and one minute*



*NOTE: DOCTOR 4.0's "log rate" (frequency of sending data to the portal) remains anyway still set to one sending per second (this is also why it can be "intelligent"), and it cannot be changed.

Parameters: they are flux , temperature , vibrations , sound and Modbus .

For each of them, the graphs of the acquired data are shown. They are displayed over a period of time that goes from 00:00 of the current day up to that precise moment.

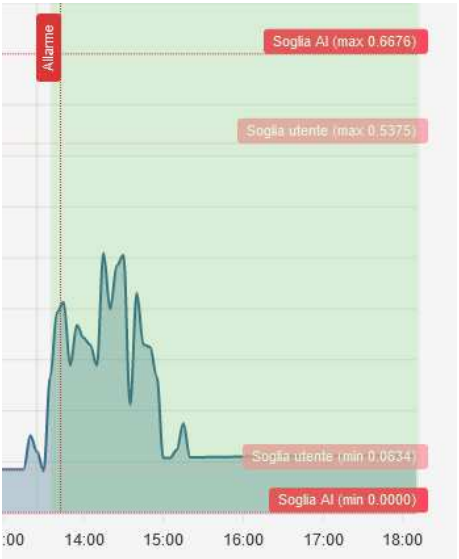


By clicking on one of the parameters, a graph is displayed showing the data recorded during the day.

Each alarm is displayed on the graph

By clicking on "show alarm thresholds"

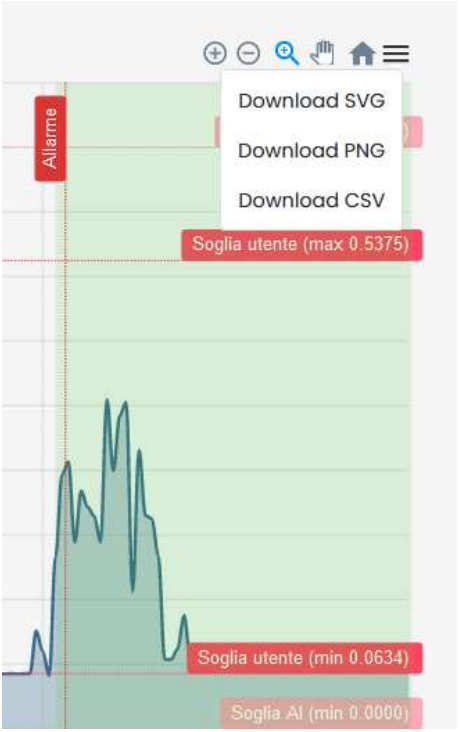
, the AI alarm thresholds are displayed. They represent the limits of normality, as calculated by AI machine learning



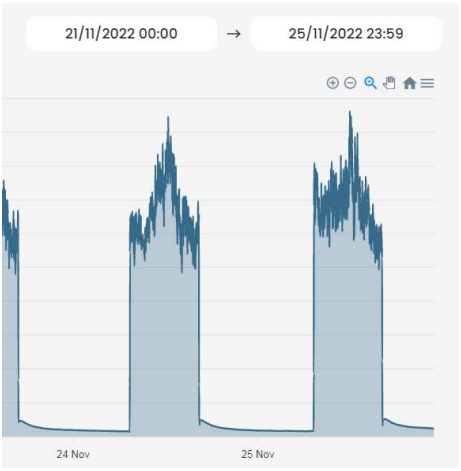
“Manual” alarm thresholds can also be entered, and then you cha chose which thresholds to use, whether those “AI” set by artificial intelligence or the “Manual” ones set by the user.

At the first modification of the thresholds, which can be done by dragging the AI threshold pre-set by the artificial intelligence (raising it or lowering it), both thresholds will be shown.

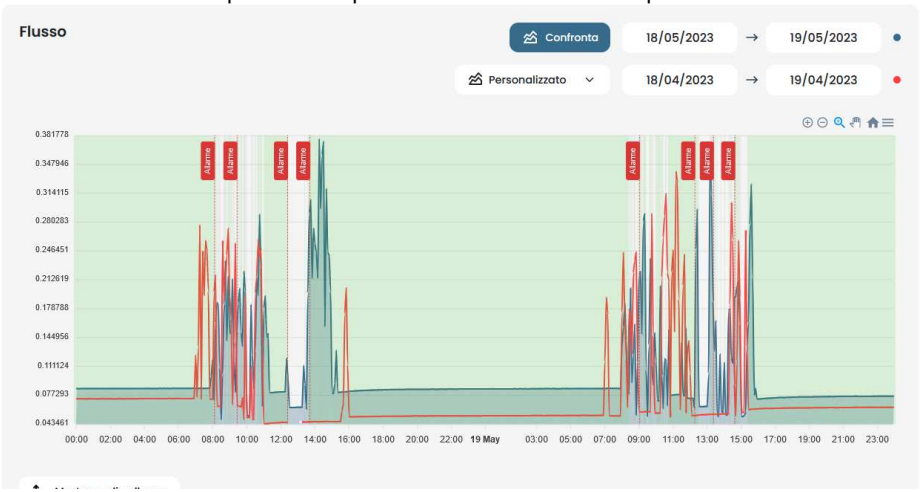
The data of the graphs shown can be downloaded through the small menu ☰ at the top right of the graph, allowing downloads in several formats (SVG, PNG, CSV).



