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INTELLIGENT HYDRAULICS USING ARTIFICIAL INTELLIGENCE

Ștefan Mihai ȘEFU[1,*], Bogdan Alexandru TUDOR[1]

[1] National Institute of Research & Development for Optoelectronics / INOE 2000 – Subsidiary Hydraulics and Pneumatics Research Institute

* sefu.ihp@fluidas.ro

Abstract: *With the progress made in the fields of programming and electronic systems, the next step was taken, artificial intelligence. By using AI in modern systems, we want to support man in all his activities by introducing systems that can process a certain set of information by themselves without man intervening in the process. Although the use of AI comes to the aid of humans, it increases the level of knowledge necessary for the operator to be able to operate such systems. In this paper, the authors want to bring an update on the field of intelligent hydraulics and the degree of use of AI in modern hydraulic systems.*

Keywords: *Intelligent hydraulics, artificial intelligence, modernization, intelligent hydraulic pump, smart hydraulic, energy efficiency*

1. Introduction

A first attempt to define artificial intelligence (AI) was given by its parents Minsky and McCarthy, who considered it to be any activity that is now done by a machine and was previously done by a human. Researcher Francois Chollet said that artificial intelligence is related to the ability of a system to adapt and improvise in a new environment, to generalize its knowledge and apply it to unknown scenarios. Intelligence is the efficiency with which new skills are acquired to solve non-specific tasks. Intelligence is often thought of as the ability of humans, or in the case of artificial intelligence, of machines to learn, but we are actually discussing how effectively new things can be learned. According to specialist Lynne Parker A.I. is basically an umbrella term for a broad set of methods, algorithms, and technologies made by appropriate software, such as machine learning, natural language processing, or robotics. Since the industry has already entered the era of artificial intelligence, hydraulics could not remain outside the phenomenon. Even if the definition of intelligent hydraulics is still under discussion, it has been accepted that in any variant to ensure features such as the existence of a programmable block, a system of communication with the outside world of the machine, the existence of a hard suitable for the purpose, the existence of a diagnostic capacity. The level of intelligence is different from machine to machine and is basically given by the level of control, command, monitoring and organology of the equipment. The faster, more precise and more capable the cars are of self-adaptation to specific conditions, the smarter the car is considered to be. It is already evident that the level of intelligence required and accepted is also constantly increasing, that is, there will be a visible increase in the ability to store, transmit and process data, in addition to the development of actuation and acquisition equipment [1].
Smart products are defined by a number of basic characteristics, usually codified and divided into static and passive or dynamic and active.
When the concept of Industry 4.0 began to be used more often in the real economy, it was switched to an identification of products - smaller milestones and especially passive ones through unique codes such as the serial number, to which a quantity of information is attached in depending on the level of digitization.
The transition to production based on intelligent technologies has made the manufacturing phases to be taken over and recorded digitally, which essentially serves to streamline the assembly and maintenance of equipment and systems.
Even if the introduction of artificial intelligence knows an intense development, the role of the operator will not disappear, but his activity will be modernized and adapted to new technologies. The

unfortunate problem is that this process will be done primarily to optimize profits and quite a bit for the public good.
In order for the ethical elements of development to be respected, it is necessary for the use of artificial intelligence to be made transparent and responsible in compliance with laws and legal norms, and the technologies and procedures to be easily explainable and aimed at solving the expectations of the population. Ethics is applicable in all sub-fields of manufacturing including design, operation and maintenance. It is important that products are designed to be safe and reliable right from the design stage. It cannot be accepted that manufacturers can bypass or exclude the good of buyers by blaming artificial intelligence that would apply all the laws and regulations in force too strictly. Damage or accidents caused by automated machines cannot be accepted as the fault of the technology and not the manufacturer. For example, technology based on artificial intelligence that has penetrated the medical field cannot be held responsible for possible errors and accidents, given the obligation of producers and users for special human supervision, in all phases, from conception to the exploitation of the results [2].
The relationship between artificial intelligence and intelligent hydraulics:
The area of use of artificial intelligence is very large, but even more important is the permanent increase in the number of fields in which it is applied. Very important are the applications in technology, and in this direction essential are the applications in the subassemblies that ensure the movement. In principle, the movement is ensured by electric drive or by hydraulic drive. In recent years, intelligent hydraulic equipment has emerged as the basis of artificial intelligence involved in the technologies of mobile machinery industries, agricultural machinery production, aviation, metallurgy and steelmaking, machine building, etc. Interestingly, both hydraulic equipment and systems are used, as well as hydraulically actuated test stands. Practically all ideas, methods, solutions valid for artificial intelligence are also valid for intelligent hydraulics.

