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USING ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN SUPPORTING BUSINESS DECISIONS FOR STORING ENERGY IN GRAVITATIONAL FORM

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Abstract

Energy management is important for all farms and choosing the most suitable form of storing energy is essential in mitigating associated risks, seizing opportunities and thus maximizing productivity. We propose the small scale environmentally friendly method of storing energy in gravitational form, which involves pumping water available in open ponds to higher altitudes to store surplus energy, and releasing it to lower altitudes when additional energy is required. For small farms that benefit of suitable geographical position for storing energy this way, i.e. sufficiently high height gradient, this method would be particularly beneficial as it decreases the need to rely on external energy providers. In addition, it has the potential of helping the environment, as local flora and fauna may benefit from the presence of water especially during drought periods. For the purpose of remote control and data acquisition in such locations, we propose using long range and low power communication (LoRa) infrastructure and LoraWAN protocol - such infrastructure has the added benefit of assisting farmers in making better decisions for their crops, as well as providing warnings if required. To assess the feasibility of the method, we carried out a case study on a local small farm. Initial results indicate that the costs involved when using this method are comparable to other energy storage methods, but storing energy gravitationally has the added advantage of being more environmentally friendly. For a more detailed and larger scale feasibility test, we propose to use Artificial Intelligence (AI) for choosing the most suitable locations for placing the ponds and Machine Learning (ML) techniques to examine correlations and draw a conclusion on whether the presence of new ponds is overall beneficial. Such an investigation also offers insight from a quantitative perspective, informing economic calculations such as pay-back period (PBP) and Return on Investment (ROI) of the project.

Key words: *artificial intelligence, machine learning, LoRa, LoRaWAN, renewable energy, energy storing*

INTRODUCTION

In the present context regarding the energy crisis, it is important not only to explore the ways of increasing the energy usage efficiency, but to also analyze the possibility of producing and storing energy at local level. This is especially relevant for small businesses located in rural areas which may be irreversibly affected by energy price and/or its availability (Figure 1, Table 1). From a durable development point of view, the best approach is to find a way to store the energy in an ecological and environmentally friendly way, with a positive environmental impact.

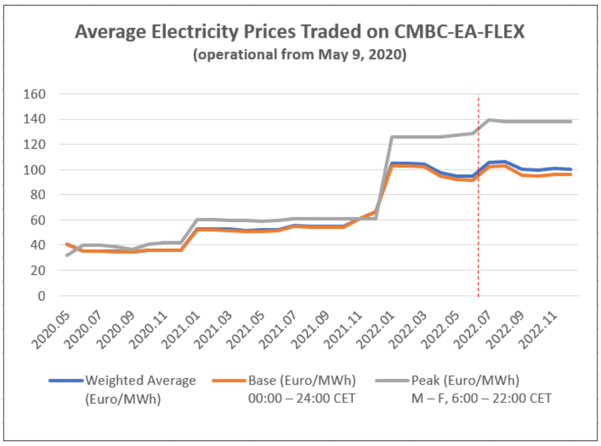

Fig. 1. Average Electricity Prices Trade on OPCOM CMBC-EA-FLEX
Source: own processing based on OPCOM statistics [22].

Table 1. Average Prices Traded on CMBC-EA-FLEX, extract

Month	Weighted Average (Euro/MWh)	Base (Euro/MWh) 00:00–24:00 CET	Peak (Euro/MWh) M – F, 6:00–22:00 CET
2021.11	60.99	61	60.92
2021.12	66.13	66.68	61.01
2022.01	104.55	102.69	126.02
2022.02	104.66	102.71	126.04
2022.03	103.97	101.94	126.05
2022.04	97.2	94.83	126.03
2022.05	95.07	92.28	127.17
2022.06	94.6	91.5	128.56
2022.07	105.76	102.04	139.13

Source: own processing based on OPCOM statistics [22].

Based on a study published by the Romanian gas and electricity market operator (OPCOM) up to July 2022, over the last year the Weighted average electricity price has increased by roughly 100%, from 52.29 Euro/MWh in June 2021, up to 105.76 in July 2022. For the Peak price (available from Monday to Friday from 6:00 AM to 10:00 PM) the increase is even more dramatic, from 59.28 Euro/MWh to 139.13 (135% up).

Looking back at the statistics of the indices calculated based on the former model operational by May 2020 (CMBC-EA), the increase in the previous 5 years was around 50% for the Weighted Average Price and 70% for the Peak price. This means the increase in both prices has doubled in the last year in comparison with the increase for the prior 5 years, between 2015 and 2020 (Fig.2).

