

## **Difficulties and possible mistakes in applying AI techniques in industrial control systems by new generation of engineers.**

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**Abstract.** Nowadays, Artificial Intelligence (AI) is making its entrance in absolutely all fields and only the economic level of the promoting states is responsible for the percentage of the insertion of this new technology. The economic aspect is not directly connected with the AI because there is already a wide range of open-source software's and AI analysis models but is strictly connected with the digitalization level of the country and/or company that wants to follow this trend. This article proposes a subjective analysis of some situation that young engineers can face by early use of dedicated software's for data analysis rise from different systems.

**Keywords:** Artificial Intelligence, engineering, data analysis, digitalization

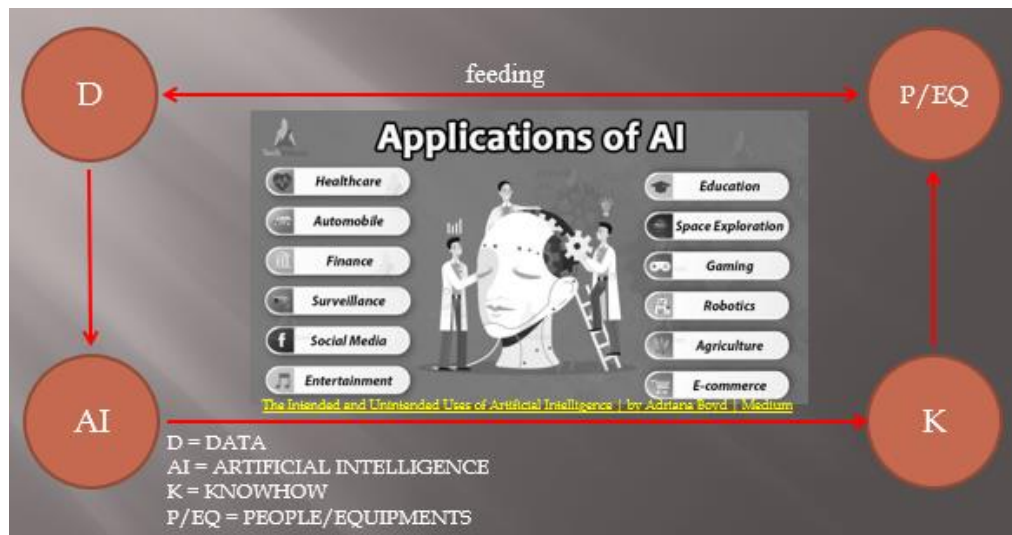
### **1. Introduction.**

“Never let your feet run faster than your shoes” [1] say a Scottish proverb. Not coincidentally, this paper aims to analyze several situations that could put the young engineers in difficulty. The AI is part of Digital Transformation (DT) already announced at the World Economic Forum (WEF) and offer a big impact on digital technologies, business, and wider society over the next decades. [2]

For a better understanding and adaptation of this subject, few publications approach the definition of these terms, as follow:

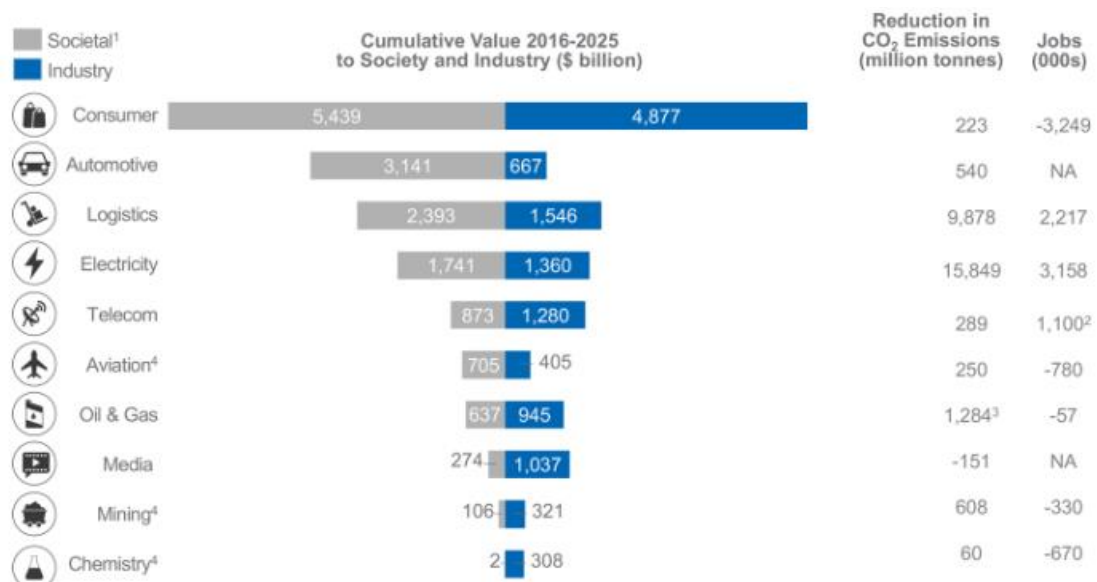
- Digitization: the process of converting information locked in physical documents from analog to digital system.[3]
- Digitalization: the process of using digitized information to work more simply, efficiently and to eliminate human errors.[3]
- DT: changing the way you conduct your activity. It's about taking a step back and revisiting everything you do, from internal system to external impact. A key element of your DT is to understand the true potential of your technology.[3]

If the topic is analyzed according to the newest terms in domain, means that we are already in the epoch described by the figure 1, as follow.



**Figure 1.** The operating cycle of AI systems.

In the same positive way, on WEF page are available tens of reports that underline the impact of DT in our society and outline the glaming future through new AI technologies insertion in varous domains. According to WEF the digitalization has a huge potential and its estimated that it could delivered around 100 trillion of dollars in value to business and society in the near future. [4]

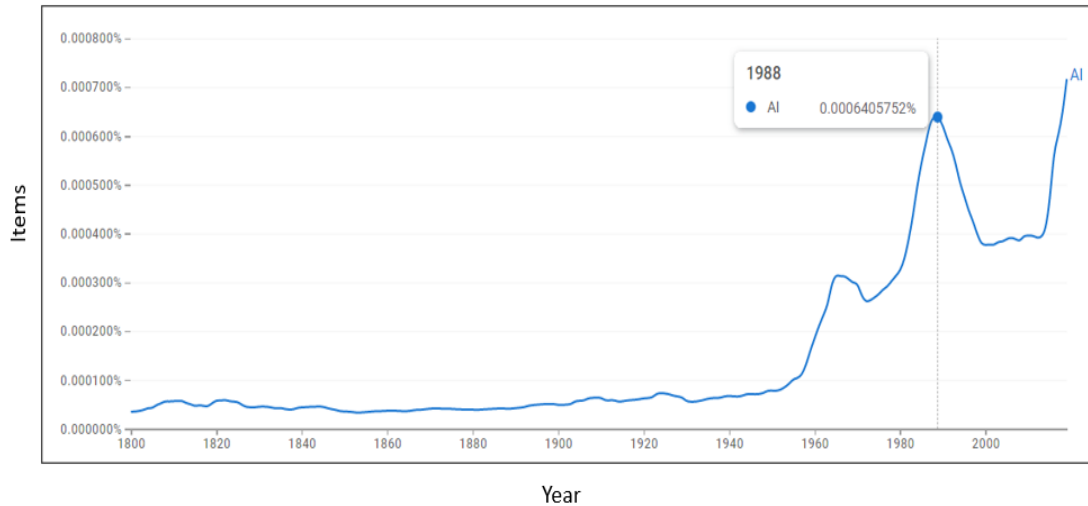


**Figure 2.** The value of digitalization analysed by the DT initiative. [4]

Also, the same report, mention the obstacles that may appear during the implementation of these systems, with few examples, mentioned here bellow [4]:

- Infrastructure gaps.
- Lack of public trust in new technologies.
- Unfit regulatory frameworks.