2. The importance of intelligent hydraulics

Intelligent hydraulic systems help end users gain better insight into their equipment, which improves machine performance and increases productivity.

Intelligent hydraulics is a necessity and not a technological fad to which hydraulic actuation also aligns. Among the elements that show the importance of intelligent hydraulics are the following:

a) Creates new jobs that involve knowledge from modern technical-scientific fields. Traditional operators who often have elementary training will no longer find easy work, instead the number of jobs that require workers to know some elements of electronics, mechanics, electricity, hydraulics and Informatics.

b) Reduces unnecessary energy consumption in areas such as transport, metallurgy, manufacturing technologies. The fact that the intelligent hydraulics will adapt the energy consumption to the necessary, optimize the energy balance of the machine and solve the energy efficiency shows the modernity and usefulness of the concept.

c) Saves the person from performing operations that require great effort and repetitive, physically tiring, but especially mentally.

d) Essentially contributes to the modernization of machinery drive systems. Over time, the specialists have worked, are working and will work on energy efficiency and increasing productivity from the design, production and maintenance phases of both the technological lines and the final products that reach clients, individuals or legal entities. There is no variant of development without the involvement of artificial intelligence, therefore also of intelligent hydraulics.

3. The advantages of intelligent hydraulics

Lately it has been accepted that intelligent hydraulics is important in the process of technological modernization of the economy. However, companies have been restrained in its industrial application, although there are many economic advantages such as:

- Intelligent hydraulics create competitive advantages that can be vital for manufacturers. The level of economic efficiency of intelligent hydraulic systems leads to the creation of competitive advantages, which very often can drive some firms out of the market, or produce an unexpectedly high demand from the market. The fact that intelligent hydraulics increases efficiency and productivity has made many companies active in the field in order not to be excluded from the market. In the near future, the market will no longer accept products with low efficiency or low productivity. The price of energy will drive out of the market producers who do not adapt to trends and customer demands.
- Obtaining special economic results as a result of modern equipment and systems, which have acceptable expenses for the activities that give intelligence. With the reduction and stabilization of the prices of intelligent hydraulic equipment, electronic calculation blocks and data transmission and reception systems, the reluctance to use AI (and therefore also intelligent hydraulics) of manufacturers has been reduced very seriously.
- Easy access to high class computing systems. For a long time and in many countries, difficult economic, technical and scientific access to high-performance technologies and equipment was a decisive factor blocking progress. Today, the unrestricted existence on the market of methods, equipment and high-performance computing systems, such as processors and PCs, but also cloud systems, allow anyone fairly easy access to everything necessary for smart technologies.
- The ability to solve concrete problems. Intelligent hydraulics make an essential contribution to reducing the risks of important functional errors, especially in workplaces that are dangerous for humans.

Intelligent hydraulics have the ability to work faster than humans, to be available at any time of the day, but above all to perform difficult and repetitive work.
The fear that intelligent technical systems will reduce the number of jobs is unfounded, although those requiring lower professional training will be reduced, but the number of those requiring higher qualifications will increase significantly.

4. General applications of intelligent hydraulics

Intelligent hydraulics began to be used more and more in almost all industrial fields.

- In the field of car, rail, naval or air transport, it must be specified that the modernization involves the fields of planning, the fields of tracking, the technological fields of actuation of various sub-assemblies and devices and even the actuations of energy-efficient tractions.
- In the field of machines and automatic machines such as robots and manipulators, hydraulics and pneumatics equipped with artificial intelligence occupy a dominant position in opposition to electric variants.
- In the field of agricultural machinery and machinery, intelligent hydraulics will allow a revolutionary development of the entire agricultural sector.
- In the fields of machine tools and technological manufacturing lines, with all directives without technical support to favor electric drives, a special involvement of intelligent hydraulics is foreseen.
- In all technical fields where there are complex machines that need powers greater than 20kw.

The need to move to intelligent technology in the field of hydraulic drives is for machines and machines in manufacturing technologies to become even smarter, so to increase efficiency and productivity it is necessary to improve connectivity. Intelligent hydraulic systems are always prompter and can provide general intelligence either by using only intelligent equipment or by selecting areas