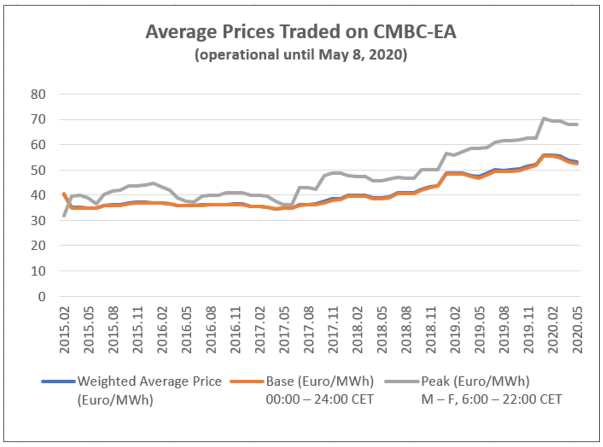

Fig. 2. Average Prices Trade on CMBC-EA
Source: own processing based on OPCOM statistics [23].

As a consequence of the energy price increase, the water price has also increased. This has a strong impact on farmers as it limits their ability to water the crops, especially during periods of significant drought. All these factors have a negative impact on the quality and quantity of the crops produced by farms.

In order to mitigate these risks, it is advisable for small farmers to analyze their specific conditions and the feasibility of investing in electrical energy production equipment (solar, wind, micro-hydro, micro-thermo, a. s. o.). Larger farms are more likely to be able to afford such analysis and investments.

One very important risk which has to be monitored and taken into consideration for evaluation from qualitative and quantitative perspectives, comes from the uncertainty of the local governmental approach, which, in the case of Romania, is very likely to be changed on very short legal notice, which may affect the initial business plan as well.

The notion of "prosumer" was introduced into the Romanian legislation five years ago, in March 2017. A prosumer is an end user that also has the capacity of producing energy. By law, prosumers are integrated into the national distribution infrastructure. When it comes to the commercial perspective, the approach was changed during the short period of time since the concept was introduced. For the time being, the current approach in Romania is to exchange the active energy produced and transferred on-grid with the one consumed from the grid by the prosumers in a "1 to 1" ratio. Nevertheless, the prosumers pay the same fixed costs per KWh of the energy consumed from the national electrical system, like all end users.

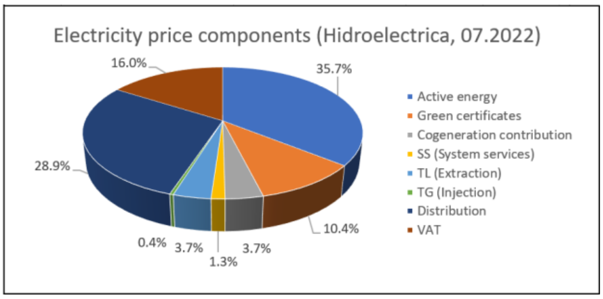

Fig. 3. Electricity bill price structure in July, 2022.
Source: own processing based on Hidroelectrica invoice

Invoiced services	Invoicing period	Quantity	Unit	Unit price wo VAT (RON/unit)	Value wo VAT (RON)	VAT (RON)
Active energy time zone 1	09/25/2021-10/31/2021	213	KWh	0.68543	146.00	27.74
Contribution to cogeneration	09/25/2021-10/31/2022	213	KWh	0.01712	3.65	0.69
Green certificates	09/25/2021-10/31/2021	213	KWh	0.0640659	13.65	2.59
Excise duties	-	213	KWh	0.00523	1.11	0.21
Total					164.41	31.23
Active energy delivered on-grid	09/25/2021-10/31/2021	260	KWh	0.19656	-51.11	
To be paid					113.30	31.23
Total					144.53	

Fig. 4. Example of energy invoice before legal modification in 2022
Source: own processing.

Consequently, based on the current legislation, a prosumer has to transfer on-grid more than 250 KWh from its production in order to be able to consume with no additional costs from the system 100 KWh, when needed, i.e. 150% more. In terms of **efficiency** this is **equivalent to a system with η=35.7%**.

Before the last legal modification in 2022 the percentage was even lower, less than 25%, due to different energy selling and buying prices (Fig. 4.).

In contrast, Canada for example had two types of contracts signed for 20 years with Hydro One [13]:

-Net Metering: this allows saving energy on the grid, similar to a large battery, where it can be later withdrawn from at no charge, or pay 0.077 CAD /KWh for what exceeds the production [13];

-microFIT: this is a sell only contract [14]. The produced power is sold at a fixed rate for cash that is sent every month. This selling rate is 0.29 CAD/KWh, about 3 times the rate paid for under Net Metering.