Even if some people are skeptical regarding the powerful of the AI techniques, it is certainty that the AI subject is on an upward slope as shown in the figure here below.



**Figure 3.** Graph generated with google n-gram viewer that shown the AI evolution between 1950 – 2019.[5]

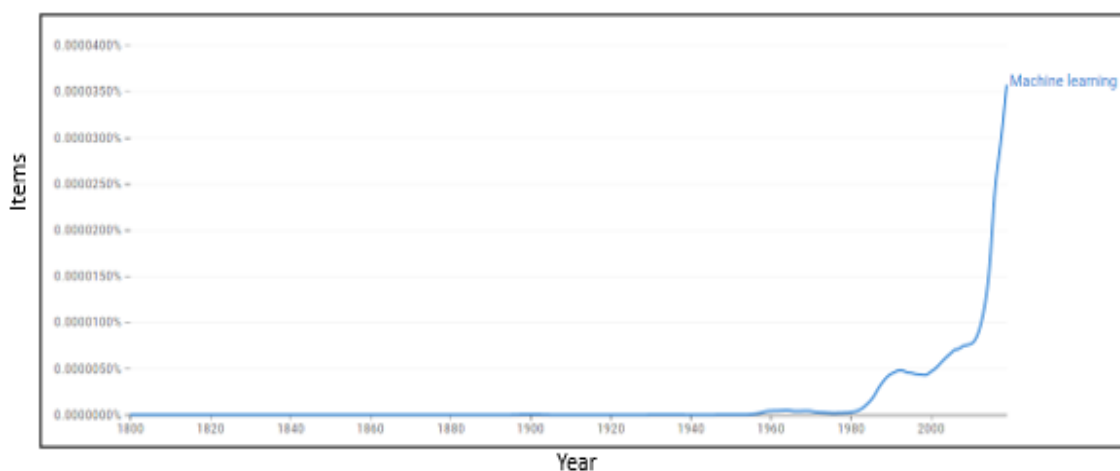
## 2. AI techniques and applications for engineers

This chapter aims to bring to light the AI term both as symbolism and application. Nowadays almost everything is intelligent, from shoes [6] to intelligent robots that are used to conduct surgical heart disease operation [7,8].

According to Oxford English Dictionary, AI is the capacity of systems (computers or other machines) to exhibit or simulate intelligent behavior and other definitions are correlated the AI with Human Intelligence (HI).[9]

According to European Commission (EC) the AI system represent the software that is developed with ML (Machine Learning) algorithms and/or statistical analysis.[10]

If we search on google n-gram viewer the evolution of ML (Fig.4), and we compare with Fig 3 we can obviously see that ML techniques was almost inexistent or very little used before 1980 and explode in many domains after 2010.



**Figure 4.** Graph generated with google n-gram viewer that shown the ML evolution between 1950 – 2019.[5]

As conclusion, we can say that before 1980 the AI concept was both as symbol and application, different compared to AI after 2010.

Nowadays, engineers have the possibility to apply AI techniques to solve problems related to power systems that are not solvable by conventional techniques. AI applications are wider used for fault diagnosis and condition monitoring of electrical equipment, but the most common are fuzzy logic control system (FLCS) incorporated in process computers and equipment's. With FLCS is possible to create rules for how the machine respond to the inputs that continuum account the possible conditions, better than elementary binary 1.