with important influence in the operation of the assembly and only those will be equipped with intelligence. The intelligence of hydraulics allows better communication not only with the central command and control system but with all the machines in the entire plant. Also important is the compatibility with the Internet of Things-IoT, one of the bases of the Industry 4.0 process, which makes full use of the individual performances of each installation.
The life of the machinery is essential for the user of the hydraulic installation, which is why intelligent systems are needed to detect faults before they occur to reduce downtime. It's good to know when the uses become dangerous, when the filtration starts getting worse, or when the machines start going out of tune. In this way, we can talk about a timely service and a low repair time [3].
As a result, the intelligence of the hydraulics allows the transition to a proactive maintenance, through which the danger of a failure is detected in time, so the operators can plan to stop the machine only when necessary and often this allows the full supply to be made and on time, thus reducing stocks.
Another motivation for switching to intelligent hydraulics is that problem identification, so diagnosis becomes easier and thus maintenance becomes cheaper, as well as minimizing machine downtime.
The increase in costs with the modernization of machines and the introduction of intelligent components is amortized quite quickly by reducing the downtime and increasing the quality of the products.
Using intelligent hydraulics in figure 1 we can see parameters that we can measure and the benefits of knowing them [4].

5. Intelligent hydraulics

The trend of recent years in hydraulic drives has been and still is towards smarter components and systems that have greater freedom, flexibility and efficiency. It finds that manufacturers of complex machinery are looking for smarter hydraulic drive components and subassemblies. Hydraulic drive suppliers need to know that the level of intelligence is changing extremely quickly. Users of hydraulic pumps take into account their efficiency, the controllability that increases the precision and dynamics of the pumping systems, the versatility that ensures good operational flexibility of them, but also the level of noise and vibrations that can negatively influence the whole machine. Beneficiaries want intelligent hydraulics to lead to smooth and efficient hydraulic response.

6. Intelligent hydraulic equipment

6.1 Smart pumps and pumping units

The most important hydraulic equipment that has been equipped with artificial intelligence are pumps and pumping units. The intelligent drive and control of hydraulic pumps required by industrial applications ensures not only the efficiency, controllability and versatility of the system but also the control of noise, temperature and vibration. Intelligent pumps created for Industry 4.0 allow the visualization of operational information regarding flows, pressures, yields, temperatures, speeds at any time. The fact that this data, as well as others, can be accessed not only directly but also via the cloud enables efficient control of mobile machinery as well. Crucially, the sensors and control system elements are integrated into the pump allowing easy connection to both the hydraulic system and the large machine. This allows the variation of the flow (speed) and the adjustment of the initial settings according to the requirements of the machine and the situation at each moment of the mechano-hydraulic parameters, existing on the machine. The advantages of using this type of pump can be concentrated in:
- Remote control and command
- Good functional efficiency
- Predictive maintenance that improves uptime and reduces maintenance costs

Figure 1 shows the hydraulic pump and its control and data acquisition elements. The PLC module can be connected to the Internet and controlled remotely or by Artificial Intelligence.