This means that from an economic point of view, it clearly makes sense to sell what is produced by the micro green plant at the high price (microFIT) and buy for household or farm use at the lower price (NetMetering); both types of contracts could simultaneously be signed for the same location/user, but the systems would need to be independent and not interconnected. It seems not all countries provide this incentive and even Canada has stopped new homes from joining this program, but it will be still active for other 14-15 years for the ones who have already signed such contracts [15].

The example above shows the importance of the local laws/governmental approaches and their stability in time for business and investment decisions.

For storing energy, large or small ponds can be used for collecting water from rain or by pumping from lower altitudes, using surplus energy from a solar or wind power plant or using cheaper off-peak electricity for pumping and deliver during peak hours produced energy through some micro hydro generators. The efficiency of pumping water into small ponds might not be immediately apparent. However, this approach has been used for a long time for large (CHEAP) systems, like Sacuieu–Dragan [12], Frunzaru [28], Tarnita [12] [19].

In such big systems, the equipment efficiency is high, about 75%-80% for pumping up and 90%-92% for generating electricity; so total efficiency for large systems is about 70%. This may decrease to 50%-60% when systems are smaller and if water evaporation is taken into consideration. While these figures might seem relatively low, from a commercial perspective in Romania, these systems are almost twice more efficient than injecting energy on-grid.

In the Sacuieu – Dragan hydro system for example, there are two 5MW pumps for elevating the water 190m high. In Frunzaru the pumping power is greater, but the pumping height is lower. The decision for implementing such a project is a centralized one due to its high costs and ecological and political impact, so huge delays may be expected for the implementation. Tarnița project is such an example where the implementation has been postponed several times, so, at the authority level (Ministry of Energy) the interest decreased at such a level as even the project web site is not valid anymore [19]. The Tarnița project was considered economically inefficient, which is debatable since a Swiss project, Nant de Drance power plant, with less capacity (900MW vs 1,000MW) and twice the budget (2 Bln Euro vs 1 Bln Euro) is considered a very successful one after 14 years of implementation [20][27][1].

The same result like in the Sacuieu – Dragan hydro system (10MW total pumping power) may be obtained for example from 5,000 small pumping facilities with a 2KW pumping power each; there is no need to pump up to 190m (which may increase the costs and decrease the efficiency), but water can be very simply pumped up 50-60m high with standard equipment available at small prices due to large scale production for this range of power and pressure values. Regarding the environmental impact of the new small ponds, intuitively we can imagine it would be a positive one as the presence of water helps both the local flora and fauna.

In this context, the purpose of the paper is to analyze and propose the gravitational energy storage in small ponds and manage this resource using remote data acquisition and a cloud machine learning platform which can optimize the process and support farmers in their decisions.

MATERIALS AND METHODS

In this paper we propose to use Artificial Intelligence (AI) and Machine Learning (ML) as methods to analyze data sets collected through drone cameras or various sensors transmitting relevant field parameters using low power communication (LoRa).

AI "is the science and engineering of making intelligent machines, especially intelligent computer programs" [18]. Intelligence is thought of as an ability of acquiring and applying knowledge and skills. It is a trait specific to humans and a few animal species, and nowadays an argument can be made that intelligence is specific to some machines as well. Rapidly evolving technology, both hardware and software, allows us to develop very powerful algorithms that run on performant machines. For a long time, humans have tried simulating true intelligence on computers, but in the last 70 decades, significant progress has been made. In the 1950s, Alan Turing proposed the Turing test. This test was designed for detecting human-like intelligence in a machine.

ML "is the study of computer algorithms that improve automatically through experience and by the use of data" [30]. ML aims to address the problem of creating machines that learn and evolve through experience [17]. It combines the fields of computer science and statistics and resides at the heart of AI and data science.

The three main learning paradigms in ML are supervised, unsupervised, and reinforcement learning.

- Supervised learning: learning with previously labeled inputs that serve as objectives. There is a set of input information comprised of information-target pairs. This set is usually split into an information vector, and a vector containing one or more associated defined output values for each training example [24].
- Unsupervised learning: is distinguished by the absence of labels in the training set. Most of the time, the criterion for success is a network's ability to increase or decrease a cost function correlated to it [24].
- Reinforcement learning: models learn to make a sequence of decisions. The model gains the ability of completing a task in a rather complex and ambiguous environment. The encountered scenario is similar to a game. In order to solve the problem, the computer uses a "trial and

error" system. It is then rewarded or punished based on the decision outcome. The aim of the algorithm is to maximize the total score [3].