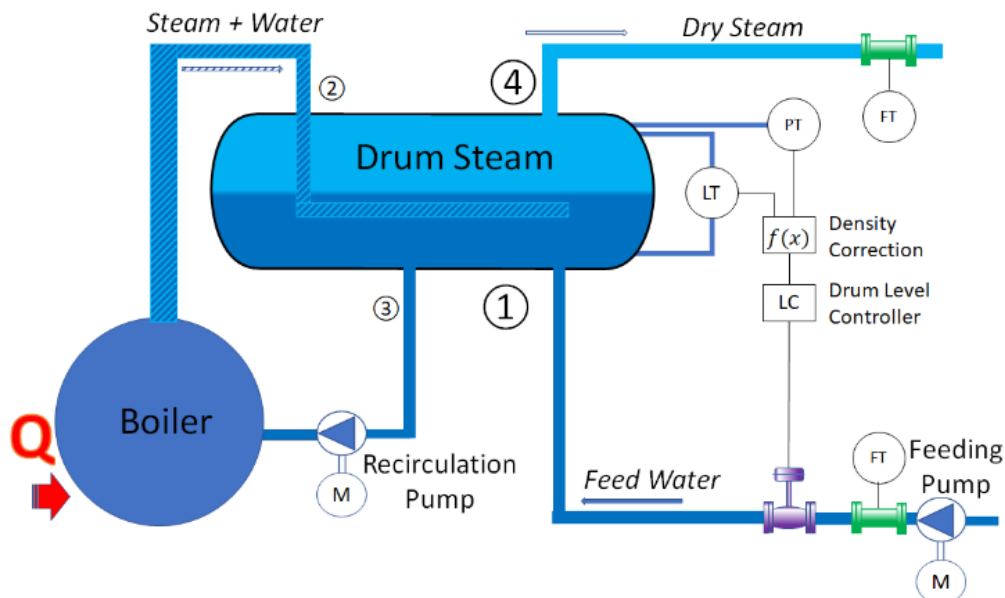
The most powerful companies on the AI market are: OpenAI, DeepMind, Nvidia, Sgnifyd and Vortex 1. All these companies are using AI in engineering also. On the first page of OpenAI site it's mentioned the vision for the future Artificial General Intelligence (AGI) that sounds like this: "Our mission is to ensure that artificial general intelligence – AI systems that are generally smarter than humans – benefits all of humanity ". [11] With this sentence, it can obviously see that the concept of AI promoted until 2010 is totally different both as symbolistic and application from today's AI. Anyhow, until these new AI systems will be implemented and applied on large-scale in all fields, including engineering, young engineers will face a big challenge during this transfer process, from HI to AI.

In the following is presented a case-study highlighting the pitfall that those who implement control systems by using AI techniques can have without knowing in depth the processes and without having experiences working with the entire mechanism of analysis to an engineering situation such as measurements, data transfer, data accessibility, data analysis, simulation of the process, interpretation of results and intervention and correction of solutions.

### 3. Case-study – Steam drum level control.

Most of the plants are using water and steam in processes. Water is used for cooling reactors, steam is used for heating reactors, in chemical plants. Also, steam is used to produce electrical energy in turbogenerators or to act turbo-blowers.

An example of how the steam is produced is showed in fig.5.



**Figure 5.** Steam Drum-Boiler.

The system looks like being simple. The boiler received the heat from different sources: coal, gas, oil, biomass, and even nuclear reaction. The water is boiling, and the mixture of water and steam is transferred to steam drum trough port 2, where it is separated. The dry steam, without liquid phase is used in turbines (energy plant) or in heat changers(chemistry) and the separated water is pumped back by the recirculation

pump into the boiler (port 3). In the steam drum we must ensure a level around at the half of it. The feed water pump introduces trough [port 1 in the system a quantity of fresh demineralized water equal with the mass of steam used at port 4. The pressure in the steam drum is the pressure required for the acting turbine or for heating, usually tens of bars.

Mathematical model is based on global mass balance and global energy balance [12].

$$\frac{d}{dt}(M_{tf} + M_{tg}) = \dot{m}_1 - \dot{m}_4 \quad (1)$$

$$\frac{d}{dt}(M_{tg}u_g + M_{tf}u_f + E_m) = Q + \dot{m}_1h_1 - \dot{m}_4h_4 - q_{amb} \quad (2)$$

where:

$M_{tf}$  – total mass of fluid

$M_{tg}$  – total mass of gas (steam)