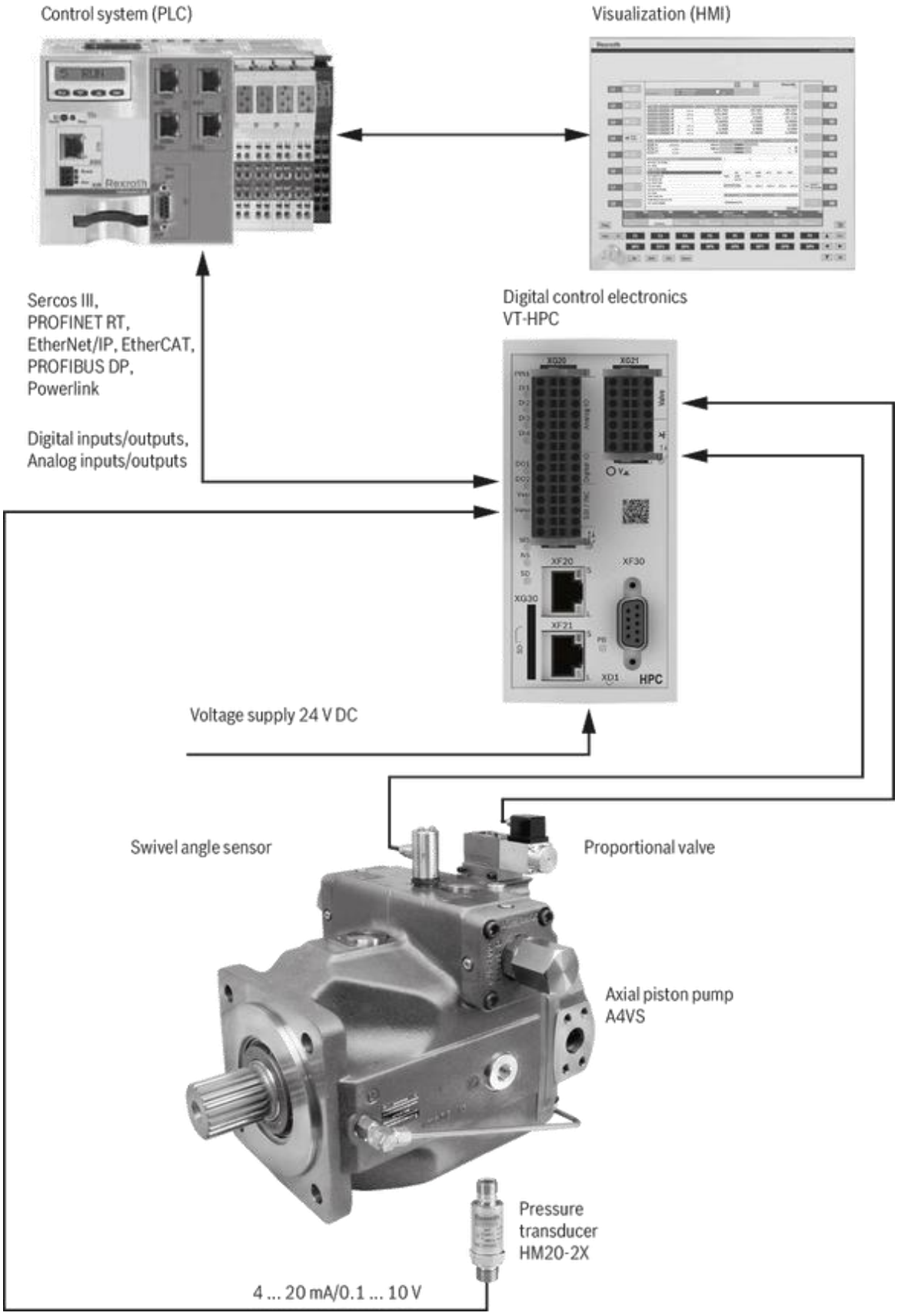

Fig. 1. Smart hydraulic pump [5]

6.2 Actuators and pipelines

The hydraulic actuator is a piece of equipment that converts the energy of a fluid under pressure into mechanical energy. The actuator can be linear, rotary or semi-rotary, so a cylinder or a rotary motor. The actuator has become from a simple piece of equipment to a complex one by adding sensors and command and control blocks. If we only refer to the intelligent hydraulic cylinder, it is composed of an ordinary cylinder to which a linear sensor and an electronic block are attached inside or outside to ensure the commanded position or speed. It accurately provides distances within the stroke (typically from 0 to 3m), forces (from 1 to 500kN) or fixed or adjustable speeds. The cylinder's intelligence allows it remote control which is very important in many applications.
The actuator combines the intelligence of electronic servoing with the power density of hydraulic actuation. Although the system of smart cylinders is complex, as it allows good precision, but also predictability, repeatability and safety, it is surprising that users can be at an average level of professional training in the field. This advantage helps users reduce expenses related to the professional level of maintenance specialists.
Smart actuators are complex hydraulic equipment, consisting of cylinder, transducers, electronic control block and a suitable computer system.
The most important advantages of intelligent hydraulic actuators are:

- It represents a compact assembly with all the components tested by the manufacturers
- Maximum energy density and adaptation of consumption to demand
- Permanent and precise position control, speed, force, noise and low leakage.
- High reliability and minimal maintenance
- Acceptable price

The use of intelligent hydraulic actuators is becoming more and more intensive in a wide range of industries, from agricultural applications where even the depth of plowing or seeding is controlled, to heavy equipment for construction and mining.
Referred to by many names such as: electronic position-sensing, electro-hydraulic control, intelligent cylinders and smart cylinders; this technology utilizes linear transducers (sensors) to communicate the cylinder's piston position back to the overall hydraulic system.
Increased control, functionality and sensor-instrumented cylinders are becoming more important and more common in heavy industrial, mobile, and agricultural equipment.