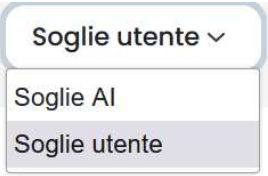
It is also possible to choose the time period for the data to be shown



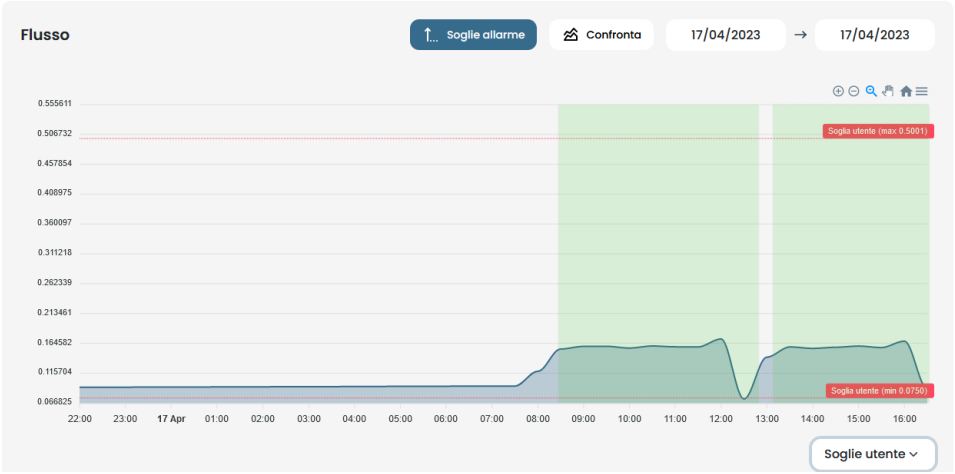
You can also compare two periods as in the example below.



10.1.4 Alarms



It is possible to manually set the alarm thresholds (user thresholds) and to send the alarms from these instead of those calculated by the A.I.

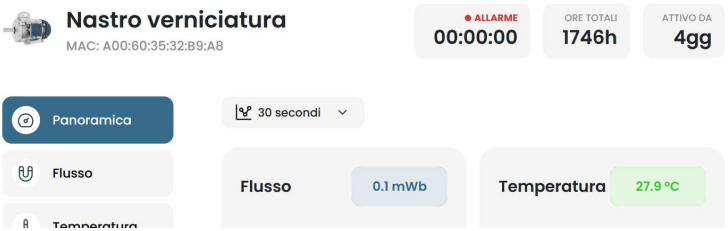


Make the manual thresholds prevail over those of the A.I. it may be desirable when the platform has collected anomalous operating data, or in the initial self-learning phase (about a month), or when it is believed to know the correct functioning of a machine more than the numbers detected by each sensor can make an algorithm understand.

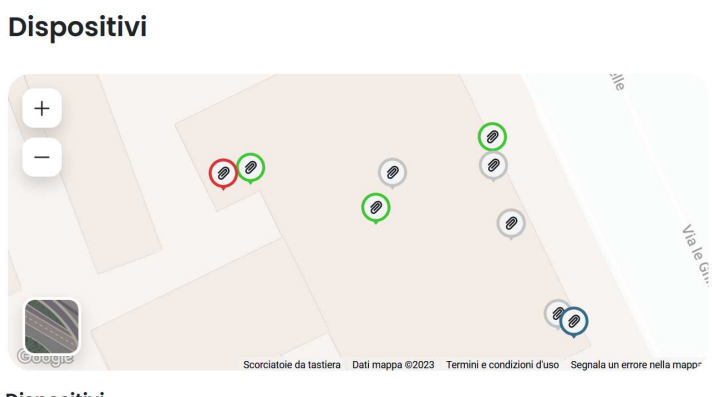
It is also possible to inhibit the minimum alarm thresholds (minimum temperature, minimum vibrations, etc.)