$\dot{m}_1$  – total flow trough port 1 – feed water

$\dot{m}_4$  – total flow trough port 4 – dry steam

$h_1$  - specific enthalpy of feed water

$h_4$  - specific enthalpy of dry steam

$u_g$  - specific internal energy of gas

$u_f$  - specific internal energy of liquid

$q_{amb}$  – heat changed with environment – can be neglected

$$E_m = m_t C_p t_{sat}$$

where:

$m_t$  – total mass of boiler-drum structure

$C_p$  - specific heat at constant pressure

$t_{sat}$  – working temperature of boiler-drum system

$Q$  – heat

(3)

Regarding the level in steam drum, there are 2 dangerous situations (excepting the pressure too high – treated separately by steam relief valve):

- The level is too high – the water drops can get out through port 4 and damage the turbine in a power plant.
- The level is too low – the recirculation pump has not water at inlet, the boiler pipes can get dry and superheat.

The control loop system must keep the level in steam drum, measured with LT (Level Transducer) and corrected with pressure (measured by PT-pressure transducer) between low and high limits. The controller (LC – level controller) is acting the electric valve and introduce feed water in steam drum.

The system is approximately linear and can be modeled only in quasi-stationary functioning. At start up and shut down the system is strongly nonlinear. Additional, two phenomena can appear:

- The shrinking – lowering the level in steam drum when extracting less steam because of pressure increasing.
- The swelling – increasing the level when extracting more steam because of pressure decreasing.

These effects make almost impossible using of a classical PID controller with feedback. An advanced controller is a cascade controller with feedforward. The steam flow is used like measured disturbing and immediately compensated by injecting water, the level is used like feedback for the master PID controller, and the water flow is used like feedback for the slave controller.

Better results with stable level, are achieved by using MPC (model predictive control) combined with machine learning algorithms.

#### 4. Simulation results with Orange data mining software.

To build the steam drum-boiler operating model, the following steps have been followed:

- extract relevant data (steam drum-boiler pressure, water level of the tank, valve position of the water inlet, steam flow output)
- the database collected from the process was loaded into Orange-data mining software.
- It was established the target for the model output – water flow.
- It was established the predictors with the help of which the model of water flow was build.
- According to accuracy classes of mathematical modelling used by Orange software it was decided random forest model for this process.
- After completing these steps, the precision of the model is 0.923 as per fig 6.