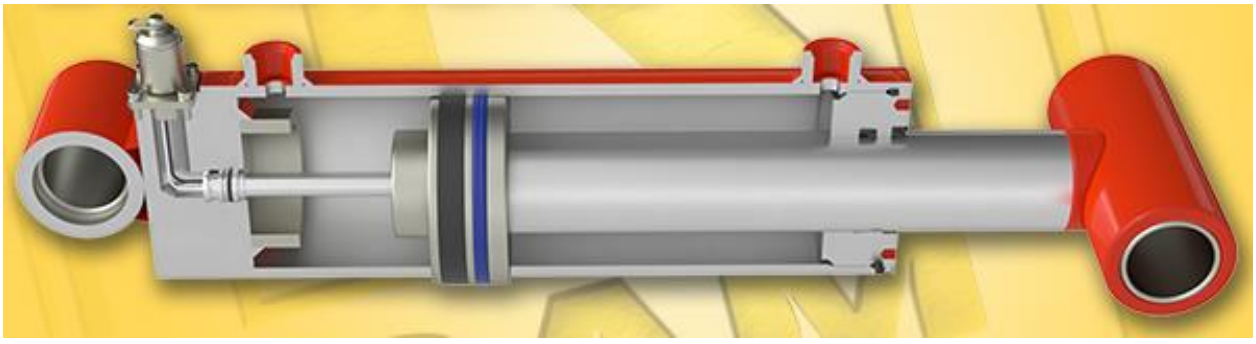

Fig. 2. Intelligent hydraulic cylinder [6]

6.3 Smart sensors

Sensors provide feedback on output based on factors such as speed, distance, pressure, temperature, fluid quality, etc. Sensors help ensure that equipment such as cranes or trailers are level. This is useful to confirm that the equipment is stabilized. In addition, position sensors can tell the operator when it is safe to move only when the outriggers or outriggers are disengaged.
Eaton’s LifeSense hydraulic hose includes a sensor that can detect hose failure or problems and send a notice through a wireless or wired network, to alert machine operators of impending failure.

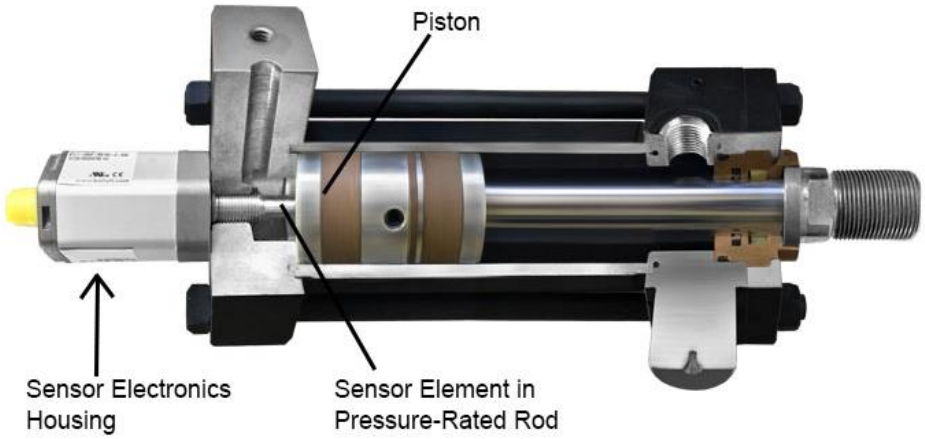

Fig. 3. Sensors for hydraulic cylinders [7]

The classic linear position feedback solution for hydraulic cylinders is the rod-style magnetostrictive sensor installed from the back end of the cylinder. The cylinder rod is gun-drilled to accept the length of the sensor probe, and a target magnet is installed on the face of the piston. A hydraulic port on the end cap provides installation access to thread in the pressure-rated sensor tube. This type of installation carries several advantages but also some potential disadvantages depending on the application.

7. Intelligent hydraulic equipment

All specialists know that precision in components is needed to minimize losses and ensure that the operator gets a "real-time" feel for the operations being undertaken. As a result, intelligent instrumentation helps achieve intelligent hydraulic systems that generate highly relevant information for the entire machine.
Intelligent hydraulic systems:
A typical intelligent hydraulic drive system is based on 4 mandatory subassemblies: (see figure 4).

1. A hydraulic pump driven by an electric or thermal engine
2. Pipes, hydraulic steering and control elements, sensors and transducers, filters and auxiliary equipment
3. A linear or rotary actuator.
4. Electronic control block

Fig. 4. Intelligent hydraulic drive system [1]

Two important clarifications must be made:

- Without a modern electronic control there is no intelligent hydraulics, so the computer has already become a basic component of the hydraulic system.
- An intelligent hydraulic system can have centralized intelligence or distributed intelligence on components and only a centrally concentrated part

The intelligent system design methodology is supported by process elements for processing and storage, cloud technologies, Internet of Things (IoT), communication technology, machine learning, simulation analysis, real data analysis, artificial intelligence and of intelligent components such as hydraulic pumps, actuators and sensors.

8. Conclusions

Intelligent hydraulics together with artificial intelligence have a superior energy efficiency compared to classic drives. At the same time, this modernization will not cause the loss of jobs for operators, but will increase the level of knowledge required by the operator. The modernization of the components of the hydraulic installations helps to measure the functional parameters in real time, and with artificial intelligence the installations can be stopped from operation so that the system does not fail completely.

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