By clicking on the bell icon at the top , you can view both current and past alarms
The alarm state occurs when an alarm threshold is exceeded.
The presence of an alarm in progress in a DOCTOR 4.0 is indicated by the red color,

both in the view of the single device,

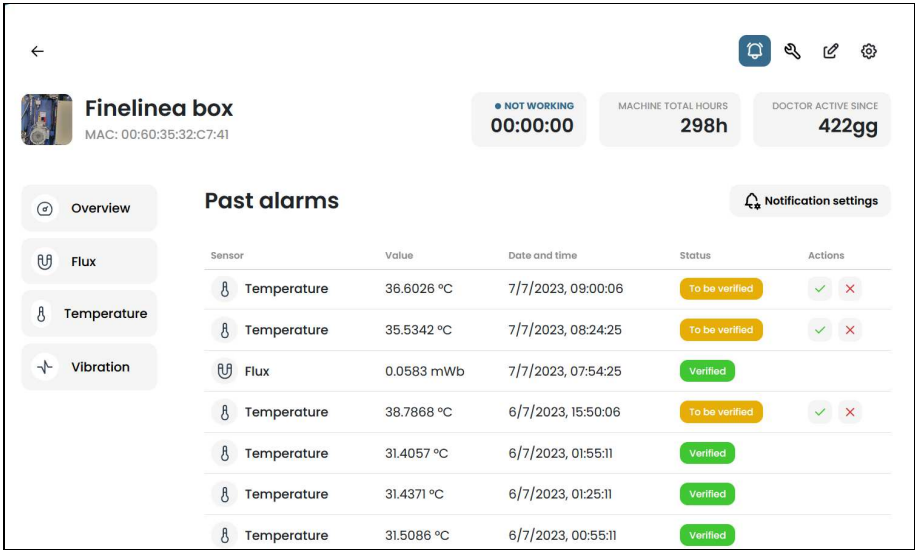


in the map,



and in the list of DOCTORs

The alarm log displays :
- Machine given name;
- Type of alarm;
- Recorded value;
- Date and time of the event;
- State of the alarm;



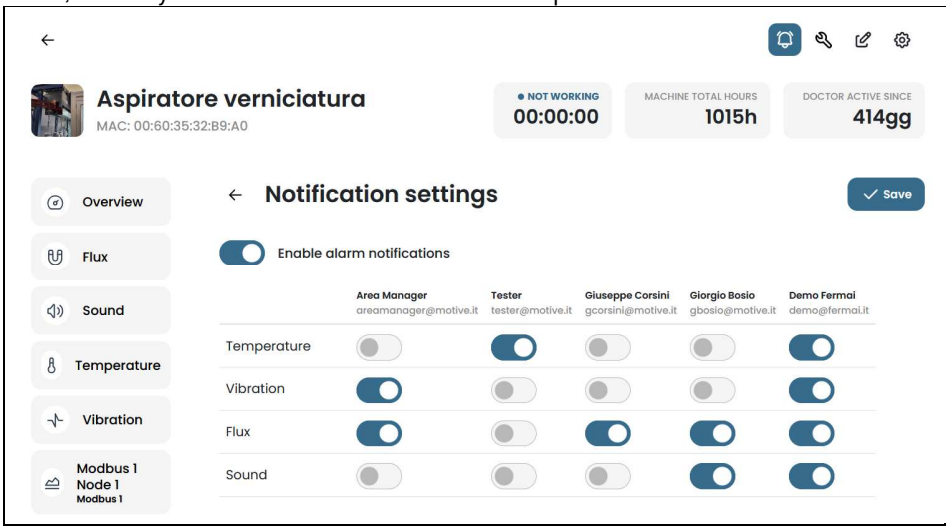
When the status is set as "To be verified" it is possible, thanks to the two side keys, to confirm the occurred verification of the alarm or not to verify it at the moment.

When an alarm occurs, the portal sends a message to the email address that was entered during registration.

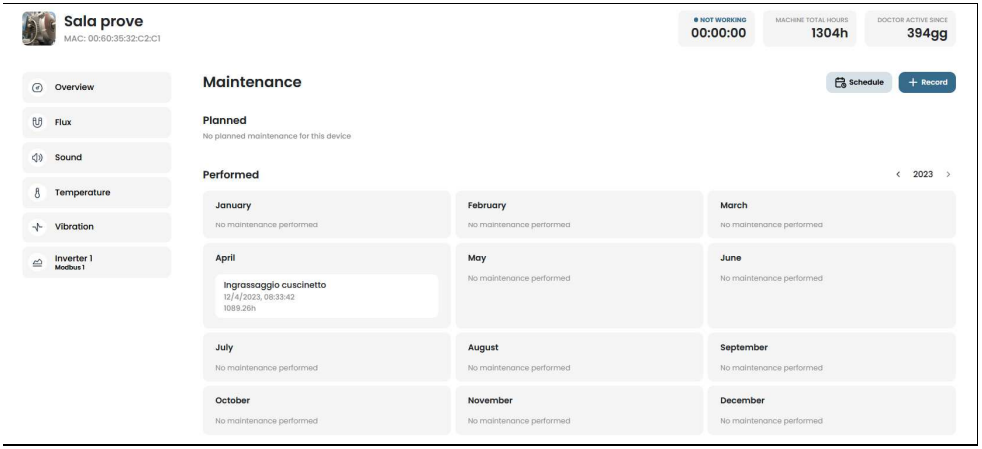
Within the alarm log page, it is possible to manage who to notify or not to notify each type of alarm. For this, click first on