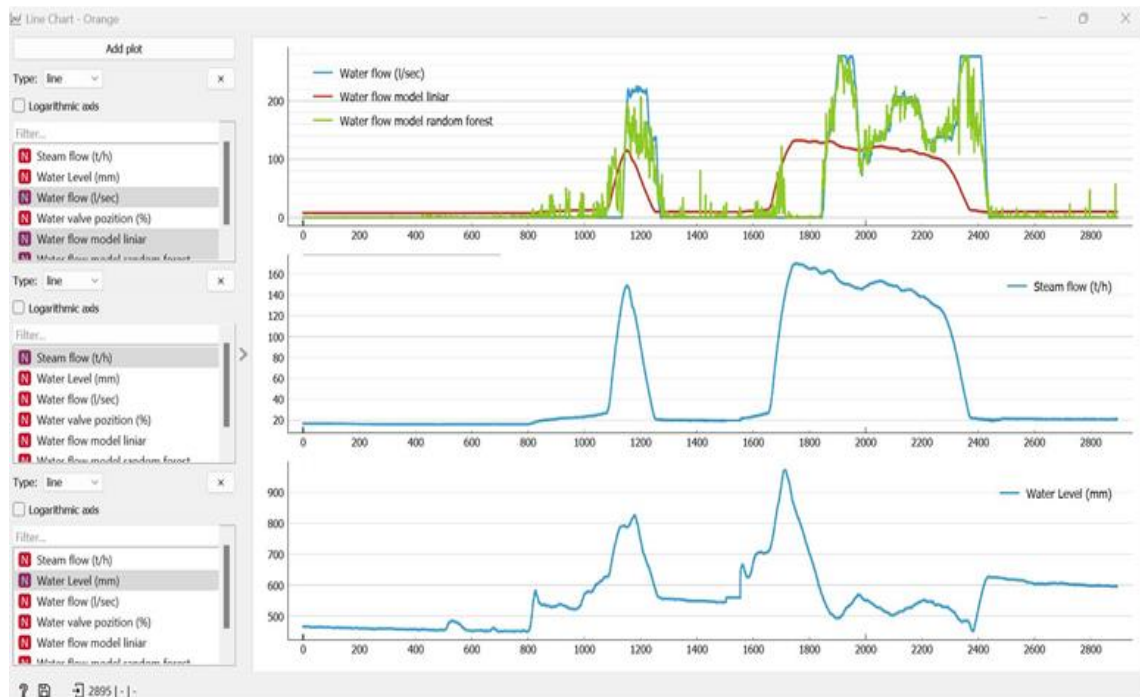


Figure 6. Comparison between different ML techniques with Orange data-mining for the water flow model on drum-boiler process.

The performance score results of the applied models are described in Table.1.

**Table 1.** Performance score.

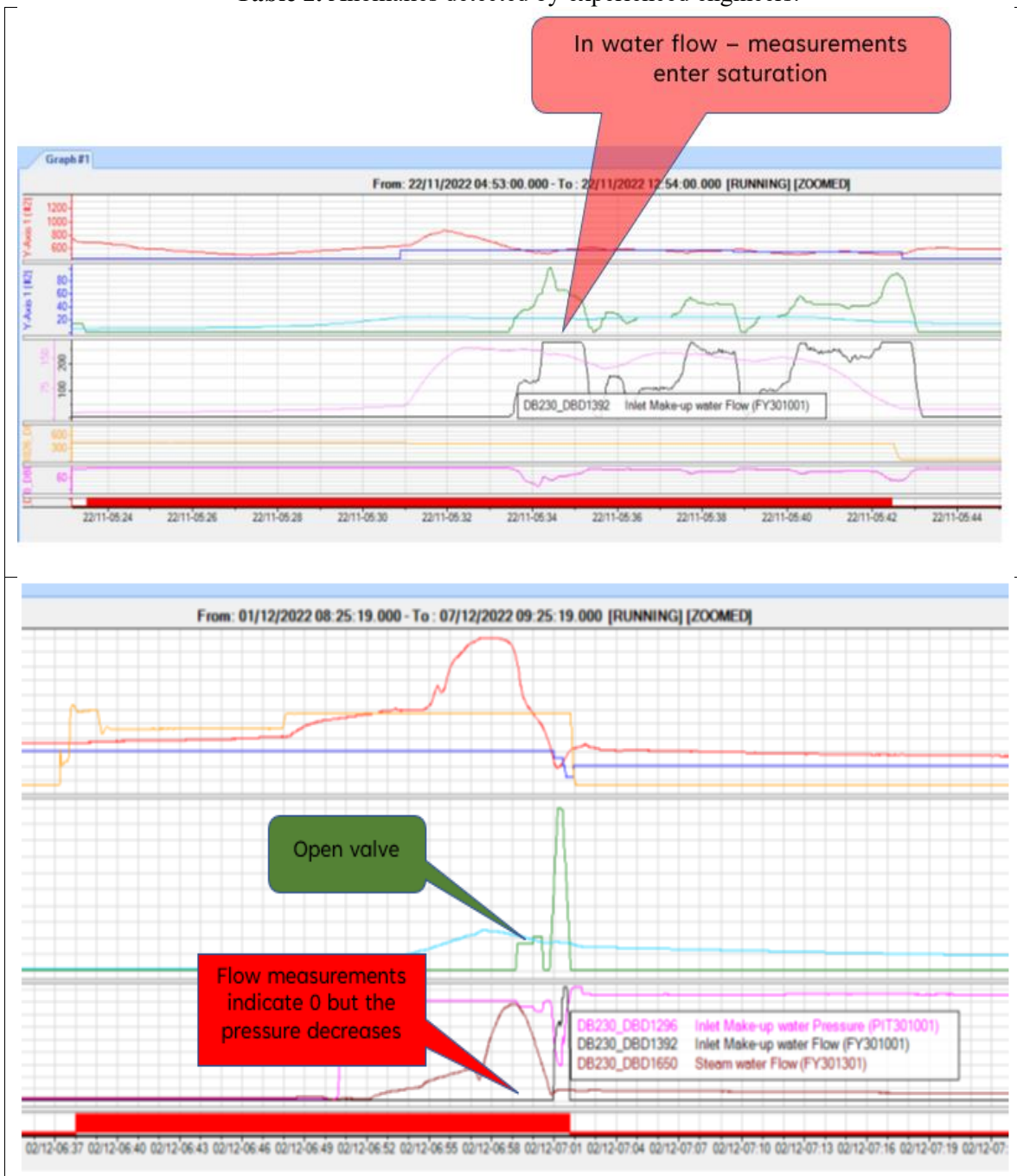
<b>Model</b>	<b>MSE</b>	<b>RMSE</b>	<b>MAE</b>	<b>R<sup>2</sup></b>
<b>Water flow model linear</b>	3108.751	55.756	26.893	0.260
<b>Water flow model neural network</b>	1821.440	42.678	20.709	0.566
<b>Water flow model gradient boosting</b>	1612.232	40.153	18.828	0.616
<b>Water flow random forest</b>	323.238	17.979	6.075	0.923