Data harvesting is a crucial part of ML. In order for the training process to succeed in supervised learning, the training data must be structured as follows:

- The content - the data representing what the program should be able to predict
- The correct answer (known as target attribute) - the correct identifier for the data that the model should predict/classify. This is what allows the model to acknowledge if the prediction was correct or not.

A model is a program that has been provided with a set of data and an algorithm to interpret that data (a learning algorithm). The desired result is an improved program that can now make predictions on data that is not in the training set, but has similar characteristics. The model artifact developed by the process of training is referred to as an ML model [17]. The learning algorithm searches the training data for patterns that connect the input data attributes to the goal (the result to be predicted), and it outputs a ML model that uses these patterns. The generated model is then used for making predictions for new data, for which it does not know the target attributes.

Artificial neural networks (ANNs) are computer systems that are loosely based on the biological networks that make up both the animal and human brain. An ANN, which can be used with all three ML paradigms, is constructed of nodes (often called artificial neurons). These nodes are connected, much like in a biological brain. Each connection can send a signal to other neurons. One such neuron has the ability to receive a signal, take some action based on it and afterwards send new signals to other connected neurons. The motivation behind this architecture is the massive amount of computation that can be done by the human brain, which is remarkably good at recognition and classification tasks. Such tasks are accomplished using a biological neural network that may be mathematically modeled as a weighted and directed graph of highly interconnected vertices [11]. The most significant advantage of ANNs over traditional systems is their high degree of parallelism, as opposed to the traditional sequentially operated system. Artificial neural networks are organized in layers such as convolutional layers, pooling layers, fully connected layers, recurrent layers or normalization layers. These layers serve the purpose of receiving data, processing it, and outputting a certain result [4]. A layer's output usually serves as the next layer's input. Every connection between 2 neurons is associated with a numerical value which represents the strength of the connection and is called weight [4]. The most significant aspect in transforming an input into an output is the weights. This is because when the network gets an input for one node, it is transferred to the next node via the connection between them, but only after it has been multiplied with that connection's weight [4].

Activation functions have the purpose of deciding what neurons should be active based on the weighted sum calculated [10]. This in turn defines the output produced by the layer [2]. There are plenty of activation functions, and some of them are better suited in some cases than others. For example: while a recurrent neural network most often uses sigmoid activation or tanh activation, multilayer perceptrons and convolutional neural networks are usually coupled with ReLU activation.

Gradient Descent "is an optimization algorithm for finding a local minimum of a differentiable function" [5]. Gradient Descent is used for identifying the values of the parameters of a function in order to minimize the cost function [5]. This cost function represents the average of all loss functions (loss functions compute the loss of the model at a certain point in training) [5].

Backpropagation is a common approach for the calculation of derivatives inside an ANN and is vital for the process of training a feed-forward network [31]. The gradient of a loss function can be calculated via backpropagation for each of the network's weights. This allows each weight to be updated independently across several training iterations, lowering the loss function [31]. The gradient is computed while moving back through front through the model, from the final layer to the first [31].

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RESULTS AND DISCUSSIONS

Use case

In small solar, wind or micro-hydro implementations for farms or household usage, an inverter is normally used for converting variable electrical parameters inputs to fixed output voltage (230V/240V/380V) suitable for all devices or appliances. In order to store the surplus energy produced by this kind of system, a special type of inverter is needed (a hybrid inverter which uses batteries). The batteries are modular and usually a multiple of 3KWh or 5KWh.

For gravitationally storing 5KWh of energy a volume of 30 $m^3$of water should be elevated 60meters, or 60$m^3$for 30meters (Fig.5).

A 30 m^3 pond is equivalent to a medium home swimming pool of 4m*7m*1.1m. From the investment point of view a battery module of 5KWh is equivalent to a system consisting of one 1KW pump, one 1KW Home Scale Micro Hydro, one 30 m^3 frame pool and corresponding piping.

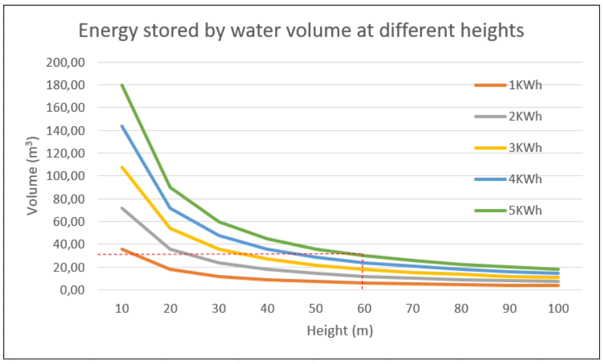

Fig. 5. Water volume needed for storing different energy levels depending on height
Source: own processing.