Notification settings

Then, make your selections as in the example below



10.1.5 Maintenance

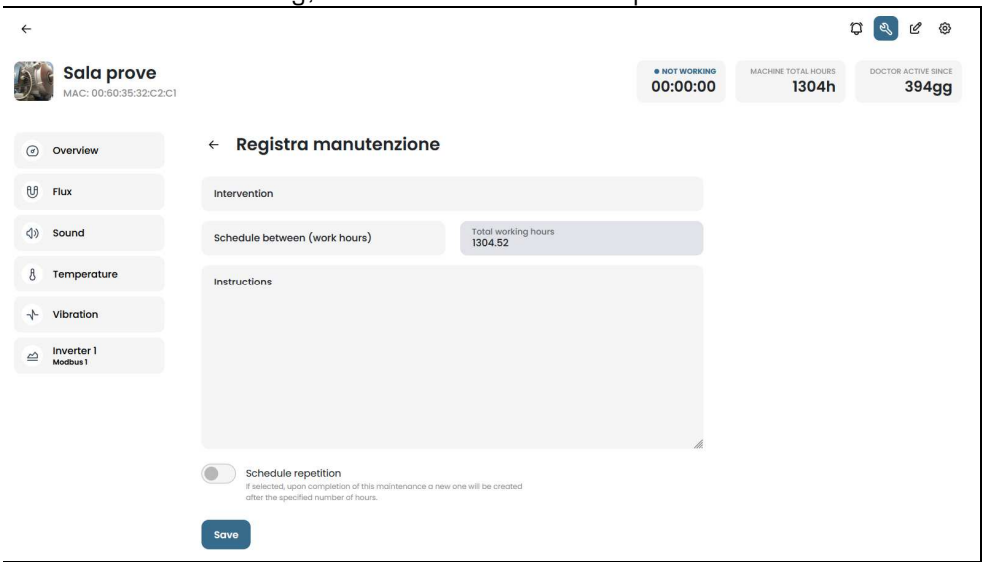


Predictive maintenance is evolution, but preventive maintenance should not be neglected. The more the A.I. will have data, the more it will detect operating anomalies but, in the meantime, it is always better to also follow the machine manufacturer's manual. DOCTOR 4.0 counts the operating hours and, better than any agenda, its portal can tell you when it's time to do the required preventive maintenance

DOCTOR 4.0 allows you to manage a maintenance register. For example, an oil change can be planned for a mechanical gearbox. The main advantage of using DOCTOR 4.0 for this option is that the working hours of the machine are automatically counted. DOCTOR 4.0 is in fact able to understand from its flow and vibration measurements when the machine is working or not, and count the working time.

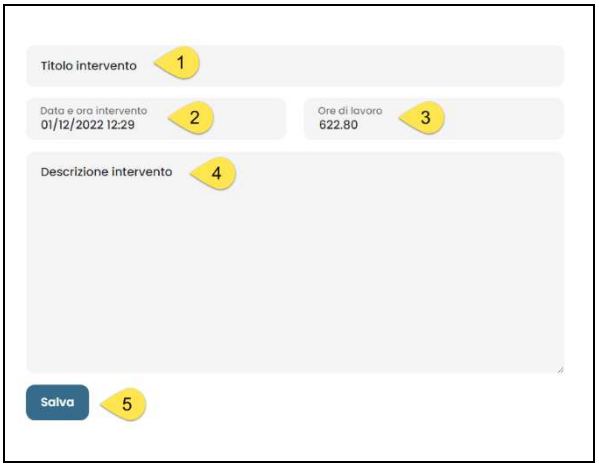
By pressing the button located at the top of the screen, the page dedicated to maintenance opens.
It is then possible to plan a maintenance, or record a carried one

By selecting “Schedule”, it is possible to choose after how many hours, of the machine working, maintenance is to be repeated.



To record a maintenance intervention, click on 

1. Give a title to the intervention (like “bearings regrease”)
2. Date and hour of the intervention
3. How many hours the machine had been working before the intervention (it’s automatic)
4. Description of the intervention;
5. Save the data



10.1.6 Edit : within this section it is possible to make changes to DOCTOR 4.0, including:

- machine name,
- typology,
- initial work time, corresponding to that already worked by the machine before the activation of DOCTOR 4.0. It will be added to the working time counted by DOCTOR 4.0 from its activation onwards.

A map is also shown which allows you to view the position of each DOCTOR 4.0, providing its coordinates. In this section, by dragging the DOCTOR 4.0 icon, it is possible to reposition it on the map