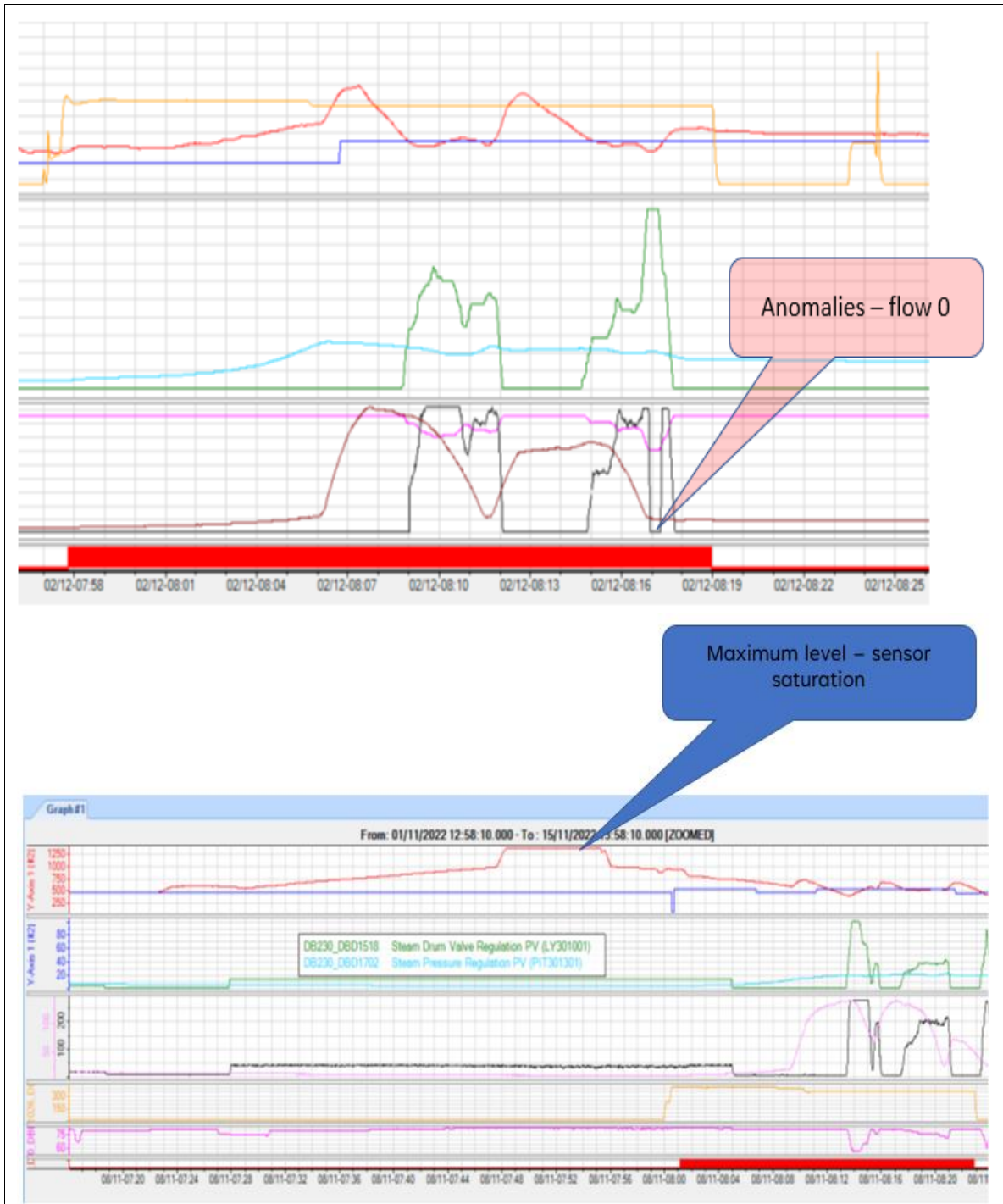
Obviously, until the implementation of the resulted model it is mandatory an additional check by a team of experts in drum-boiler installation to avoid possible anomalies. The anomalies may occur due to a wrong result through software modelling.