So, only based on this financial criterion it is not obvious which approach is better to be selected for storing energy. Very important for optimizing the system yield is the functioning point of the pump, as this parameter can vary a lot and thus dramatically influence the overall system efficiency. For example, from the characteristic functioning curves for Pedrollo 4Block pump series, including efficiency graph [26], the maximum pump efficiency is η**=67%** for 100 l/min and decrease to η**=30.6%**. for 40 l/min or 200 l/min. Very important is also the piping system as the energy loss on thin tubes is very high.

The scaling of the battery storage is linear while the price per water storage installed KWh decreases, so, for larger capacities the gravitational storage might be a better option. From the operational point of view a combined approach can cover more requirements: the smallest battery present in the inverter system can very quickly cover any energy request (due to increased power demand, outage or a line defect for example) including any automated start of the micro-hydro generator, while a pond can accumulate energy cheaper, even free from rain, and in larger quantities.

From the eco point of view a pond is more friendly to the environment in comparison to a battery which has a large non-eco footprint.

Specific to the solar and wind renewable energy sources is their uncertainty in terms of quantity and time of production, which runs the risk of not being aligned with the needs. Therefore, it is very useful to be able to store the energy and potentially also transfer it on-grid when in excess. On the other hand, once water is accumulated in the ponds, micro-hydro and hydro generators can start to produce energy on demand, but with variable delay (depending mainly on size).

The typical load curve has a base load during day time, two peaks (during mornings and evenings) and off-peak during nights (Fig.6).

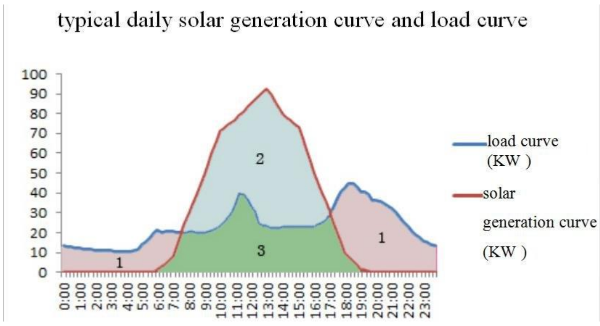

Fig. 6. Typical daily solar generation curve and load curve according to Yan Fan
Source: [8].

The plot in Fig. 8. is a qualitative one, corresponding on average to some specific monitoring period; the amplitudes differ from summer to winter, both to load and solar generation curves.

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The national electrical power system (which is now interconnected with the systems from the neighboring countries) is more efficient to constant loads; each increase in demand needs technical actions to the system in order to adapt. This deviation is also reflected in the price due to the law of supply and demand (Fig.7).

Unfortunately, for the time being in Romania, the price paid to the prosumers for the injected electrical power into the national system is not differentiated based on the delivery time (peak or off-peak). So, this opportunity cannot be seized locally by consuming/storing energy off-peak and delivering it during peak hours like in the large pumping hydro power plants.

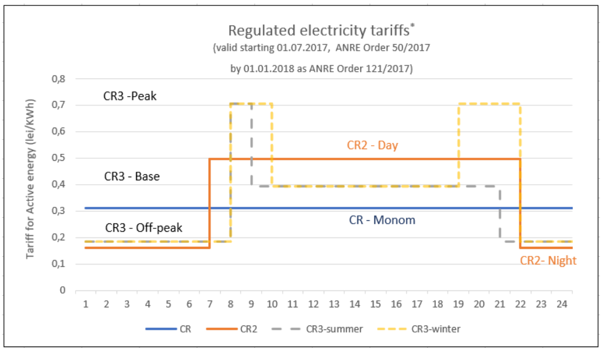

Fig. 7. Regulated electricity tariffs by 01.01.2018
Source: own processing based on ANRE Order [21].

Ponds placement

This section presents the usage of AI first in obtaining a high-resolution aerial view of an area including the 3D Digital Terrain Model (DTM) based on an overfly with a home-use Mavic Pro drone. This is a very important step for identifying the most suitable location for placing a water accumulation pond.

The area of interest is isolated based on several constraints:

- altitude differences
- property status and possibility of using it for building a pond
- easy access for digging and piping between ponds

Specialized software is then used for planning the flight [6] (Figure 8). Several input parameters must be established:

- flight altitude
- needed resolution
- requested precision

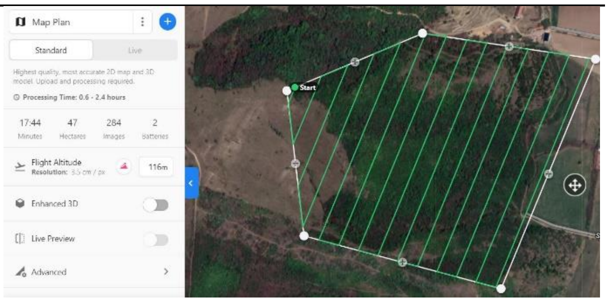

Fig.8. Planned flight path over the analyzed area
Source: own processing.