According to results through simulation, the model for the automated control of the functions of the drum-boiler is possible without doing any changes in the installation, and the only step to be done is to implement the model coefficients for all the important parameters.

Anyhow, this conclusion can be embraced by the young engineers without experience in this kind of installation and without knowing in detail the entire analyzed process. Of course, the young engineer will sustain the obtained model because the results are acquired with the help of an advanced software that uses dedicated algorithms and analysis modules similar with all AI systems. More than that, the software validates the obtained model with a very high precision. The best choice to implement is resulted the water flow random forest model (R square is 0.923).

If this process control model would be done by a dedicated project implementation team of engineers with high experience in technology, process, measurements, and mathematics, then a lot of anomalies would be acknowledged. Few examples of detected anomalies are exemplified the table here below.

**Table 2.** Anomalies detected by experienced engineers.




In addition to problems generated by bad function of the measurements equipment's, identify and exemplified in Table 1, the experienced engineers detect dangerous situation also in the operation of the equipment through faulty control (see fig.7).



**Figure 7.** Dangerous situation in control operation of the equipment.

If the feed water pump is common for 2 or more steam drums, if the pressure drops below 25 bars when feeds one drum and if the second valve is opening, the flow of water is reversed. This situation may cause an important fault of the equipment itself and of the entire connection line with other equipment's.

## 5. Conclusions.

As was described previously there is a point of attention regarding the trap in which the young engineers can fall by using too early advanced analysis method as ML and be 100% confident in the results. To implement a correct control model achieved through sophisticated algorithms few steps need to be followed:

- To analyze the process behavior and the connection between the variables and the process objectives
- To double check the source, accuracy, consistency, relevance, and correctitude of the collected data
- To adapt the level of applied mathematics to the complexity of the process.

In the steam drum-boiler example, an experienced engineer first would have checked and identified hardware problems in installation to avoid mathematical modelling based on a database which contains erroneous data.

As main conclusion, after tens of simulations in the past 3 years, similar with the subject presented in this paper, it can be state that the AI modules available today can be very useful if they are applied by experienced engineers in the field of researched topics. For the process described in this paper, the recommendation is that the steam drum level control to be analysed by engineers with high experience in the following domain:

- Thermodynamics
- Instrumentation – Sensors and Actuators
- Automation Systems for Process Control
- Machine Learning

This recommendation is done due to the risk that may arise in such processes.

**Acknowledgment**

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