The resulting set of 2D aerial photos are then processed for obtaining AI-generated DTMs and topographic maps or orthophoto plans (aerial views not affected by optical distortions, built using these photos like in a puzzle) [7]. Using strong AI algorithms, similar points are identified in the photos and thus the measurement of the distances between them from different points of view can be done. By using this technique, the altitudes of the points can be calculated. Points with the same elevation are put on the same level curve (Fig.9. and Fig.10.).

It is important to note that the obtained level curves are optical ones and not ground level curves. This is more relevant in areas with trees where the curves correspond to trees tops, not to ground. The most suitable areas for placing ponds are the ones with lower curve density, where the terrain is approximately flat.

It is also important to note that such local investigation is needed as usual topographic plans or Google Maps Terrain are not suitable for such small areas targeted by small pond projects due to their low accuracy precision for this purpose.

Fig.9. The resulted ortophotoplan and 3D DTM for the surveyed area
Source: own processing.

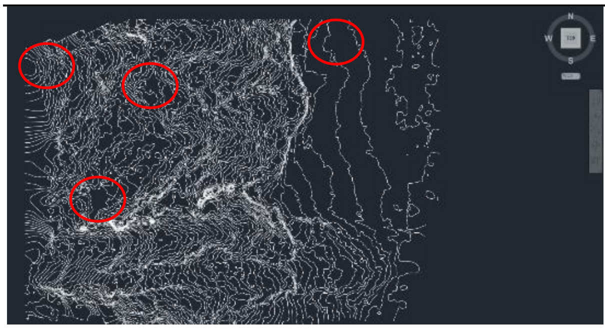

Fig.10. The 3D DTM for the surveyed area
Source: own processing.

Among the identified flat areas some are located closer to roads or easier to access and these are the ones to be selected for further analysis. The "short listed areas" should be directly inspected and evaluated more precisely on field.

Using this cheap method, the most suitable areas can be identified and the project can continue further with the next steps.

More precise DTM results can be obtained using LIDAR scanners (Laser Imaging, Detection, and Ranging), but this approach is an expensive one and specialized equipment and services are required.

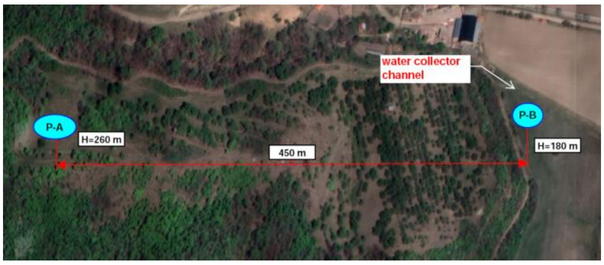

Fig. 11. The ponds positions and dimensional parameters
Source: own processing.

As a result of this process two locations were chosen, Pond A (at 260m altitude) and Pond B (at 180m altitude). The direct distance between the ponds is 450m and the piping length is about 600m. There is a forest road nearby which can be used for installing the system and for facilitating further maintenance activities. In that area the system can also benefit from a rainwater collector channel in order to store such a natural resource instead of just letting it drain into the nearest river (Fig.11.).

Machine learning in energy storage systems

Due to the current technological advancements, energy storage systems (ESS) and energy storage devices (ESD) must have higher performance, greater reliability, have better durability and better management strategies. Since these systems rely on the condition of numerous indicators, advanced control strategies must consider trade-offs with respect to a large number of parameters when designing such systems. ML has the power of significantly speeding up calculations, capturing intricate systems in order to increase prediction accuracy, and taking the best decisions possible based on complete data readings. It is appropriate for real-time management thanks to the computational efficiency [9].

There are various types of energy storage devices. Some energy storage devices use electrochemical technology: batteries, flow batteries, capacitors, fuel cells. Other ESDs are of physical nature: pumped-storage, compressed air storage, superconducting magnets, molten salts, etc.

Thanks to the massive computational processing power of modern computers, ML is very useful in multi-factor problems. Layers of highly connected neurons process the input data and identify the optimal solution for the targeted problem.

Due to the number of factors involved in calculating optimizations for the production, storage and supply of energy, ML is a powerful tool to employ for its management.

The prosumer is faced with the problem of choosing the best course of action for the use of produced energy. Depending on the time of day, price per KWh varies, but so does the production of energy and the household use. The amount of energy stored in the available ESDs is also an important factor. ML can be used in the optimization of energy production as well as in the management of the produced energy. Depending on factors such as the time of day, weather, precipitation and price of the KWh, different ESDs would be optimal. A ML model trained on data collected previously would be able to make predictions based on this information and maximize the financial outcome. The model could be retrained with an enriched training dataset (obtained by adding the newly harvested data).

The model could then employ "trial and error" approach in order to optimize the performance. The adaptability of pumped-storage hydropower plants (PSHP) offsets the unpredictable and inconsistent nature of photovoltaic and wind power output. This helps increase the reliability of the power grid and encourage the integration of renewable energy (RE) sources [25]. The need for high-quality control of the pumped-storage unit is becoming more and more clear as PSHP and RE integrated systems grow in size. The control of the pumped storage unit has demonstrated to be more challenging than the control of the conventional hydropower generating unit. In the paper "Controller Optimization Approach Using LSTM-Based Identification Model for Pumped-Storage Units", Feng et al. have attempted the optimization of a Pumped-Storage Unit through the use of Long Short-Term Memory networks (LSTMs). Their results have revealed that the ML model had a better accuracy and better generalization capability than the other approaches.

Machine learning in the impact on the environment

At first glance, the environmental impact generated by the introduction of 2 open water reservoirs appears to be positive. Open water reservoirs increase the relative humidity in the area through the process of water evaporation. Out of all fire risk spikes (on the FWI95 and ISI95 scale systems), decreased relative humidity was the determining factor in 75% of the cases [16]. The impact on the local fauna should be a positive one as well. Two drinking water sources would be introduced into the environment.

The impact of the introduction of accumulation ponds can be analyzed using ML. A plethora of factors are required for conducting a comprehensive analysis. ML is particularly useful in multi-factor problems thanks to the impressive computing capacity. Data should be collected from the location of the lakes as well as from a control area. The data harvested could help in making correlations between humidity levels and fire risk, or water availability and fauna well-being. ML could help in discovering complex correlations and also quantitative relationships that could not be discovered through human judgement.

ML is thus very useful in status analyzing, forecasts and decision making but it requires specific IT knowledge and powerful computational capabilities. For small to medium farms, it is not feasible to implement such systems in order to better manage (including energy management). For large farms it might be feasible, but, as this is not their core business, investments are more likely to go to their specific needs. So, a platform which offers data collecting and processing capabilities (including ML) can help farms of all sizes in optimizing their activities, receiving alerts based on "spot signals" collected and interpreted by ML models and even drive some of the activities (for example the command of watering systems or the energy management in order to optimize consumption, storage and generation). Such a service is planned to be offered on myiot.ro platform developed through the PleIT project by Smart League Company [29].

CONCLUSIONS

Long range and low power communication (LoRa) infrastructure, LoRaWAN protocol and the Machine Learning platform form a system that has the added benefit of assisting farmers in collecting data, receive warnings, making better decisions for their crops and even drive some of the remote activities (for example the command of watering systems or the energy management in order to optimize consumption, storage and generation). The system output can be used for building a project charter and in taking operational and investments decisions.

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REFERENCES

[1]ALPIQ.com, 2022, The Nant de Drance power plant is a complex masterpiece, https://www.alpiq.com/power-generation/hydropower-plants/pumped-storage-power-plants/nant-de-drance, Accessed on 7/15/2022

[2]Brownlee, J., 2020, Deep Learning for Computer Vision: Image Classification, Object Detection and Face Recognition in Python, 1-544.

[3]Deepesense.ai, 2022, What is reinforcement learning. The complete guide. https://deepsense.ai/what-is-reinforcement-learning-the-complete-guide/, Accessed on 7/15/2022

[4]Deeplizard.com, 2022, Machine Learning & Deep Learning Fundamentals https://deeplizard.com/learn/video/FK77zZxaBoI, Accessed on 6/15/2022.

[5]Donges, N., 2019, Gradient Descent: an introduction to 1 of machine learning's most popular algorithms. https://builtin.com/data-science/gradient-descent, Accessed on 6/15/2022.

[6]Dronedeploy.com, 2022, Product/Mobile, https://www.dronedeploy.com/product/mobile/, Accessed on 6/15/2022.

[7]Dronedeploy.com, 2022, Product/Photogrammetry, https://www.dronedeploy.com/product/photogrammetry/, Accessed on 6/15/2022.

[8]Fan, Y., Pei, G., Yingying, L., Zhang, Z., Xiao, W., 2018, Impacts on Operation and Benefit After New Energy Generation Access to Power Grid, IOP Conf. Ser.: Earth Environ, Sci. 168 012034.

[9]Gao, T., Lu, W., 2021, Machine learning toward advanced energy storage devices and systems, iScience, 24 (1), Article 101936.

[10]Geeksforgeeks.org, 2022, Activation functions in Neural Networks, https://www.geeksforgeeks.org/activation-functions-neural-networks/, Accessed on 6/15/2022.

[11]Hassoun, M., 1996, Transactions on information theory, IEEE, 42, 1322-1324.

[12]Hidroelectrica, https://www.hidroelectrica.ro/article/37, Accessed on 7/15/2022

[13]Hydro One, https://www.hydroone.com/business-services/generators/net-metering, Accessed on 7/15/2022

[14]Ieso.ca, 2022, microFIT Program, https://www.ieso.ca/en/Get-Involved/microfit/news-overview, Accessed on 7/15/2022

[15] Independent Electricity System Operator, Ontario, Canada, https://www.ieso.ca/en/Sector-Participants/Feed-in-Tariff-Program/Overview, Accessed on 7/15/2022

[16]Jain, P., Castellanos-Acuna, D., Coogan, S.C., Abatzoglou, J.T., Flannigan, M.D., 2022. Observed increases in extreme fire weather driven by atmospheric humidity and temperature. Nature Climate Change, 12(1), pp.63-70.

[17]Jordan, M., Mitchell, T., 2015, Machine learning: Trends, perspectives, and prospects, Science, 349, 255-260.

[18]McCarthy, J. , 2004, What is artificial intelligence? Artificial Intelligence, 1-14.

[19]Ministry of Energy, 2022, Hidro Tarnita SA, http://energie.gov.ro/companiile-din-subordine/hidro-tarnita-s-a/, Accessed on 7/15/2022

[20]Nant de Drance, 2022, Power Plant, https://www.nant-de-drance.ch/en/the-plant, Accessed on 7/15/2022

[21] National Energy Regulatory Authority Autoritatea Nationala de Reglementare in domeniul Energiei (ANRE), Order 50/2017, Official Gazetteal, Part I , No. 481/26.VI.2017.

[22]OPCOM- Operatorul Pietei de Energie Electrica si Gaze Naturale (The operator of the Electric Energy and Natural Gas Market), Statistics on Flexible Extended Auctions Mechanism for Electricity, https://www.opcom.ro/rapoarte/pccb_le_flex/statistici_flex.php?lang=en, (last updated: 7/11/2022) Accessed on 7/15/2022

[23]OPCOM,Operatorul Pietei de Energie Electrica si Gaze Naturale, Archive Results (CMBC-EA) for Electricity (operational until May 8, 2020) https://www.opcom.ro/rapoarte/pccb_le/statistici_PCCB_LE.php?lang=en, Accessed on 7/15/2022

[24]O'Shea, K., Nash, R. , 2015, An Introduction To Convolutional Neural Networks, arXiv, 1-11.

[25]Papaefthymiou, S.V., Papathanassiou, S.A., 2014, Optimum sizing of wind-pumped storage hybrod power stations in island systems, Renew. Energy, Vol.64, 187-196. In Feng, C., Chang, L., Li, C., Ding, T., Mai, Z., 2019. Controller optimization approach using LSTM-based identification model for pumped-storage units. IEEE access, 7, pp.32714-32727.

[26]Pedrollo.com, 2022, 4Block submersible Pumps, Catalogue,https://www.pedrollo.com/public/allegati/4BLOCK_EN_50Hz.pdf, Accessed on 6/15/2022.

[27]Pini Smart Engineering, 2022, Pumped storage hydropower plant Nant de Drance, Canton of Valais, Switzerland, https://www.pini.group/pini/expertise/energy-power/nant-de-drance.html, Accessed on 7/15/2022

[28]Romanian Association for Microhydroenergy (Asociatia Romana pentru Microhidroenergie), 2014, The first hydropower facility with pumping storage in Romania, at Frunzaru (Prima amenajare hidroenergetica cu acumulare in Romania, la Frunzaru), https://www.asociatiamhc.ro/prima-amenajare, Accessed on 7/15/2022

[29]Smartleague.ro, 2022, Rezultate. Rezultatul practic al cercetarii si dezvoltarii (produsul dezvoltat)-Results. The practical result of the research and development (developed product), within Perpetual Low Energy IoT project, https://www.smartleague.ro/rezultate/, Accessed on 7/15/2022.

[30]Wikipedia, 2022, Machine learning, https://en.wikipedia.org/wiki/Machine_learning, Accessed on 7/15/2022.

[31]Wood, T., What is Backpropagation? https://deepai.org/machine-learning-glossary-and-terms/backpropagation, Accessed on 6/15/2022.